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FINAL REPORT

FOR THE

OPERATOR INFLUENCE

OF UNEXPLODED ORDNANCE

SENSOR TECHNOLOGIES

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MILITARY ENVIRONMENTAL TECHNOLOGY
DEMONSTRATION CENTER (METDC)

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MEMORANDUM FOR Program Manager, Booz Allen Hamilton, 4692 Millennium Drive, Suite 200, Belcamp, MD 21017-1535 (ATT/Mr. Patrick McDonnell)

SUBJECT: Final Report for the Operator Influence of Unexploded Ordnance Sensor Technologies, DTC Project Number: 8-CO-160-UXO-023.

1. Subject report is approved and forwarded for final publication.

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14. ABSTRACT

The U.S. Army Environmental Command (USAEC), through the Environmental Quality Technology (EQT) Program, requested Aberdeen Test Center's (ATC) Military Environmental Technology Demonstration Center (METDC) to develop and execute a plan to determine and document, if it exists, a level of influence that operators may have on unexploded ordnance (UXO) detection technology results. The primary objective of the test was to determine this level of influence and to perform an analysis of operator detection activities to identify factors that produce variations in operator performance. ATC tested a total of ten operators (five novices and five experts), using a Schonstedt magnetometer. The experts had more experience with the geophysical detection than the novices. Overall, the results showed that the position and speed of the detector head impacted performance measurements. In addition, the data indicated that perhaps periodic refresher training would be beneficial to expert operators to improve their results in the field.

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EXECUTIVE SUMMARY

a. The U.S. Army Environmental Command (USAEC), through the Environmental Quality Technology (EQT) Program, requested Aberdeen Test Center's (ATC) Military Environmental Technology Demonstration Center (METDC) to develop and execute a plan to determine and document, if it exists, a level of influence that operators may have on unexploded ordnance (UXO) detection technology results. The primary objective of the test was to determine this level of influence and to perform an analysis of operator detection activities to identify the factors that produce variations in operator performance.

b. Until recently, the UXO and Countermine communities both have relied on anecdotal evidence to account for the widely differing levels of detection achieved from various operators. However, recent empirical investigations of operator influence in the countermine community have discovered substantial variability in detection performance between operators of both currently fielded equipment (AN19/PSS-12) and an advanced technology then under development (HSATMIDS/PSS-14).

c. To date, there has been no similar attempt to objectively define the level of operator influence in the UXO arena. This effort sought to determine if similar individual differences in operator performance exist and, if so, to identify their bases. As in the Countermine work, this effort also sought an explicit description of the human factors producing any differences found. Such a description, which could be cast as a cognitive model, holds potential to serve as a resource for designing operator training that can maximize the potential of fielded UXO detection tools and improve detection.

d. ATC tested a total of ten operators (five novices and five experts), using a Schonstedt magnetometer. The experts had more experience with geophysical detection than the novices.

e. The testing indicated anomalies in some of the results relating to expert versus novice performance. The overall performance of the novices was better than the performance of the experts. The variability of the novices' probability of detection (P_d) results was less affected by factors such as detector head height and velocity than the variability of the experts' results. In addition, P_d was affected diametrically by detector head height for the novices versus the experts.

f. Overall, the results showed that that the position and speed of the detector head impacted performance measurements. In addition, the data indicated that perhaps periodic refresher training would be beneficial to expert operators to improve their results in the field.

h. This effort provides but a glimpse into operator influence of UXO detection and bears further study. Increasing overall sample size would allow cogent conformation of this initial study and an inferential statistical analysis versus the descriptive analysis accomplished herein.

1.1 TEST OBJECTIVES

a. The primary objective of this test program was to quantitatively determine the level of influence that individual operators have on unexploded ordnance (UXO) sensors. This level of influence was first evaluated by observing the performance of expert and novice operators engaged in a blind search for a variety of UXO targets. Empirical data were collected for both novice and expert performance levels with a commercial handheld magnetometer. Data recorded were scored on traditional metrics such as probability of detection (P_d), false alarm rates (FAR), and time during the course of traversing a one-third acre test plot. This information was intended to provide insight into maximizing operator performance.

b. In summary, the main focus of this effort was to observe, identify, and describe operator actions during UXO detection operations.

1.2 TEST AUTHORITY

The U.S. Army Aberdeen Test Center (ATC) Military Environmental Technology Demonstration Center (METDC) performed testing at Aberdeen Proving Ground (APG), Maryland. The APG Standardized UXO Technology Demonstration Site was used for the test. The U.S. Army Environmental Command (USAEC) under the Army Environmental Quality Technology (EQT) Program sponsored the test. This test was performed under U.S. Army Developmental Test Command (DTC) Project No. 8-CO-160-UXO-023 in support of the user requirement outlined in the EQT A (1.6a) UXO Screening, Detection and Management Plan. The U.S. Army Research Laboratory (ARL) Human Factors group and Concurrent Technologies Corporation, Inc. (CTC) provided support to assess the human factors directly relevant to the objectives and methods described herein.

1.3 TEST CONCEPT

a. Highly experienced users of the Schonstedt device (experts) were tested in UXO detection as well as operators who recently completed training on the instrument (novices). Ten test participants, comprising five experts and five novices in the field, were chosen to participate in the testing.

b. The novice participants were civilian trained UXO technicians. These individuals were certified as Level I UXO Technicians through training received through the Texas Engineering Extension Service (TEEX), an extension of the Texas Agricultural and Mechanical (A&M) University System (TAMUS). The 5-week training curriculum emphasizes environmental theory, ordnance identification, safety, and explosives with practical experience time allotted for detection equipment.

c. The expert participant was required to have prior military experience, successful completion of an Explosive Ordnance Disposal (EOD) Program, and previous UXO detection experience. Expert participants were randomly selected from a Government organization currently engaged in active UXO site remediation. Personnel were fluent with current Tactics, Techniques and Procedures (TTPs) as well as the specific instruments used in this study. Overall, the expert participant was required to demonstrate a high level of confidence with the detection technology.

d. Inclusion of expert operators in the test introduced operator skill/experience as a dimension of operator differences likely to account for variability in performance hypothesized on the basis of the referenced countermine findings. The operators were instrumented to capture qualitative information capable of revealing how they used their equipment and the information it provided to detect targets. It was hypothesized that experts would produce the highest detection performance.

e. To date, no similar attempt has been made to objectively define the level of operator influence in the UXO arena. This effort was executed to determine if similar individual differences in operator performance exist and, if so, to identify their sources. Similar to the countermine work, this effort provides an explicit description of the human factors producing any differences found. It is the intent of the Test and Evaluation team that data observed could be a resource for designing operator training that can maximize the potential of fielded UXO detection tools and improve detection capability.

f. The field portion of the test commenced during September 2004 and continued through November 2005. The test participants were monitored using several methods throughout the practical exercise, and the results were recorded, processed, evaluated, and scored. Several human factors were evaluated, including (but not limited to) physiological stress/anxiety levels, height of the operator instrument with reference to ground, sweep rate, and walking/pacing or velocity of the operator. The final product will summarize results of observed differences in trends of expert versus novice UXO technicians. A flow chart of the overall test concept is provided in appendix C.

g. An integrated team was established for the review, comment, direction, and conduct of this. Members of this team included:

(1) ATC, DTC.

(2) ARL Human Research and Evaluation Directorate.

(3) U.S. Army Corps of Engineers (ACE) - Huntsville.

(4) Concurrent Technologies Corporation (CTC).

(5) Scientific Research Corporation (SRC).

1.4 SYSTEM DESCRIPTION

a. For this investigation, participants used a magnetometer commonly found within the UXO community.

b. The Schonstedt model 52-CX (fig. 1-1) is a magnetometer designed to locate changes in magnetic energy fields. Intended originally for locating subsurface ferrous infrastructure components, this device was also found to be effective at locating buried UXO.

Figure 1-1. Schonstedt magnetic locator.

c. The 52-CX uses two coaxially mounted magnetic sensors within its nonmagnetic structure. The output signals of the two sensors are directed such that they oppose each other. When the axis of the sensors is located within a uniform magnetic field, the components of that magnetic field are equal and opposite. Thus, no signal is outputted through an onboard speaker within the nonmagnetic structure of the 52-CX. If the axis of the sensors does encounter a magnetic field other than that of the earth's natural uniform field, the rates of magnetic flux and overall field will generally be higher at one sensor. Therefore, a net difference between the two sensors will be observed and an audible output will be provided to the operator. This audible output will change frequency and intensity as the net magnetic field changes. The 52-CX has a five-step potentiometer that allows the user to account for high levels of subsurface background metallic content by changing sensitivities of the magnetic field sensors. In addition, this allows the user to customize the operation of the detector for specific target sizes. For instance, larger targets will often saturate the localized magnetic field. An operator will change the sensitivity of the 52-CX to account for this phenomena so as to allow for smaller targets to be identified and located. The detector is powered by two 9-volt alkaline batteries. Its simple operation and ease of use account for its popularity within the UXO community.

d. No modifications were made to the Schonstedt for testing purposes.

e. Operators were required to use headphones while operating the Schonstedt Model 52-CX. A variable potentiometer was used to control the volume output from the external speaker. This field-hardened potentiometer was constructed by ARL and attached to the Schonstedt headphones-jack output by the existing external audio connection. This functioned as a variable resistor and limited current flowing into connected headphones, based on the radial position of the knob. The audio signal was delivered to the operator via Audio Technical Model ATH-M30 headphones.

1.5 UNIQUE TEST REQUIREMENTS

a. Test Equipment.

(1) A tracking system capable of observing and recording dynamic motions of UXO detection systems was required for this test. The system was essential to input Universal Transverse Mercator (UTM) test grid boundary as well as target location coordinates.

(2) A potentiometer to control audio output of all UXO detection systems was required for this test.

(3) The participants were provided with all equipment necessary for testing

(4) Audio/visual equipment capable of documenting static and dynamic test operations.

b. Personnel. Two on-site observers monitored the field operations. Test staff recorded data and signal processing activities, operated data collection equipment, and conducted maintenance activities. Geodetics support was required to operate telemetry equipment and survey locations of operator declarations.

c. Field Activities.

(1) Target emplacement.

(a) The objective during this phase of testing was to emplace the UXO test items (targets) within the area designated as the test bed.

(b) Targets were selected from the Standardized Site Repository at APG. The targets represent five ordnance types, including 40mm projectiles, 60mm mortars, 81mm mortars, 105mm projectiles, and 155mm projectiles. These ordnance types were chosen because they are indicative of the common munitions found, readily available, and representative of various associated aspect ratios and sizes. Sixty targets were emplaced. Sketches of the ordnance are provided in appendix H.

(c) Prior to target emplacement, all items were degaussed in accordance with MIL-M-19595 by ATC personnel. The process of degaussing or demagnetization ensured that any magnetic flux stored in the munitions was near or close to zero upon entrenchment. The munitions were then separated in crated compartments, stored, and secured to maintain the integrity of the magnetic field.

(2) Test Procedures.

(a) The test bed was located within the APG Standardized UXO Technology Demonstration Test Site (fig. 1-2) between the calibration test area and the blind grid test area. The location selected for the test bed is approximately one-third acre in size. Grid lane spacing was fixed at 1.5-meter widths in accordance with standard practices. Geodetics support was necessary to verify the coordinates for test bed boundaries and target emplacement/ground truth.

Figure 1-2. APG Standardized UXO Technology Demonstration Site.

(b) Sixty ordnance items were emplaced within the test bed. No clutter was emplaced. It was intended that no signatures from neighboring items would overlap; therefore, the halo size was selected to accommodate the largest item, a 155mm projectile. The default halo for this item was chosen to be 1 meter in diameter. Orientations of 0 and 90^{o} magnetic north were chosen because of the local maximum and minimum amplitudes of the magnetic fields at these angles.

(c) Detection of the 60 ordnance items with a two-failure allotment resulted in a 90-percent reliability with a 95-percent confidence rating. After emplacement of the targets, the area was reseeded and maintained to minimize visual and physical evidence of target locations. Additional soil and seeding was required to compensate for settling effects. The site was also allowed to age and weather for 8 months before testing to further minimize physical and visual evidence of target locations. Any soil that was used as fill had the same composition and properties of the soil already found on the site, as stated in the Standardized UXO Technology Demonstration Site Handbook. The area was periodically inspected for signs of erosion and/or target exposure.

(d) All targets emplaced within the test bed were within the 95th percentile of the maximum recovered depth listed in the ACE Recovery Depths Database. Each ordnance type was buried at an assigned target depth. The target types and corresponding depths are provided in table A-1 in appendix A.

1.6 TESTING METHODOLOGY

The objective of this phase of testing was to observe and record UXO Technicians while executing a MAG and flag operation on a pre-seeded test grid.

a. Requirements.

(1) Novice operators completed the 5-week course for certification as a UXO Technician Level I at Texas A&M University System, TEEX (app B).

(2) Training variations were expected for each expert operator. At a minimum, each expert operator was required to have 5 years of experience in the UXO detection field and successful completion of a Department of Defense (DOD) certified training program. Operators with previous military experience were required to have certification from the Army Bomb Disposal School located at APG or the Naval Explosive Ordnance Disposal (EOD) School, Indian Head, Maryland.

b. Test Procedures.

(1) Five participants of each group (novice/expert) used an identical Schonstedt model 52-Cx instrument to survey the designated test bed. The Schonstedts were checked for serviceability between operators. Each operator was provided identical information about the objectives of the test and instructions. The operators underwent a hearing assessment performed by a certified audiologist prior to the demonstration.

(2) A practice session was conducted to familiarize each operator with the task. Each operator was allotted time in a test pit. This area consisted of nine targets located on surface covered with inverted plastic buckets. Each bucket was cut to a recorded height that allowed instruments to respond to the various magnetic fields of each target. The 40mm grenade projectiles were oriented in a horizontal and vertical position. Three heights of each orientation allowed operators to experience the full range of magnetic signatures. Ten-pound shot puts were placed under three plastic buckets also at varying heights. The shot puts and 40mm grenade provided both ferrous and nonferrous situations for the operator to encounter prior to testing. Photographs of the test pit are provided in appendix G. The duration of each test bed period was recorded in the on-site daily logbook. Only one operator was allowed in the test bed during test activities.

(3) The survey portion of the test was expected to take approximately 6 hours based on prior knowledge from subject matter experts at the operational level of UXO remediation. Each participant was permitted time for standard field operations, such as mobilization/setup, calibration, and demobilization as well as time to address any equipment issues that surfaced during testing.

(4) Throughout the survey process, test staff strived to adhere to consistency in environmental factors relating to weather and conditions on the field. The start and stop times of each operator were recorded to compute survey completion times.

(5) Each participant was instructed that they would be traversing the test plot in two instances: with and without the laser tracking system. Thus, each participant scanned the same test grid twice, with the same UXO detection equipment. Test participants were directed to begin on opposite sides of the test grid between iterations to limit memory from previous sweeps. In addition, one sweep was limited per day; therefore, no person could complete both sweeps in the same day.

(6) The stress data were collected during both iterations for each individual. A test staff member administered the subjective questionnaires and saliva samples during the test.

(7) The audiological testing was performed only once at the beginning of the test.

c. Data Required. The data required are provided in appendix F. The required test observational data included all recorded, signal processing, and operational field data; video footage; auditory testing results; detector head height; and sweep rate. Start and stop times of the operators, as well as time spent performing calibration and mobilization, were recorded on-site. The operators were required to have a hearing assessment prior to the test.

d. Objective. This phase of testing will describe the methodology for analyzing observed and recorded data during UXO sweep operations.

e. Requirements.

(1) Two main stages of data handling were performed during testing. The first stage concentrated on acquisition and represented gathering and capturing information of each participant as testing was completed. Data captured were reported on an operator-by-operator basis. The second stage of data analysis included identification of any trends between common sets or groupings within the testing parameters.

(2) ATC Statistical and CTC analyzed the data to obtain the metrics for scoring P_d, and false alarm rate (FAR) for each novice and expert operator. The submittal reflected response stage (P_d^{res}) scoring only. The performance rating data were further reviewed for any correlations with the test observational data.

(3) The captured data and descriptions are presented in Table 1-1. Further details are provided in appendix E.

TABLE 1-1. LIST OF DATA

Detection Results	**Operator Performance**	**Ordnance**	**Stress**	**Hearing**	**Demographics**
P_d	Forward velocity	Type	Anxiety	PTA	Age
BAR	Detector height	Depth	Depression		Gender
	Sweep rate	Orientation	Hostility		Education
	Total time	Azimuth	Positive Affect		UXO experience
	Average lane time		Dysphoria		Detector experience
	% area covered		Salivary, amalase		
			Workload		
			Cortisol		

(4) Analysis of test observational, cognitive, and relational data constituted the second stage of analysis, which was performed by CTC, ARL, and ATC. The data were analyzed and the results of the test were documented to determine if qualitative factors and differences in performance impacted operator scores.

f. Data Acquisition.

(1) The Threat Minefield System (TMS) was used to capture real-time motions of detector shaft and the operator. Originally intended and designed for the countermine community, this device was constructed for virtual mine operations.

(2) TMS consisted of a laser-based tracking technology. Optical receivers were attached to the shaft of the detection equipment and the operator's feet. Four rotating lasers were positioned around the perimeter of the test course. The rotating lasers provided a virtual 3-dimensional volume of laser energy. This laser energy was received by optical sensors positioned on the operator's feet and detection equipment shaft. An onboard processor then calculated the position of the sensors and reported absolute positioning via wireless link to a master computer control system. Telemetry data were stored onboard the master controller computer in a dedicated hard drive.

(3) Video documentation of testing consisted of digital video, streaming video, and static photographs. A live real-time video feed of the detector-head was provided and sent via TMS wireless link to the master control computer. This was saved with any operator tracking data. Digital video of an operator's lane coverage was obtained during the test. The video was captured at the opposing end of a lane, which recorded the sweeping portion and end of that lane. A post debrief was conducted interviewing each operator to obtain comments or suggestions. This video was edited and consolidated for ancillary data input to analysis. Static still photographs were acquired throughout testing for documentation purposes. Every effort was made to record common situations encountered during testing procedures (e.g., lane coverage, bucket test, equipment layout, field positioning).

(4) A daily logbook was kept with time data.

(5) The factor of human stress was captured and quantified by subjecting UXO technicians to a written battery of questions as well as incorporating saliva samples measurements at various times throughout the test. The workload was also measured via written questionnaire. The ARL's Human Research and Engineering Directorate served as subject matter experts on this portion of the testing.

g. Data Analysis/Procedures.

(1) Detection results were organized and data reduction was performed. This process confirmed that usable information was recorded and showed where any data gaps existed from test dates. Data gaps were noted and recorded. Metrics were organized by individual operator, date, and grouping of operator (expert or novice).

(2) Data were compartmentalized and separated into subgroups that consisted of the following:

(a) Manual information was gathered: data generated by recording target declarations manual with GPS.

(b) Telemetry information was gathered: data observed and recorded with the TMS system including target declarations, movement patterns, detector height, sweep rate, lane times, and forward velocity.

(c) Video record was made: real-time captured video from TMS system, operator lane recordings, and static digital photography.

(d) Audiology testing was performed: hearing test results from each operator and detection equipment audio-output sound characterization.

(e) Psychological evaluation was performed: stress test results from both questionnaires and salivary amylase sampling. These results confirmed operator stress levels at both a qualitative and quantitative sense.

(f) On-site observations were made: general observations from test personnel located on-site during test operations.

(3) A priority of review was given to the fundamental performance data. Elements such as P_d, FAR, time, and detector height are the primary indicators of operator performance. P_d and FAR are two traditional elements reviewed to determine the performance of emerging UXO detection technologies. Time is a critical data point, as it is directly proportional to the cost associated with typical UXO clearance operations. Detector height can be critical, as it may relate to operator performance and effectiveness in locating buried items. It is currently unknown what, if any, critical height must be maintained to provide the greatest probability of locating UXO with the least amount of background alarms.

(4) Multiple target declarations within 1-meter halos were consolidated, and corrected values were compared with ground truth. This allowed for artificially inflated FAR score due to multiple target declaration.

(5) Analyses of performance examined the effects of individual operators, operator experience level, equipment, target, and types. Procedures involved aggregation of data by conditions, examination of resulting distributions, and selection of appropriate inferential statistical tests.

(6) Trends produced by data were recorded. Sources for these trends were investigated by reviewing all performance information on file.

(7) An error analysis examined the qualities of any targets missed and related the qualities of the missed targets to operator variables, individual operator's performance indexes, and equipment used.

h. Organization and Responsibilities.

(1) USAEC provided overall management and funding of the test program.

(2) ATC was the lead agency for preparation of the DTP and test report; operation of the test facility; conduct of the test; real-time, laser-based human tracking system operation; still photographic documentation; real-time kinematics (RTK) global positioning system recording of declared targets; statistical regression modeling manually marked GPS targets; and communicating with other members of the team.

(3) ARL Human Research and Engineering Directorate performed auditory testing of test participants; sound modeling and characterization of UXO detection equipment; odification of any UXO equipment for proper audio output; stress analysis of all test participants; and analysis of data for input into test report.

(4) CTC performed analysis of telemetry data and general input into test report under contract to ATC.

(5) SRC performed upgrades to existing TMS hardware and software system and general information technology related support under contract to ATC.

SECTION 2. UN-INSTRUMENTED DATA

2.1 EXPERT

2.1.1 Performance Measurements

a. Probability of Detection (P_d).

(1) For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If the distance was less than 1 meter, then a target was considered detected regardless of which lane the target was in. Multiple detections of the same target were ignored. The number of detected targets in the field were divided by the total number of targets in the field (60 targets) and multiplied by 100. This result was defined as the P_d and will be referred to as P_d. P_d is a dimensionless number with values ranging from zero to one.

(2) Expert participants demonstrated P_d rates from 0.917 to 1. Their average P_d was 0.957 with a standard deviation of 0.0401.

b. False Alarm Rate (FAR).

(1) For each alarm an operator declared in a particular lane, the distance between each of the targets in the field and the alarm was calculated. If no target was within 1 meter of the alarm, then the alarm was considered a false alarm. The total numbers of false alarms were divided by the area of the field (1131.5 square meters). The result was defined as the FAR and will be referred to as FAR. FAR has a unit of false alarms per meters squared.

(2) Expert participants demonstrated FAR rates from 0.034 to 0.154 false alarms per meters squared. The average FAR was 0.087 per meters squared with a standard deviation of 0.0435 false alarms per meters squared.

c. Distance from Optimal Point (DOP).

(1) An ROC curve is an industry standard that is used to compare the performance of operators and equipment in UXO and mine detection. It consists of the FAR on the *x*-axis versus the P_d on the *y*-axis. Curves nearer the upper left-hand corner of the chart are considered to be higher performance from a detector. Therefore, in order to compare the operators' performance versus each of the characteristics, the DOP was calculated as the distance from the upper left-hand corner (coordinates 0, 1) that an operators' point (FAR, P_d) is on the ROC curve, as shown in the following equation:

$$Dist\_DOP = \sqrt{(1-Pd)^2 + (0-FAR)^2}$$

(2) The DOP value is a dimensionless number; however, in general the greater the value the lower overall performance within P_d and FAR dimensions. Expert participants demonstrated DOP's between 0.075 and 0.154. Their average DOP was 0.108 with a standard deviation of 0.0302.

2.1.2 Time Measurements

a. Lane Velocity.

(1) The time operators required to complete each lane was manually recorded in an on-site daily log. Time delays due to equipment issues or data recording were also recorded and then subtracted from the total lane time. This lane length was then divided by the "corrected" lane time. The result was defined as the lane velocity.

(2) Expert participants demonstrated lane velocities between 0.088 m/s and 0.01 m/s. The average lane velocity was 0.094 m/s with a standard deviation of 0.0044.

b. Total Time.

(1) The time operators required to execute a UXO sweep operation on all 33 lanes of the test site. Corrected lane times were used for the following summation:

$$Total\_Time = \sum_{i=1}^{33} i\_lanes$$

(2) Expert participants demonstrated total times between 8199 and 9086 seconds. The average total times were 8482 seconds with a standard deviation of 374.7 seconds.

2.1.3 Data Summary

TABLE 2.1-1. EXPERT PERFORMANCE DATA

	Operator	P_d	FAR, 1/m^2	DOP	Lane Velocity, m/s	Total Time, s
Experts	E-1	100.0%	0.154	0.154	0.095	8238
	E-2	91.7%	0.072	0.110	0.088	9086
	E-3	100.0%	0.087	0.087	0.100	8279
	E-4	93.3%	0.034	0.075	0.092	8608
	E-5	93.3%	0.090	0.112	0.096	8199
	Mean	**95.7%**	**0.087**	**0.108**	**0.094**	**8482**
	Std. Dev.	**0.0401**	**0.0435**	**0.0302**	**0.0044**	**374.7**

2.1.4 Ordnance. Five different ordnance types were used: 40mm, 60mm, 81mm, 105mm, and 155mm. Each type was buried at a specific depth: 6, 12, 18, 24, and 30 inches. The ordnance was placed in both the horizontal and vertical orientations. The P_d measurements for each ordnance type, depth, and orientation are presented in Table 2.1-2.

TABLE 2.1-2. EXPERTS WITHOUT INSTRUMENTATION - P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Expert
Horizontal	40mm	100.0
	60mm	96.0
	81mm	76.7
	105mm	100.0
	155mm	100.0
	Total	**93.8**
Vertical	40mm	100.0
	60mm	100.0
	81mm	91.4
	105mm	95.0
	155mm	97.1
	Total	**97.1**
Overall Mean		**95.7**

2.1.5 Demographics

Prior to traversing the test grid, each participant executed a basic demographic questionnaire. The results are presented as follows:

a. Age. Expert participants reported ages between 25 and 43.

b. Gender. Four of the five experts reported being male; one reported gender female.

c. Race. Four of the five experts reported Caucasian; one reported other.

d. Marital Status. Two of the five experts reported being single; two reported being married. One expert reported marital status as divorced.

e. Years of Education. Three of the five experts reported having obtaining a high school diploma or GED. The other two experts reported having 1 and 2 additional years of education, respectively.

f. Months of UXO Experience. Expert participants reported between 12 and 96 months of UXO-specific experience.

g. Months of Schonstedt Experience. Expert participants reported 12 and 84 months of Schonstedt experience.

h. Months of EOD Experience. Expert participants reported between 78 and 252 months of EOD experience. The average amount of EOD experience was 141.6 months.

i. Prior Military Experience. All experts reported having prior military experience.

j. Health.

(1) As an overall indicator of health, participants were asked to rate their current overall physical and mental health status. Choices included excellent, fair, good, and poor.

(2) Four of the five experts reported having excellent health, whereas one reported health status as good.

k. Use of Tobacco Products. All expert participants reported no use of tobacco products and for the purposes of this investigation were defined as nonsmokers.

l. Height. Experts reported heights ranging from 64 to 72 inches.

m. Weight. Experts reported weights ranging from 130 to 260 pounds.

2.1.6 <u>Hearing</u>

a. A certified audiologist performed testing on all participants. Testing began with an otoscopic examination to determine the status of the pinnae and external auditory canals. Participants then completed pure tone air conduction testing. The testing took place in a sound-treated booth through the use of a clinical diagnostic audiometer (Interacoustics AC40). Pure tones at octave frequencies of 250 to 8000 Hz and interoctaves of 3000 and 6000 Hz were presented through TDH-39 superaural headphones. Middle ear status was determined through tympanometry using a Grason-Stadler 37 Auto Tympanometer.

b. Overall, hearing tests revealed that, on average, the expert participants had normal hearing sensitivity (defined as air conduction thresholds of 20 dB HL or better). All experts demonstrated normal bilateral middle ear function.

c. One expert had mild-to-moderate high frequency hearing loss in both ears. The signals emitted from the magnetic locators were broad in their frequency spectrum, and therefore should have been able to use the lower frequency information in the signal. Indeed, in the case of this expert the frequency range of the signal from 500 to 3000 Hz was between 10 and 70 dB above threshold. Frequency plots are shown in Figures 2.1-1 through 2.1-6.

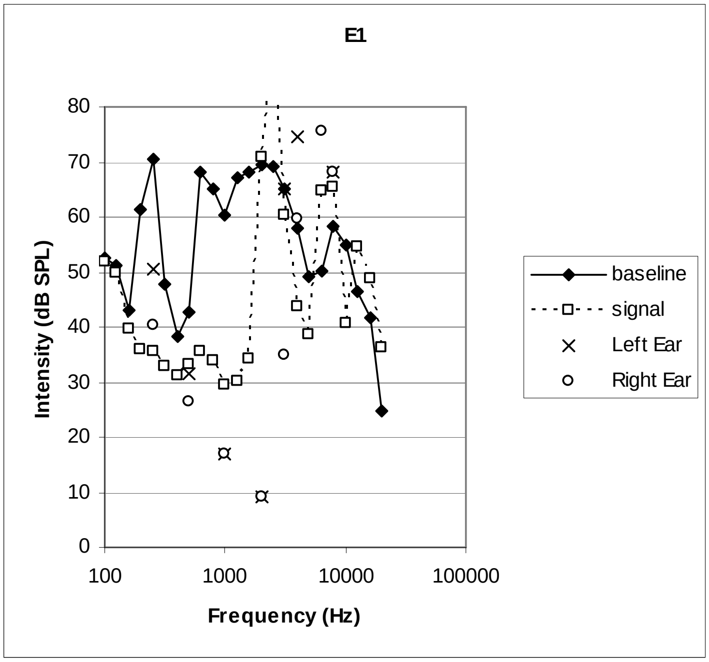

Figure 2.1-1. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from expert 1.

Note: The participant has hearing loss above 3000 Hz, but would have audibility of the signal between 500 and 3000 Hz.

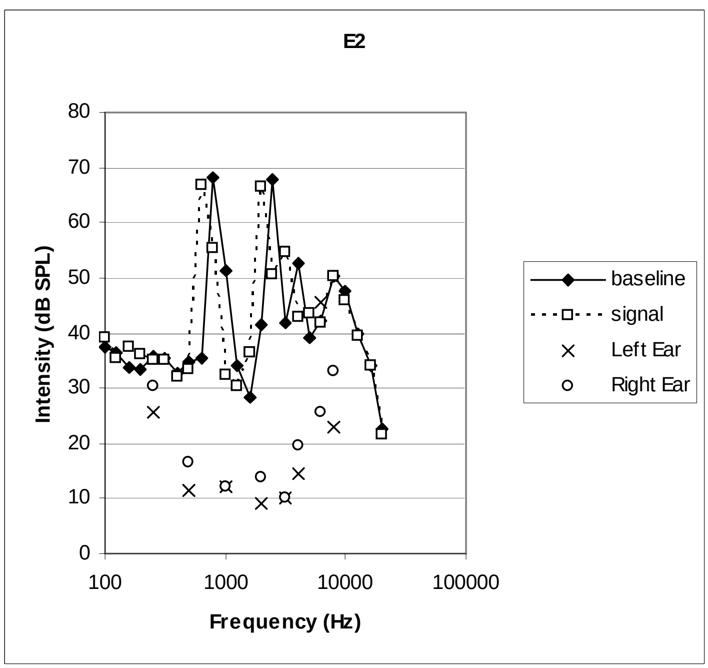

Figure 2.1-2. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from expert 2.

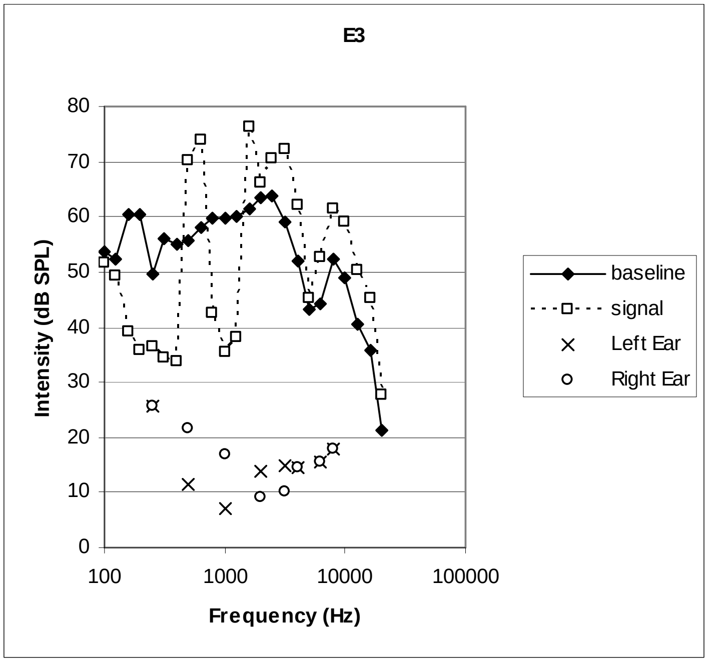

Figure 2.1-3. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from expert 3.

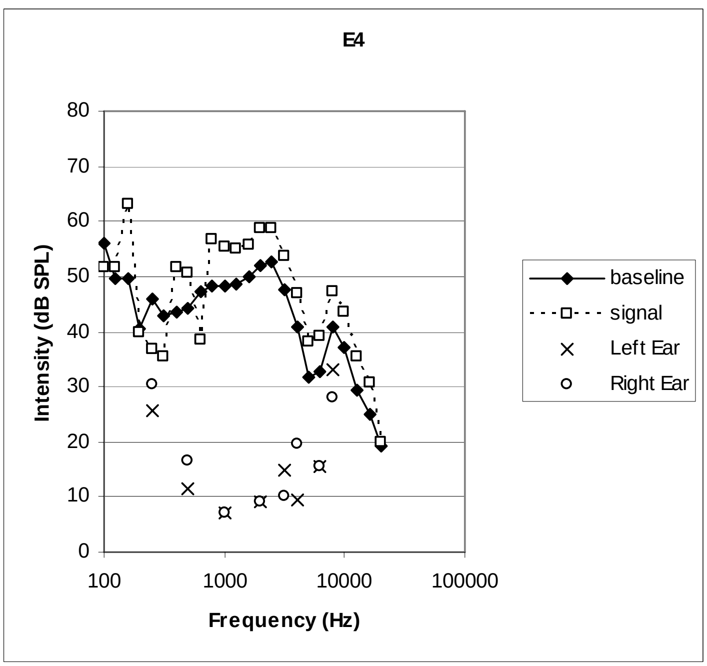

Figure 2-1.4. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from expert 4.

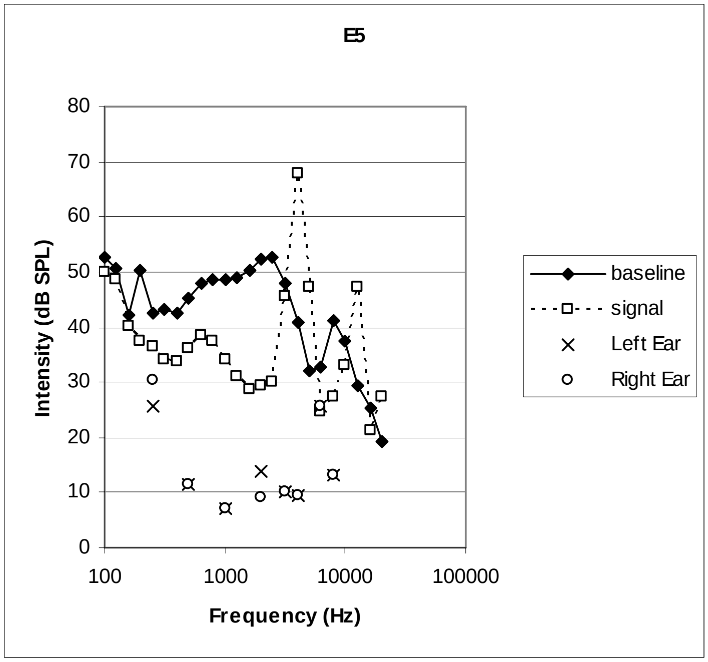

Figure 2.1-5. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from expert 5.

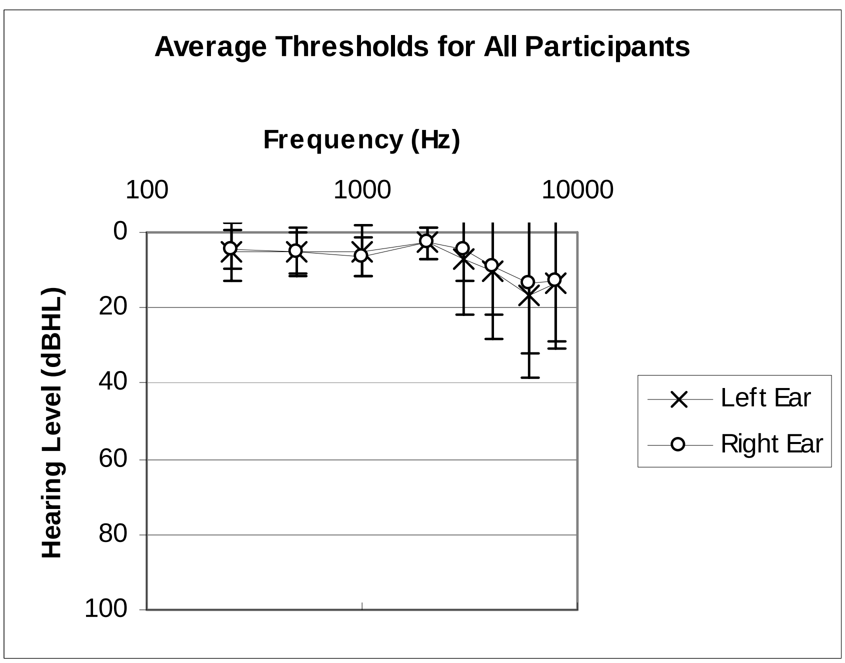

Figure 2.1-6. Average hearing thresholds for all participants (error bars indicate ±1 standard deviation).

2.1.7 Lane Orientation Effects

a. The complete test grid of 33 lanes was divided into two groups, corresponding to their magnetic compass heading.

b. Lanes 1 through 20 were situated north to south, and were 23.703 by 1.5 meters (35.6 m^2). There were 28 ordnances scattered throughout the 20 lanes. The performance data of the expert operators without instrumentation for lanes 1 through 20 are presented in Table 2.1-3.

TABLE 2.1-3. SUMMARY TABLE OF EXPERTS WITHOUT INSTRUMENTATION FOR LANES 1 THROUGH 20

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Experts	E-1	100.0%	0.198	0.198	0.091	5371
	E-2	85.7%	0.093	0.170	0.095	5304
	E-3	100.0%	0.124	0.124	0.092	5634
	E-4	89.3%	0.048	0.117	0.095	5223
	E-5	96.4%	0.120	0.125	0.091	5419
	Mean	**94.3%**	**0.116**	**0.147**	**0.093**	**5390**
	Std. Dev.	**0.0649**	**0.0548**	**0.0357**	**0.0020**	**154.9**

c. Lanes 21 through 33 were positioned east to west. Lanes 21 through 26 were 17.55 meters by 1.5 meters (26.325 m^2), and lanes 27 through 33 were 25.00 by 1.5 meters (37.5 m^2). There were 32 ordnances placed throughout the 13 lanes. The performance data without instrumentation for only lanes 21 through 33 are presented in Table 2.1-4.

TABLE 2.1-4. SUMMARY TABLE OF ALL OPERATORS WITHOUT INSTRUMENTATION FOR LANES 21 THOUGH 33

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Experts	E-1	100.0%	0.078	0.078	0.101	2867
	E-2	96.9%	0.036	0.047	0.078	3782
	E-3	100.0%	0.026	0.026	0.111	2645
	E-4	96.9%	0.010	0.033	0.086	3385
	E-5	90.6%	0.040	0.102	0.103	2780
	Mean	**96.9%**	**0.038**	**0.057**	**0.096**	**3092**
	Std. Dev.	**0.0383**	**0.0255**	**0.0321**	**0.0133**	**476.9**

2.2 NOVICE

2.2.1 Performance Measurements

a. P_d.

(1) For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If the distance was less than 1 meter, then a target was considered detected regardless of which lane the target was in. Multiple detections of the same target were ignored. The number of detected targets in the field were divided by the total number of targets in the field (60 targets) and multiplied by 100. This result was defined as the P_d and will be referred to as P_d. P_d is a dimensionless number with values ranging from zero to one.

(2) Novice participants demonstrated P_d rates from 0.933 to 1. The average P_d was 0.97 with a standard deviation of 0.0274.

b. FAR.

(1) For each alarm an operator declared in a particular lane, the distance between each of the targets in the field and the alarm was calculated. If no target was within one meter of the alarm, then the alarm was considered a false alarm. The total numbers of false alarms were divided by the area of the field (1131.5 m^2). The result was defined as the FAR and will be referred to as FAR. FAR has a unit of false alarms per m^2.

(2) Novice participants demonstrated FAR rates from 0.017 to 0.168 false alarms per m^2. The average FAR was 0.063 per m^2 with a standard deviation of 0.0605 false alarms per m^2.

c. DOP.

(1) An ROC curve is an industry standard that is used to compare the performance of operators and equipment in UXO and mine detection. It consists of the FAR on the *x*-axis versus the P_d on the *y*-axis. Curves nearer the upper left-hand corner of the chart are considered to be higher performance from a detector. Therefore, in order to compare the operators' performance versus each of the characteristics, the DOP was calculated as the distance from the upper left-hand corner (coordinates 0, 1) that an operators' point (FAR, P_d) is on the ROC curve, as shown in the following equation:

$$Dist\_DOP = \sqrt{(1 - Pd)^2 + (0 - FAR)^2}$$

(2) The DOP value is a dimensionless number; however, in general the greater the value the lower overall performance within P_d and FAR dimensions.

(3) Novice participants demonstrated DOPs between 0.033 and 0.169. The average DOP was 0.079 with a standard deviation of 0.0522.

2.2.2 Time Measurements

a. Lane Velocity.

(1) The time operators required to complete each lane was manually recorded in an on-site daily log. Time delays due to equipment issues or data recording were also recorded and then subtracted from the total lane time. This lane length was then divided by the "corrected" lane time. The result was defined as the lane velocity.

(2) Novice participants demonstrated lane velocities between 0.050 m/s and 0.124 m/s. Their average lane velocity was 0.097 m/s with a standard deviation of 0.0284.

b. Total Time.

(1) The time operators required to execute a UXO sweep operation on all 33 lanes of the test site. Corrected lane times were used for the following summation:

$$Total\_Time = \sum_{i=1}^{33} i\_lanes$$

(2) Novice participants demonstrated total times between 8199 seconds and 9086 seconds. The average total times were 8482 seconds with a standard deviation of 374.7 seconds.

2.2.3 Data Summary

TABLE 2.2-1. PERFORMANCE OF UN-INSTRUMENTED NOVICE PARTICIPANTS

	Operator	**P_d**	**FAR, $1/m^2$**	**DOP**	**Lane Velocity, m/s**	**Total Time, s**
Novices	N-1	100.0%	0.057	0.057	0.104	7612
	N-2	98.3%	0.028	0.033	0.112	6810
	N-3	95.0%	0.047	0.069	0.124	6661
	N-4	98.3%	0.168	0.169	0.50	17073
	N-5	93.3%	0.017	0.069	0.094	8733
	Mean	**97.0%**	**0.063**	**0.079**	**0.097**	**9378**
	Std. Dev.	**0.0274**	**0.0605**	**0.0522**	**0.0284**	**4379.6**

2.2.4 Ordnance. Five different ordnance types were used: 40mm, 60mm, 81mm, 105mm, and 155mm. Each type was buried at a specific depth: 6, 12, 18, 24, and 30 inches. The ordnance was placed in both the horizontal and vertical orientations. The P_d measurements for each ordnance type, depth, and orientation are presented in Table 2.2-2.

TABLE 2.2-2. NOVICES WITHOUT INSTRUMENTATION - P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Novices
Horizontal	40mm	100.0%
	60mm	92.0%
	81mm	83.3%
	105mm	100.0%
	155mm	100.0%
	Total	**94.6%**
Vertical	40mm	100.0%
	60mm	97.1%
	81mm	94.3%
	105mm	100.0%
	155mm	100.0%
	Total	**98.8%**
Overall Mean		**97.0%**

2.2.5 Demographics

Prior to traversing the test grid, each participant executed a basic demographic questionnaire. The results are presented as follows:

a. Age. Novice participants reported ages between 22 and 53.

b. Gender. All five novices reported their gender as male.

c. Race. Two of the five novices reported their race as Native American and two reported their race as Pacific Islander. One novice reported Caucasian.

d. Marital Status. Three of the five novices reported being single; two reported their status as married.

e. Years of Education. Three of the five novices reported having obtaining a bachelor degree. The other two novices reported having a high school education.

f. Months of UXO Experience. Novice participants reported between 0 and 1.5 months of UXO-specific experience.

g. Months of Schonstedt Experience. Novice participants reported between 0 and 1.5 months of Schonstedt experience.

h. Months of EOD Experience. Novice participants reported 0 months of EOD experience.

i. Prior Military Experience. Four of the five novices reported having prior military experience, whereas one novice reported no military experience.

j. Health.

(1) As an overall indicator of health, participants were asked to rate their current overall physical and mental health status. Choices included excellent, fair, good, and poor.

(2) All five novices reported having good health.

k. Use of Tobacco Products. Four of the five novice participants reported no use of tobacco products and for the purposes of this investigation were defined as nonsmokers. One novice reported the use of tobacco products (cigarettes) at a rate of 1 pack per day.

l. Height. Novices reported heights ranging from 67 to 73 inches.

m. Weight. Novices reported weights ranging from 160 to 230 pounds.

2.2.6 Hearing

a. A certified audiologist performed testing on all participants. Testing began with an otoscopic examination to determine the status of the pinnae and external auditory canals. Participants then completed pure tone air conduction testing. The testing took place in a sound-treated booth through the use of a clinical diagnostic audiometer (Interacoustics AC40). Pure tones at octave frequencies of 250 to 8000 Hz and interoctaves of 3000 and 6000 Hz were presented through TDH-39 superaural headphones. Middle ear status was determined through tympanometry using a Grason-Stadler 37 Auto Tympanometer.

b. Overall, hearing tests revealed that, on average, the novice participants had normal hearing sensitivity (defined as air conduction thresholds of 20 dB HL or better). All novices demonstrated normal bilateral middle ear function.

c. Two additional participants, novices 2 and 4, had moderate hearing loss in the high frequencies, but only in one ear. In novice 2, the hearing loss was in the left ear; for novice 4 the loss was in the right ear. Frequency plots are shown in Figures 2.1-1 through 2.1-6.

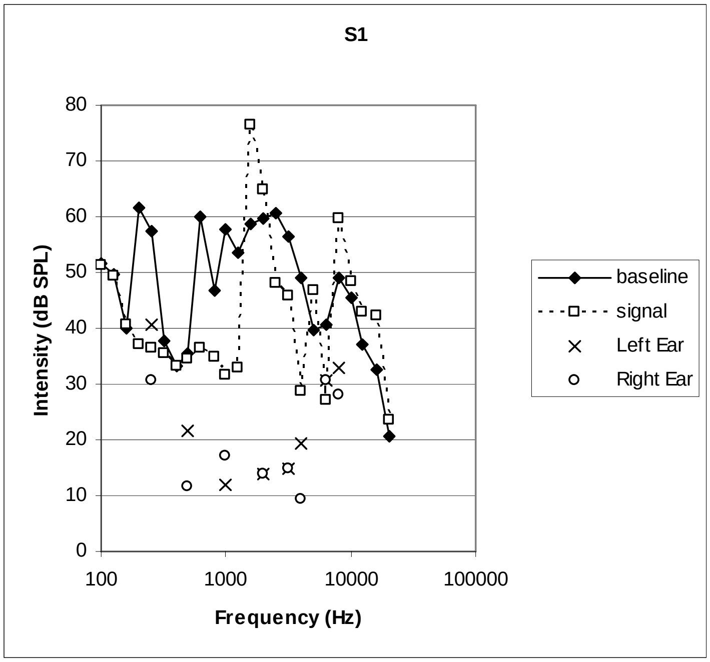

Figure 2.2-1. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from novice 1.

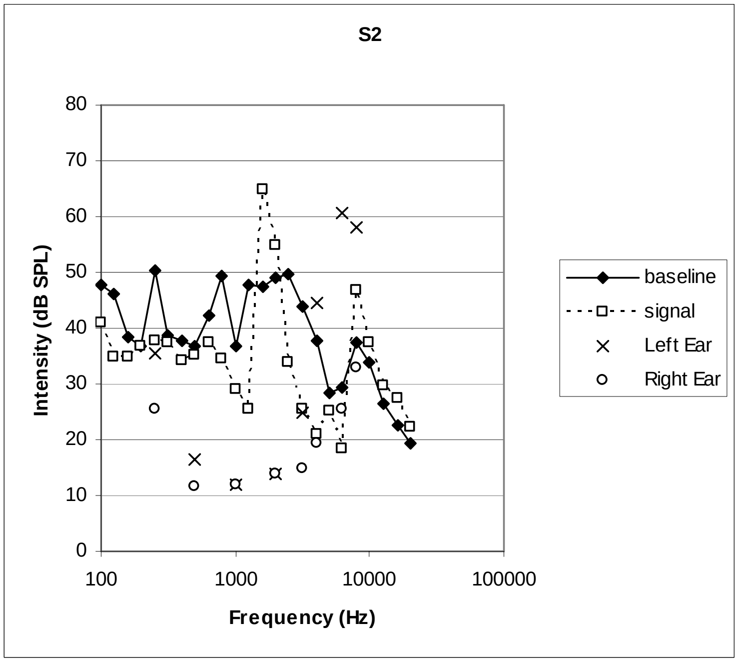

Figure 2.2-2. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from novice 2.

Note: The participant has a hearing loss in the high frequencies in the left ear, as shown by the *x* symbols.

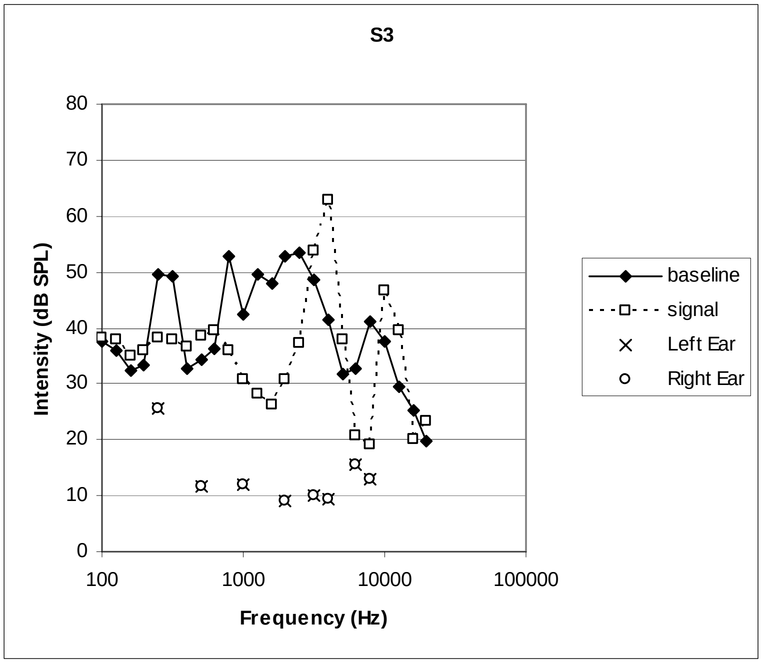

Figure 2.2-3. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from novice 3.

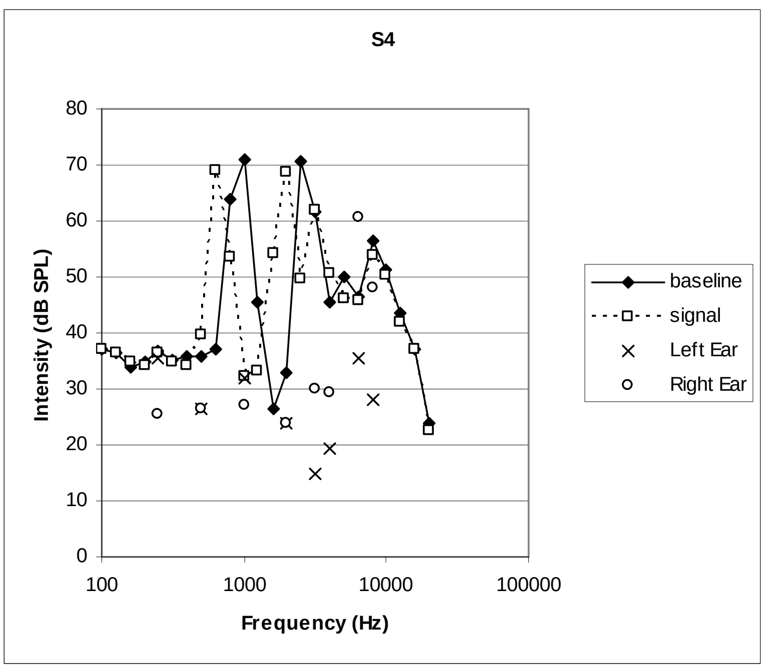

Figure 2.2-4. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from novice 4.

Note: The participant has a high frequency hearing loss in the right ear, as shown by the open circles.

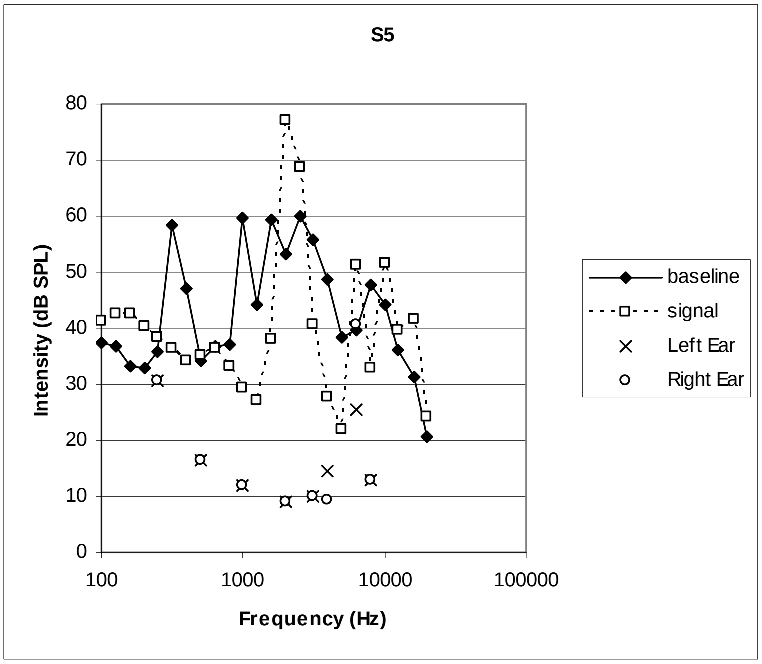

Figure 2.2-5. Plot of frequency response of baseline and signals measured from the Schonstedt detector along with hearing thresholds from novice 5.

2.2.7 Lane Orientation Effects

a. The complete test grid of 33 lanes was divided into two magnetic compass headings sections.

b. Lanes 1 through 20 was situated north to south, and was 23.703 by 1.5 meters (35.6 m^2). There were 28 ordnances scattered throughout the 20 lanes. The performance data of the novice operators without instrumentation for lanes 1 through 20 are presented in Table 2.2-3.

TABLE 2.2-3. SUMMARY TABLE OF ALL OPERATORS WITHOUT INSTRUMENTATION FOR LANES 1 THROUGH 20

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Novices	N-1	100.0%	0.083	0.083	0.101	4916
	N-2	100.0%	0.042	0.042	0.109	4400
	N-3	96.4%	0.055	0.065	0.141	3685
	N-4	100.0%	0.167	0.167	0.060	8498
	N-5	92.9%	0.023	0.075	0.112	4475
	Mean	**97.9%**	**0.074**	**0.087**	**0.105**	**5195**
	Std. Dev.	**0.0319**	**0.0566**	**0.0477**	**0.0292**	**1898.6**

c. Lanes 21 through 33 were positioned east to west. Lanes 21 through 26 were 17.55 by 1.5 meters (26.325 m^2), and lanes 27 through 33 were 25.00 by 1.5 meters (37.5 m^2). There were 32 ordnances placed throughout the 13 lanes. The performance data without instrumentation for only lanes 21 through 33 are presented in Table 2.2-4.

TABLE 2.2-4. SUMMARY TABLE OF ALL OPERATORS WITHOUT INSTRUMENTATION FOR LANES 21 THROUGH 33

	Operator	**P_d**	**FAR, $1/m^2$**	**DOP**	**Lane Velocity, m/s**	**Total Time, s**
Novices	N-1	100.0%	0.012	0.012	0.018	2696
	N-2	96.9%	0.005	0.032	0.117	2410
	N-3	93.8%	0.033	0.071	0.098	2976
	N-4	96.9%	0.169	0.172	0.035	8575
	N-5	93.8%	0.007	0.063	0.068	4258
	Mean	**96.3%**	**0.045**	**0.070**	**0.085**	**4183**
	Std. Dev.	**0.0261**	**0.0701**	**0.617**	**0.0338**	**2554.7**

2.3 DISCUSSION OF UN-INSTRUMENTED DATA

2.3.1 Performance Analysis

a. A summary of the performance data for each expert and novice without instrumentation is presented in Table 2.3-1. The P_d versus FAR of experts and novices is shown in Figure 2.3-1.

TABLE 2.3-1. SUMMARY OF PERFORMANCE DATA OF EXPERTS AND NOVICES WITHOUT INSTRUMENTATION

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	100.0%	0.154	0.154	0.095	8238
	E-2	91.7%	0.072	0.110	0.088	9086
	E-3	100.0%	0.087	0.087	0.100	8279
	E-4	93.3%	0.034	0.075	0.092	8608
	E-5	93.3%	0.090	0.112	0.096	8199
	Mean	**95.7%**	**0.087**	**0.108**	**0.094**	**8482**
	Std. Dev.	**0.0401**	**0.0435**	**0.0302**	**0.0044**	**374.7**
Novices	N-1	100.0%	0.057	0.057	0.104	7612
	N-2	98.3%	0.028	0.033	0.112	6810
	N-3	95.0%	0.047	0.069	0.124	6661
	N-4	98.3%	0.168	0.169	0.050	17073
	N-5	93.3%	0.017	0.069	0.094	8733
	Mean	**97.0%**	**0.063**	**0.079**	**0.097**	**9378**
	Std. Dev.	**0.0274**	**0.0605**	**0.0522**	**0.0284**	**4379.6**

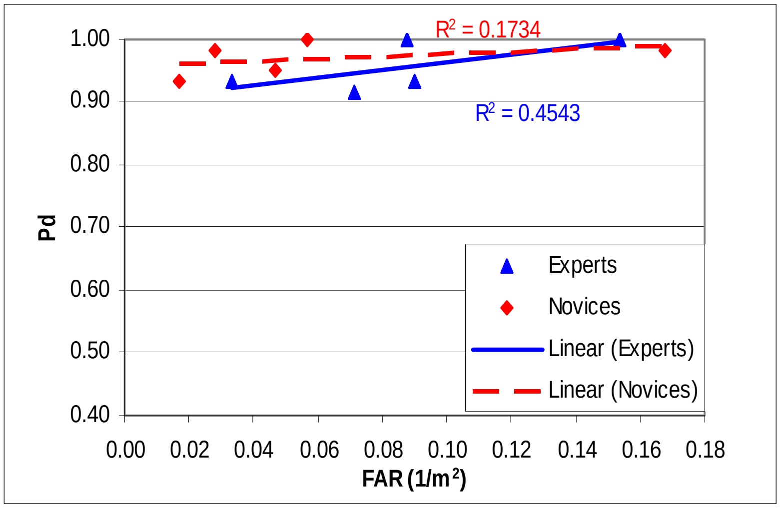

Figure 2.3-1. P_d versus FAR of experts and novices without instrumentation.

b. Using the chi-square distribution at the 0.05 significance level, P_d between experts and novices, without instrumentation, was not found to be significantly different. Using the Mann-Whitney test at the 0.05 significance level, no significant differences were found between the number of false alarms, DOP, and time between the novices and experts.

c. The comparison of average lane velocity with the three performance measurements (P_d, FAR, and DOP) is shown in Figures 2.3-2 through 2.3-4.

d. The comparison of total time with the three performance measurements is shown in Figures 2.3-5 through 2.3-7.

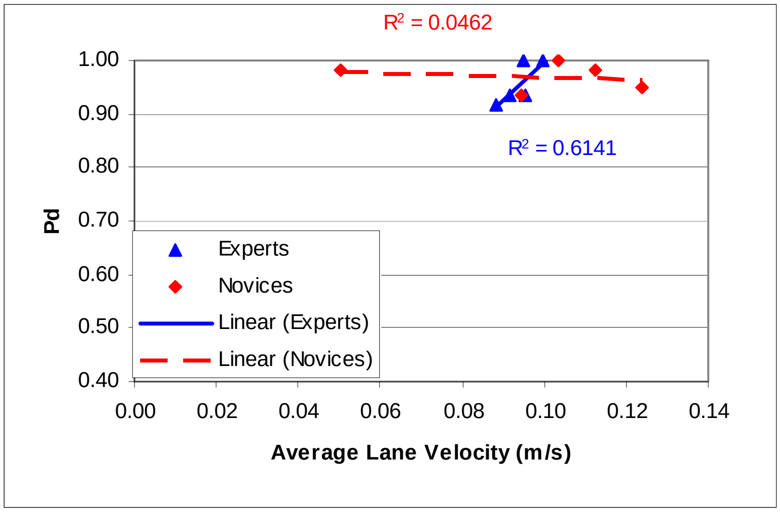

Figure 2.3-2. Experts and novices - P_d versus average lane velocity.

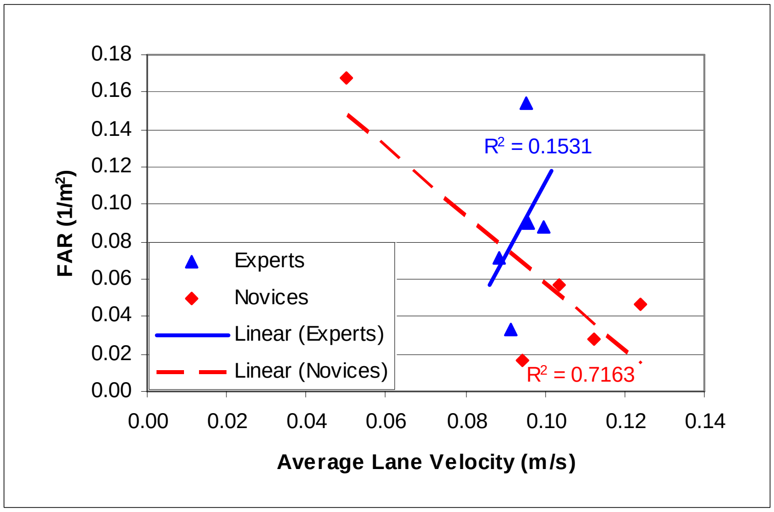

Figure 2.3-3. Experts and novices - FAR versus average lane velocity.

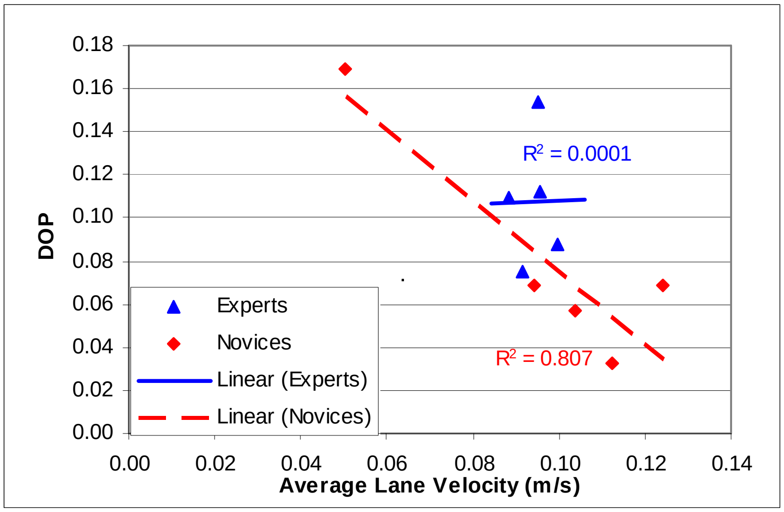

Figure 2.3-4. Experts and novices - DOP versus average lane velocity.

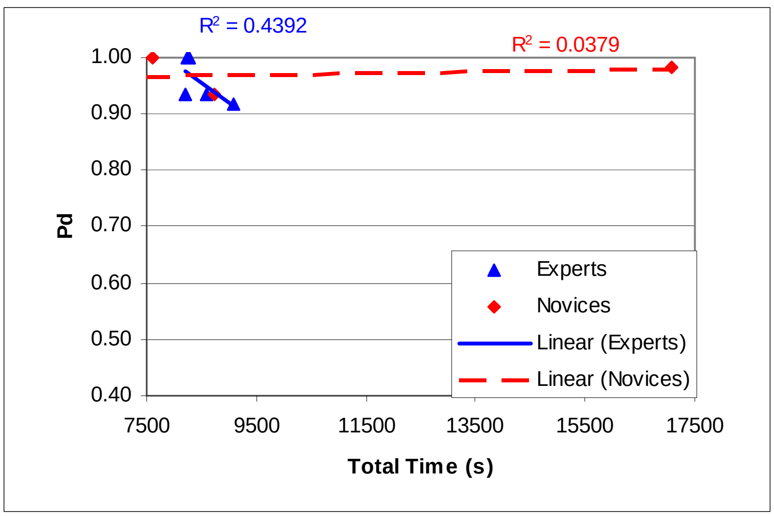

Figure 2.3-5. Experts and novices - P_d versus total time.

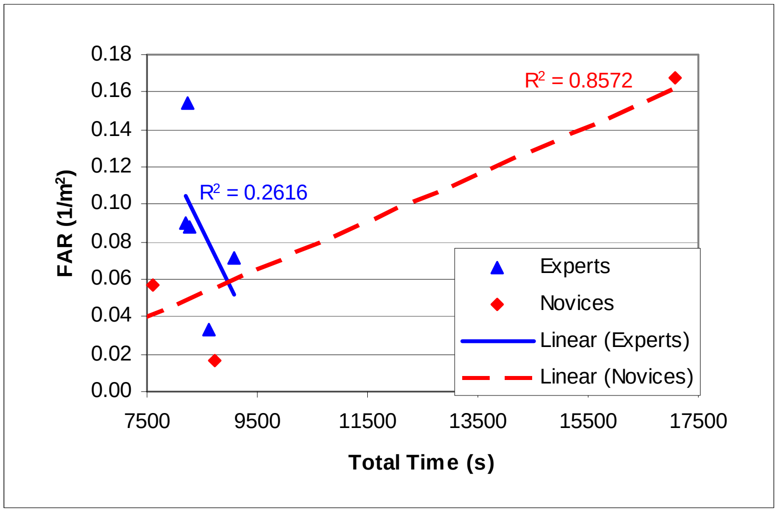

Figure 2.3-6. Experts and novices - FAR versus total time.

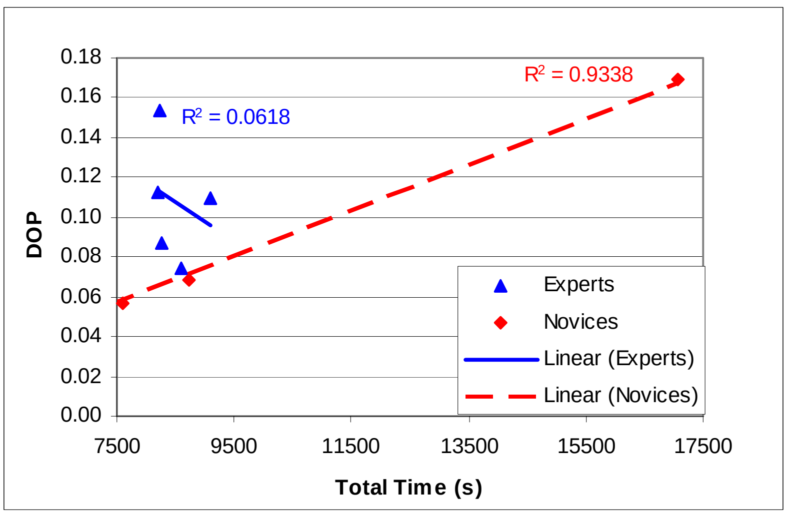

Figure 2.3-7. Experts and novices - DOP versus total time.

2.3.2 Ordnance

a. The average P_d for each ordnance type/depth and orientation for all the operators without instrumentation is presented in Table 2.3-2. All operators achieved 100 percent detection rates on the 40mm, both horizontally and vertically oriented. Operators had the lowest detection rates on the 81mm, both horizontally and vertically oriented. Overall, vertically oriented ordnance had higher P_d than horizontally oriented ordnance. Ordnance type and depths were codependent (table 2.3-2); that is, since each ordnance type was buried at a certain depth, no information can be deduced about ordnance type or depth separately.

TABLE 2.3-2. AVERAGE P_d OF ALL OPERATORS WITHOUT INSTRUMENTATION BY ORDNANCE TYPE/DEPTH AND ORIENTATION

Type	Depth, in	Horizontal	Vertical	Total
40mm	6	100.0%	100.0%	100.0%
60mm	12	94.0%	98.6%	96.7%
81mm	18	80.0%	92.9%	88.5%
105mm	24	100.0%	97.5%	98.5%
155mm	30	100.0%	98.6%	99.2%
Total		**94.2%**	**97.9%**	**96.3%**

b. The P_d by ordnance orientation and type for both novices and experts is presented in Table 2.3-3. Novices had 100 percent P_d both horizontally and vertically with three different types of ordnance: 40mm, 105mm, and 155mm. They also performed equal to or better than the experts in every category with the exception of two, the 60mm horizontally and vertically. overall, the novices averaged 1.1 percent higher with regard to P_d than the experts.

TABLE 2.3-3. EXPERTS VERSUS NOVICES WITHOUT INSTRUMENTATION - P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Novices	Experts	Total	Pd Differences
Horizontal	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	92.0%	96.0%	94.0%	-4.0%
	81mm	83.3%	76.7%	80.0%	6.7%
	105mm	100.0%	100.0%	100.0%	0.0%
	155mm	100.0%	100.0%	100.0%	0.0%
	Total	**94.6%**	**93.8%**	**94.2%**	
Vertical	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	97.1%	100.0%	98.6%	-2.9%
	81mm	94.3%	91.4%	92.9%	2.9%
	105mm	100.0%	95.0%	97.5%	5.0%
	155mm	100.0%	97.1%	98.6%	2.9%
	Total	**98.8%**	**97.1%**	**97.9%**	
Overall Total		**97.0%**	**95.7%**	**96.3%**	

2.3.3 Audiological Analysis. For all participants, hearing status was not expected to have a significant impact on performance in the study for three reasons. First, the signals from the magnetic locators presented to the listeners were provided through headphones to both ears. Therefore, hearing loss in only one ear should not impact overall performance, as the better ear would be able to compensate for the loss in the poorer ear. Second, the signals provided to the listeners were of a level high enough to be above their hearing thresholds, as shown in the graphs. Third, the signals emitted from the magnetic locators were broad in their frequency spectrum, so that an individual with a bilateral high frequency hearing loss should have been able to use the lower frequency.

2.3.4 Lane Orientation Analysis. A statistical analysis was done to compare performance data from lanes 1 through 20 (north-south lanes) with the data from lanes 21 through 33 (east-west lanes). P_d was tested using the chi-square test at the 0.05 significance level, while the number of false alarms, distance measurement, and total time were tested using the Mann-Whitney test at the 0.05 significance level. The performance measurements that were significantly different between experts and novices are presented in Table 2.3-4. Without instrumentation for all lanes, the novices and experts performed similarly. The significant difference between lanes 1 through 20 data and lanes 21 through 33 data (total time was not addressed in these comparisons because the area covered was not the same) are presented in Table 2.3-5. For experts and novices both with and without instrumentation, significantly more false alarms were found for lanes 1 through 20 than lanes 21 through 33. Common false alarms (CFA) are false alarms in which four or more operators detected a FAR within a 0.25-meter radius circle. For the operators without instrumentation (78 CFA), 86 percent occurred in lanes 1 through 20.

TABLE 2.3-4. SUMMARY OF SIGNIFICANCE TESTING OF EXPERTS VERSUS NOVICES

		P_d[a]	#FA[b]	DOP[b]
with Inst	Lanes 1-33	SIG	--	SIG
	Lanes 1-20	SIG	SIG	SIG
	Lanes 21-33	SIG	--	SIG
without Inst	Lanes 1-33	--	--	--
	Lanes 1-20	--	--	SIG
	Lanes 21-33	--	--	--

[a]Chi-square distribution, one-sided test, at 0.05 significance level.
[b]Mann-Whitney test, one-sided test, at 0.05 significance level.

TABLE 2.3-5. SUMMARY OF SIGNIFICANCE TESTING OF DATA FROM LANES 1 THROUGH 20 VERSUS LANES 21 THROUGH 33

		P_d[a]	#FA[b]	DOP[b]
with Inst	Experts	--	SIG	--
	Novices	--	SIG	--
without Inst	Experts	--	SIG	SIG
	Novices	--	SIG	--

[a]Chi-square distribution, one-sided test, at 0.05 significance level.
[b]Mann-Whitney test, one-sided test, at 0.05 significance level.

2.3.5 Stress Analysis. See appendix M.

2.3.6 Observations

a. Overall, the novices had higher P_d and lower FAR within the un-instrumented subgroup. Consequently, it was not unexpected that DOPs for the novices were also lower, on average, than those for the experts. It is also interesting to observe that despite the overall performance averages, two of the experts had a P_d of one, versus only one novice. The P_d versus FAR figure shows that for the most part, novices tended to be closer to the upper left-hand corner and experts were grouped more to the right. This matches the results from the DOP calculations shown in Table 2.3-1.

b. Two trends can be seen from the expert versus novice comparison plots (fig. 2.3-2 through 2.3-7): the quicker the novices traversed the lanes, the fewer false alarms they indicated, and they also had a better overall performance (low DOP). Also, the experts had little variation among themselves for lane velocity (standard deviation, 0.0044). The novices, on the other hand, had high variation for lane velocity (standard deviation, 0.0284).

c. When reviewing performance characteristics, some observations were clear with regard to time domain data in Figures 2.3-5 to 2.3-7. Consistent with average lane velocity, the experts had less variation among themselves then the novices for total time. Also, the more time the novices took, the more false alarms they indicated.

d. Overall, vertically oriented ordnance had higher P_d than the horizontally oriented ordnance. Both novices and experts had difficulty in locating the 61mm and 81mm mortar targets. This may have been because of the distinctive profile of the latter targets compared with the 40mm, 105mm, and 155mm targets, which share a simple projectile geometry. It was unexpected that both experts and novices located (P_d rates of 1) the 40mm projectile despite the predominantly aluminum alloy composition, albeit this target was positioned at a mere 6-inch burial depth.

e. Experts showed an overall lower average total time of 2.4 hours, whereas the novices reported an average total time of 2.6 hours. Novice 4 is an outlier in this data set and accounts for the difference in average total time. It is assumed that if novice 4 performed in a similar manner to his novice counterparts, this average would be lower. Novice 4's time performance also accounts for the considerably large standard deviation within the novice data set of 1.2 hours.

f. The demographics of experts and novices seemed to provide a wide range of individuals. Ages, races, and marital status seemed to vary with no conclusive pattern. The majority of the participants (9 of 10) were male, with only one female in the expert group. Education levels seemed to be higher in the novice group, with two participants having obtained a bachelor degree. The experts all held high school diplomas, with 1 or 2 years of additional study. It is possible that expert participants interpreted their military training as education, and this may account for the differences. All experts, and 4 out of 5 novices, reported prior military experience. Of that military experience, the experts had an average of 11.8 years of military, 4.5 years of UXO, and 2.3 years of Schonstedt specific experience. One novice reported 1.5 months of UXO and Schonstedt experience; however, this was assumed to be a subjective answer as he had graduated from the UXO program 1.5 months before participation in this study. In addition, this novice did not work on a UXO site between graduation from the UXO training program and participation in this study. It was determined that these data would be valid for inclusion for analysis.

g. The heaviest expert was consistent with the individual greatest in height, and the lightest expert was the shortest. No physical outliers were observed in either set.

h. It is interesting that most experts (four of five) reported having excellent health, whereas all novices reported having good health. All experts were nonsmokers, and only one novice reported using tobacco products.

SECTION 3. INSTRUMENTED DATA

3.1 EXPERT

3.1.1 Performance Measurements

a. P_d.

(1) For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If the distance was less than 1 meter, then a target was considered detected regardless of which lane the target was in. Multiple detections of the same target were ignored. The number of detected targets in the field were divided by the total number of targets in the field (60 targets) and multiplied by 100. This result was defined as the P_d and will be referred to as P_d. P_d is a dimensionless number with values ranging from zero to one.

(2) Expert participants demonstrated P_d rates from 0.617 to 1. Their average P_d was 0.877 with a standard deviation of 0.0159.

b. FAR.

(1) For each alarm an operator declared in a particular lane, the distance between each of the targets in the field and the alarm was calculated. If no target was within 1 meter of the alarm, then the alarm was considered a false alarm. The total numbers of false alarms were divided by the area of the field (1131.5 m^2). The result was defined as the FAR and will be referred to as FAR. FAR has a unit of false alarms per m^2.

(2) Expert participants demonstrated FAR rates from 0.012 to 0.96 false alarms per m^2. The average FAR was 0.061 per m^2 with a standard deviation of 0.0333 false alarms per m^2.

c. DOP.

(1) An ROC curve is an industry standard that is used to compare the performance of operators and equipment in UXO and mine detection. It consists of the FAR on the *x*-axis versus the P_d on the *y*-axis. Curves nearer the upper left-hand corner of the chart are considered to be higher performance from a detector. Therefore, in order to compare the operators' performance versus each of the characteristics, the DOP was calculated as the distance from the upper left-hand corner (coordinates 0, 1) that an operators' point (FAR, P_d) is on the ROC curve, as shown in the following equation:

$$Dist\_DOP = \sqrt{(1 - Pd)^2 + (0 - FAR)^2}$$

(2) The DOP value is a dimensionless number; however, in general the greater the value the lower overall performance within P_d and FAR dimensions. Expert participants demonstrated DOP's between 0.087 and 0.384. Their average DOP was 0.161 with a standard deviation of 0.1325.

3.1.2 Time Measurements

a. Lane velocity.

(1) The time operators required to complete each lane was manually recorded in an on-site daily log. Time delays due to equipment issues or data recording were also recorded and then subtracted from the total lane time. This lane length was then divided by the "corrected" lane time. The result was defined as the lane velocity.

(2) Expert participants demonstrated lane velocities between 0.069 m/s and 0.105 m/s. Their average lane velocity was 0.082 m/s with a standard deviation of 0.0147.

b. Total time.

(1) The time operators required to execute a UXO sweep operation on all 33 lanes of the test site. Corrected lane times were used for the following summation:

$$Total\_Time = \sum_{i=1}^{33} i\_lanes$$

(2) Expert participants demonstrated total times between 7574 seconds and 11,626 seconds. Their average total times were 9953 seconds with a standard deviation of 1565.4 seconds.

3.1.3 Data Summary

TABLE 3.1-1. EXPERT PERFORMANCE DATA (INSTRUMENTED)

	Operator	**P_d**	**FAR, $1/m^2$**	**DOP**	**Lane Velocity, m/s**	**Total Times**
Experts	E-1	98.3%	0.048	0.051	0.089	9304
	E-2	83.3%	0.061	0.177	0.075	10602
	E-3	100.0%	0.087	0.087	0.074	10661
	E-4	61.7%	0.012	0.384	0.105	7574
	E-5	95.0%	0.096	0.109	0.069	11626
	Mean	**87.7%**	**0.061**	**0.161**	**0.082**	**9953**
	Std. Dev.	**0.1593**	**0.0333**	**0.1325**	**0.0147**	**1565.4**

3.1.4 Ordnance. Five different ordnance types were used: 40mm, 60mm, 81mm, 105mm, and 155mm. Each type was buried at a specific depth: 6, 12, 18, 24, and 30 inches. The ordnance was placed in both the horizontal and vertical orientations. The P_d measurements for each ordnance type, depth, and orientation are presented in Table 3.1-2.

TABLE 3.1-2. P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Experts
Horizontal	40mm	100.0%
	60mm	80.0%
	81mm	70.0%
	105mm	80.0%
	155mm	100.0%
	Total	**85.4%**
Vertical	40mm	100.0%
	60mm	94.3%
	81mm	71.4%
	105mm	100.0%
	155mm	82.9%
	Total	**89.4%**

3.1.5 Demographics

a. Prior to traversing the test grid, each participant executed a basic demographic questionnaire.

b. The group of expert participants, when comparing un-instrumented with instrumented samples, was identical and contained the same personnel. Demographics of expert participants can be found in section 2.2.5.

3.1.6 Hearing. The group of expert participants, when comparing un-instrumented with instrumented samples, was identical and contained the same personnel. Hearing assessment results of expert participants can be found in section 2.2.4.

3.1.7 Lane Orientation Effects

a. The complete test grid of 33 lanes was divided into two groups, corresponding to their magnetic compass heading.

b. Lanes 1 through 20 was situated north to south, and was 23.703 by 1.5 meters (35.6 m^2). There were 28 ordnances scattered throughout the 20 lanes. The performance data of the expert operators with instrumentation of lanes 1 through 20 are presented in Table 3.1-3.

TABLE 3.1-3. SUMMARY TABLE OF ALL OPERATORS WITH INSTRUMENTATION FOR LANES 1 THROUGH 20

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Experts	E-1	100.0%	0.052	0.052	0.101	4904
	E-2	82.1%	0.082	0.196	0.068	7259
	E-3	100.0%	0.107	0.107	0.070	7030
	E-4	60.7%	0.020	0.393	0.094	5247
	E-5	92.9%	0.136	0.154	0.062	7907
	Mean	**87.1%**	**0.079**	**0.181**	**0.079**	**6469**
	Std. Dev.	**0.1648**	**0.0456**	**0.1306**	**0.0172**	**1318.1**

c. Lanes 21 through 33 was positioned east to west. Lanes 21 through 26 were 17.55 by 1.5 meters (26.325 m^2), and lanes 27 through 33 were 25.00 by 1.5 meters (37.5 m^2). There were 32 ordnances placed throughout these thirteen lanes. The performance data without instrumentation for only lanes 21 through 33 are presented in Table 3.1-4.

TABLE 3.1-4. SUMMARY TABLE OF ALL OPERATORS WITH INSTRUMENTATION FOR LANES 21 THOUGH 33

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Experts	E-1	96.9%	0.040	0.051	0.070	4400
	E-2	84.4%	0.026	0.158	0.085	3343
	E-3	100.0%	0.052	0.052	0.081	3631
	E-4	62.5%	0.000	0.375	0.121	2327
	E-5	96.9%	0.029	0.042	0.079	3719
	Mean	**88.1%**	**0.029**	**0.136**	**0.087**	**3484**
	Std. Dev.	**0.1553**	**0.0195**	**0.1420**	**0.0198**	**754.1**

3.1.8 Dynamic Measurements

a. Percentage of lane area covered.

(1) Using the TMS data, the lateral distance between the detector head and each point on a 0.25 meter square grid within the lane was calculated for each recorded coordinate of the detector head. The number of points on the grid of which the detector head came within 0.25 meters at some point during the run was divided by the total number of points on the grid and multiplied by 100. The result was defined as the percent of lane area covered.

(2) Experts were observed to have between 92.82 and 98.36 percent lane coverage rates. The average and standard deviation was 96.50 percent and 2.1 percent coverage rates, respectively.

b. Detector head height.

(1) Using the TMS data, the two sensors' positions were used to calculate a vector to determine the position of the detector head. The ground altitude at the nearest surveyed point was then subtracted from the altitude of the calculated detector head position. The result was defined as the detector head height. The data presented are considered to be an average, as they were compared with the time-stamped lane data.

(2) Experts were observed with average detector head heights between 7.09 and 9.79 inches. The average and standard deviation was 8.48 and 1.311 inches, respectively.

c. Detector head velocity.

(1) Using the TMS data, the incremental distance traveled by the detector head was calculated by taking the calculated detector head position at each instance and subtracting the calculated detector head position at the previous instance. The incremental distance traveled was then divided by the time lapse (normally 0.1 s). The result was defined as the detector head velocity.

(2) Experts were observed with detector head velocities between 1.38 and 2.62 m/s. The average and standard deviation were 1.84 and 0.463 m/s, respectively.

TABLE 3.1-5. SUMMARY OF EXPERT'S DYNAMIC DATA

	Operator	**P_d**	**FAR, $1/m^2$**	**DOP Distance**	**Lane Velocity, m/s**	**% Lane Area Covered**	**Detector Head Height, in.**	**Detector Head Velocity, m/s**
Experts	E-1	98.33%	0.0477	0.0506	0.09	97.13%	7.09	1.38
	E-2	83.33%	0.0610	0.1775	0.07	92.82%	8.88	1.74
	E-3	100.00%	0.0875	0.0875	0.07	97.26%	7.10	1.73
	E-4	61.67%	0.0124	0.3835	0.10	98.36%	9.79	2.62
	E-5	95.00%	0.0963	0.1085	0.06	96.95%	9.56	1.72
	Mean	**87.67%**	**0.0610**	**0.1615**	**0.08**	**96.50%**	**8.48**	**1.84**
	St. Dev.	**0.159**	**0.034**	**0.132**	**0.016**	**0.021**	**1.311**	**0.463**

3.2 NOVICE

3.2.1 Performance Measurements

a. P_d.

(1) For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If the distance was less than 1 meter, then a target was considered detected regardless of which lane the target was in. Multiple detections of the same target were ignored. The number of detected targets in the field were divided by the total number of targets in the field (60 targets) and multiplied by 100. This result was defined as the P_d and will be referred to as P_d. P_d is a dimensionless number with values ranging from zero to one.

(2) Novice participants demonstrated P_d rates from 0.950 to 1. Their average P_d was 0.983 with a standard deviation of 0.020.

b. FAR.

(1) For each alarm an operator declared in a particular lane, the distance between each of the targets in the field and the alarm was calculated. If no target was within 1 meter of the alarm, then the alarm was considered a false alarm. The total numbers of false alarms were divided by the area of the field (1131.5 m^2). The result was defined as the FAR and will be referred to as FAR. FAR has a unit of false alarms per m^2.

(2) Novice participants demonstrated FAR rates from 0.013 to 0.42 false alarms per m^2. The average FAR was 0.021 per m^2 with a standard deviation of 0.014 false alarms per m^2.

c. DOP.

(1) An ROC curve is an industry standard that is used to compare the performance of operators and equipment in UXO and mine detection. It consists of the FAR on the *x*-axis versus the P_d on the *y*-axis. Curves nearer the upper left-hand corner of the chart are considered to be higher performance from a detector. Therefore, in order to compare the operators' performance versus each of the characteristics, the DOP was calculated as the distance from the upper left-hand corner (coordinates 0, 1) that an operators' point (FAR, P_d) is on the ROC curve, as shown in the following equation:

$$Dist\_DOP = \sqrt{(1-Pd)^2 + (0-FAR)^2}$$

(2) The DOP value is a dimensionless number; however, in general the greater the value the lower overall performance within P_d and FAR dimensions. Novice participants demonstrated DOP's between 0.015 and 0.052. Their average DOP was 0.032 with a standard deviation of 0.0155.

3.2.2 Time Measurements

a. Lane Velocity.

(1) The time operators required to complete each lane was manually recorded in an on-site daily log. Time delays due to equipment issues or data recording were also recorded and then subtracted from the total lane time. This lane length was then divided by the "corrected" lane time. The result was defined as the lane velocity.

(2) Novice participants demonstrated lane velocities between 0.035 m/s and 0.11 m/s. Their average lane velocity was 0.087 m/s with a standard deviation of 0.0302.

b. Total time.

(1) The time operators required to execute a UXO sweep operation on all 33 lanes of the test site. Corrected lane times were used for the following summation:

$$Total\_Time = \sum_{i=1}^{33} i\_lanes$$

(2) Novice participants demonstrated total times between 7074 seconds and 23,347 seconds. Their average total times were 11,186 seconds with a standard deviation of 6851.3 seconds.

3.2.3 Data Summary

TABLE 3.2-1. SUMMARY OF PERFORMANCE DATA OF NOVICES WITH INSTRUMENTATION

	Operator	$\mathbf{P_d}$	**FAR, 1/m²**	**DOP**	**Lane Velocity, m/s**	**Total Time, s**
Novices	N-1	98.3%	0.020	0.026	0.088	8848
	N-2	98.3%	0.013	0.021	0.110	7074
	N-3	95.0%	0.016	0.052	0.097	9097
	N-4	100.0%	0.042	0.042	0.035	23347
	N-5	100.0%	0.015	0.015	0.106	7562
	Mean	**98.3%**	**0.021**	**0.032**	**0.087**	**11186**
	St. Dev.	**0.0204**	**0.0120**	**0.0155**	**0.0302**	**6851.3**

3.2.4 Ordnance. Five different ordnance types were used: 40mm, 60mm, 81mm, 105mm, and 155mm. Each type was buried at a specific depth: 6, 12, 18, 24, and 30 inches. The ordnance was placed in both the horizontal and vertical orientations. The P_d measurements for each ordnance type, depth, and orientation are presented in Table 3.2-2.

TABLE 3.2-2. NOVICES WITH INSTRUMENTATION - P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Novices
Horizontal	40mm	100.0%
	60mm	92.0%
	81mm	96.7%
	105mm	100.0%
	155mm	93.3%
	Total	**96.2%**
Vertical	40mm	100.0%
	60mm	100.0%
	81mm	100.0%
	105mm	100.0%
	155mm	100.0%
	Total	**100.0%**

3.2.5 Demographics

a. Prior to traversing the test grid, each participant executed a basic demographic questionnaire.

b. The group of novice participants, when comparing un-instrumented with instrumented samples, was identical and contained the same personnel. Demographics of novice participants can be found in section 2.2.5.

3.2.6 Hearing. The group of novice participants, when comparing un-instrumented with instrumented samples, was identical and contained the same personnel. Hearing assessment results of novice participants can be found in section 2.2.6.

3.2.7 Lane Orientation Effects

a. The complete test grid of 33 lanes was divided into two groups, corresponding to their magnetic compass heading.

b. Lanes 1 through 20 was situated north to south, and was 23.703 by 1.5 meters (35.6 m^2). There were 28 ordnance scattered throughout the 20 lanes. The performance data of the novice operators with instrumentation for lanes 1 through 20 are presented in Table 3.2-3.

TABLE 3.2-3. SUMMARY TABLE OF ALL OPERATORS WITH INSTRUMENTATION FOR LANES 1 THROUGH 20

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Novices	N-1	96.4%	0.024	0.043	0.084	5806
	N-2	96.4%	0.014	0.038	0.120	4049
	N-3	96.4%	0.018	0.040	0.087	6489
	N-4	100.0%	0.051	0.051	0.038	13696
	N-5	100.0%	0.017	0.017	0.118	4243
	Mean	**97.9%**	**0.025**	**0.038**	**0.090**	**6857**
	St. Dev.	**0.0196**	**0.0149**	**0.0126**	**0.0331**	**3960.1**

c. Lanes 21 through 33 was positioned east to west. Lanes 21 through 26 were 17.55 by 1.5 meters (26.325 m^2), and lanes 27 through 33 were 25.00 by 1.5 meters (37.5 m^2). There were 32 ordnances placed throughout these thirteen lanes. The performance data without instrumentation for only lanes 21 through 33 are presented in Table 3.2-4.

TABLE 3.2-4. SUMMARY TABLE OF NOVICE OPERATORS WITH INSTRUMENTATION FOR LANES 21 THOUGH 33

	Operator	P_d	FAR, $1/m^2$	DOP	Lane Velocity, m/s	Total Time, s
Novices	N-1	100.0%	0.014	0.014	0.093	3042
	N-2	100.0%	0.012	0.012	0.094	3025
	N-3	93.8%	0.012	0.064	0.112	2608
	N-4	100.0%	0.029	0.029	0.030	9651
	N-5	100.0%	0.012	0.012	0.087	3319
	Mean	**98.8%**	**0.016**	**0.026**	**0.083**	**4329**
	St. Dev.	**0.0280**	**0.0073**	**0.0221**	**0.0310**	**2985.9**

3.2.8 Dynamic Measurements

a. Percentage of lane area covered.

(1) Using the TMS data, the lateral distance between the detector head and each point on a 0.25 meter grid within the lane was calculated for each recorded coordinate of the detector head. The number of points on the grid of which the detector head came within 0.25 meters at some point during the run was divided by the total number of points on the grid and multiplied by 100. The result was defined as the percent of lane area covered.

(2) Novices were observed to have between 95.82 and 97.52 percent lane coverage rates. The average and standard deviation was 96.80 percent and 0.0006 coverage rates, respectively.

b. Detector head height.

(1) Using the TMS data, the two sensors' positions were used to calculate a vector to determine the position of the detector head. The ground altitude at the nearest surveyed point was then subtracted from the altitude of the calculated detector head position. The result was defined as the detector head height. The data presented are considered to be an average, as they were compared with the time-stamped lane data.

(2) Novices were observed with average detector head heights between 6.52 and 9.72 inches. The average and standard deviation was 7.70 and 1.157 inches, respectively.

c. Detector head velocity.

(1) Using the TMS data, the incremental distance traveled by the detector head was calculated by taking the calculated detector head position at each instance and subtracting the calculated detector head position at the previous instance. The incremental distance traveled was then divided by the time lapse (normally 0.1 s). The result was defined as the detector head velocity.

(2) Novices were observed with detector head velocities between 1.04 and 1.54 m/s. The average and standard deviation were 1.17 and 0.208 m/s, respectively.

TABLE 3.2-5. SUMMARY OF NOVICE'S DYNAMIC DATA

	Operator	**P_d**	**FAR, $1/m^2$**	**ROC Distance**	**Lane Velocity, m/s**	**% Lane Area Covered**	**Detector Head Height, in.**	**Detector Head Velocity, m/s**
Novices	N-1	98.33%	0.0221	0.0277	0.09	95.82%	8.24	1.14
	N-2	98.33%	0.0133	0.0213	0.11	97.03%	7.86	1.04
	N-3	95.00%	0.0159	0.0525	0.10	97.03%	6.61	1.07
	N-4	100.00%	0.0468	0.0468	0.04	97.52%	6.52	1.09
	N-5	100.00%	0.0150	0.0150	0.11	96.62%	9.27	1.54
	Mean	**98.33%**	**0.0226**	**0.0327**	**0.09**	**96.80%**	**7.70**	**1.17**
	St. Dev.	**0.020**	**0.014**	**0.016**	**0.031**	**0.006**	**1.157**	**0.208**

3.3 DISCUSSION OF INSTRUMENTED DATA

3.3.1 Performance Analysis

a. A summary of the performance data for each expert and novice with instrumentation is presented in Table 3.3-1. The P_d versus FAR of experts and novices is shown in Figure 3.3-1.

TABLE 3.3-1. SUMMARY OF PERFORMANCE DATA OF EXPERTS AND NOVICES WITH INSTRUMENTATION

	Operator	**P_d**	**FAR, $1/m^2$**	**DOP**	**Lane Velocity, m/s**	**Total Time, s**
Experts	E-1	98.3%	0.048	0.051	0.089	9304
	E-2	83.3%	0.061	0.177	0.075	10602
	E-3	100.0%	0.087	0.087	0.074	10661
	E-4	61.7%	0.012	0.384	0.105	7574
	E-5	95.0%	0.096	0.109	0.069	11626
	Mean	**87.7%**	**0.061**	**0.161**	**0.082**	**9953**
	St. Dev.	**0.1593**	**0.0333**	**0.1325**	**0.0147**	**1565.4**
Novices	N-1	98.3%	0.020	0.026	0.088	8848
	N-2	98.3%	0.013	0.021	0.110	7074
	N-3	95.0%	0.016	0.052	0.097	9097
	N-4	100.0%	0.042	0.042	0.035	23347
	N-5	100.0%	0.015	0.015	0.106	7562
	Mean	**98.3%**	**0.021**	**0.032**	**0.087**	**11186**
	St. Dev.	**0.0204**	**0.0120**	**0.0155**	**0.0302**	**6851.3**

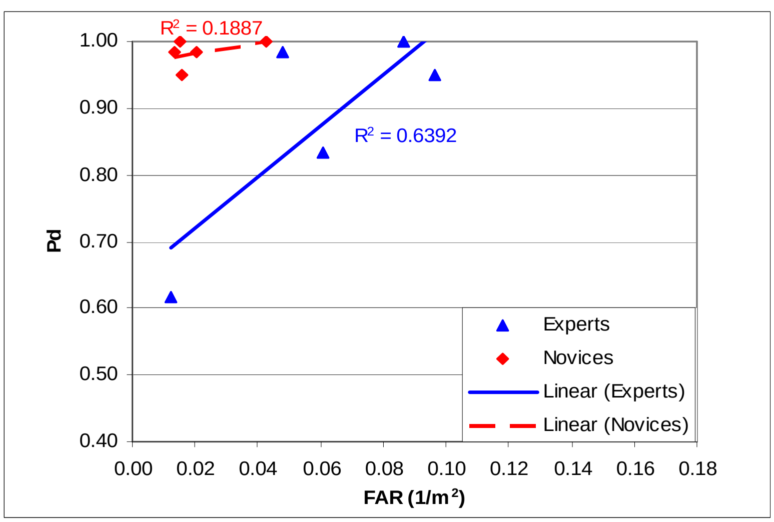

Figure 3.3-1. P_d versus FAR of experts and novices with instrumentation.

b. Using the chi-square distribution at 0.05 significance level, the novice P_d with instrumentation was found to be significantly greater than the expert P_d with instrumentation. Using the Mann-Whitney test at the 0.05 significance level, no significant differences were found between the number of false alarms and time, but the DOP of the novices was significantly less than the experts

c. The comparison of average lane velocity with the three performance measurements (P_d, FAR, and DOP) is shown in Figures 3.3-2 through 3.3-4.

d. The comparison of total time with the three performance measurements is shown in Figures 3.3-5 through 3.3-7.

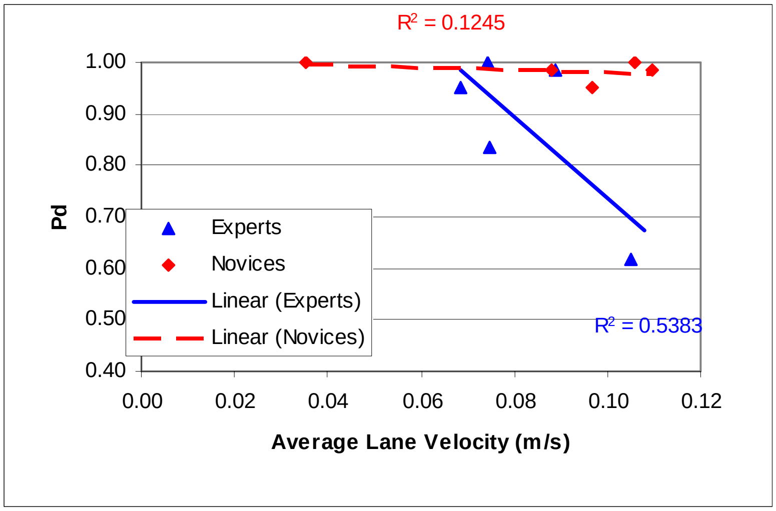

Figure 3.3-2. Experts and novices - P_d versus average lane velocity.

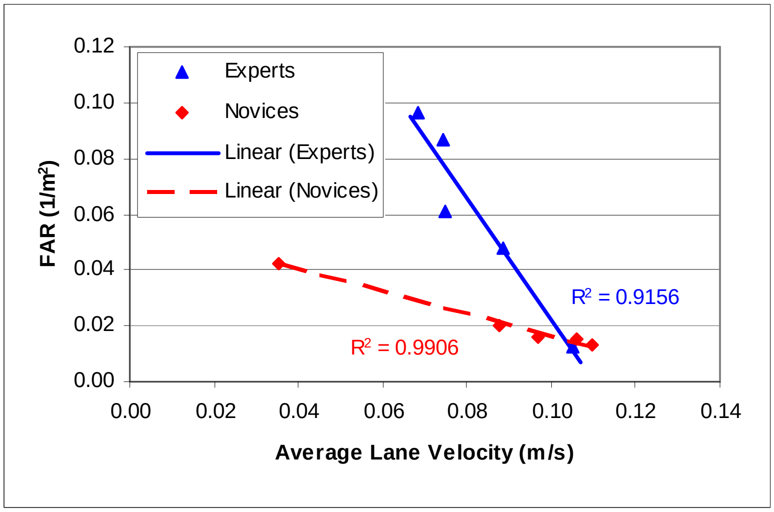

Figure 3.3-3. Experts and novices - FAR versus average lane velocity.

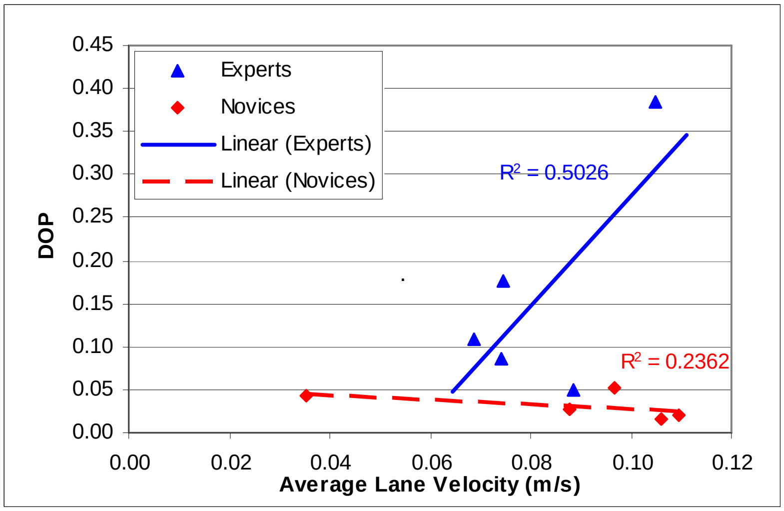

Figure 3.3-4. Experts and novices - DOP versus average lane velocity.

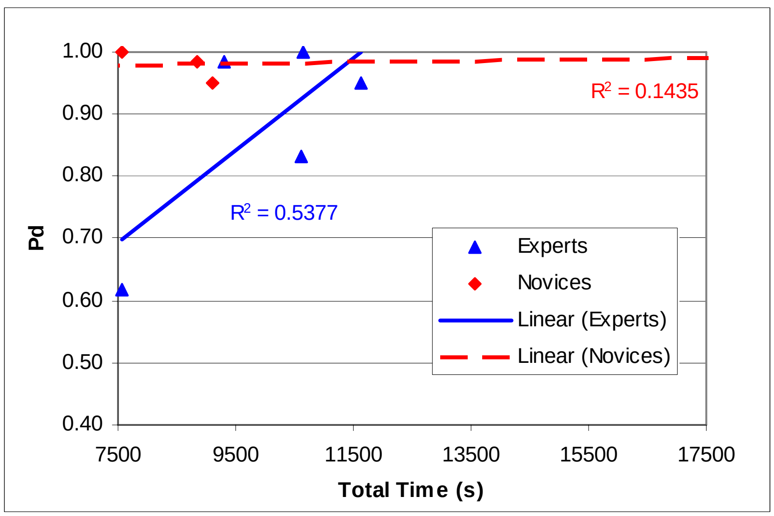

Figure 3.3-5. Experts and novices - P_d versus total time.

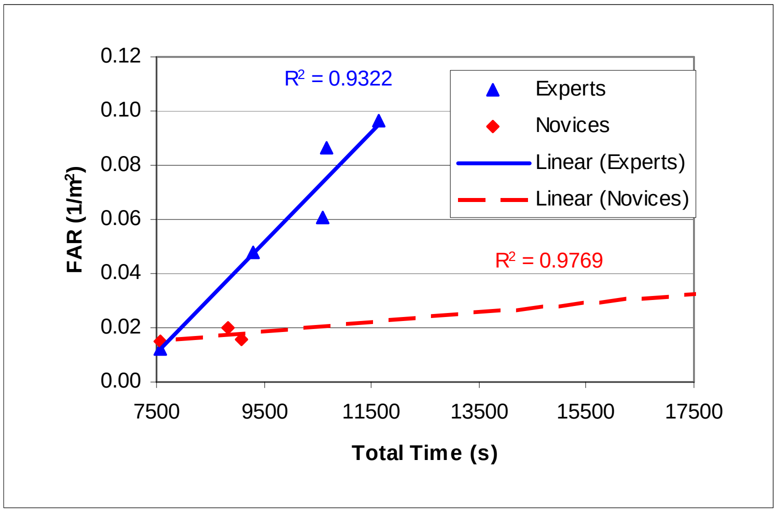

Figure 3.3-6. Experts and novices - FAR versus total time.

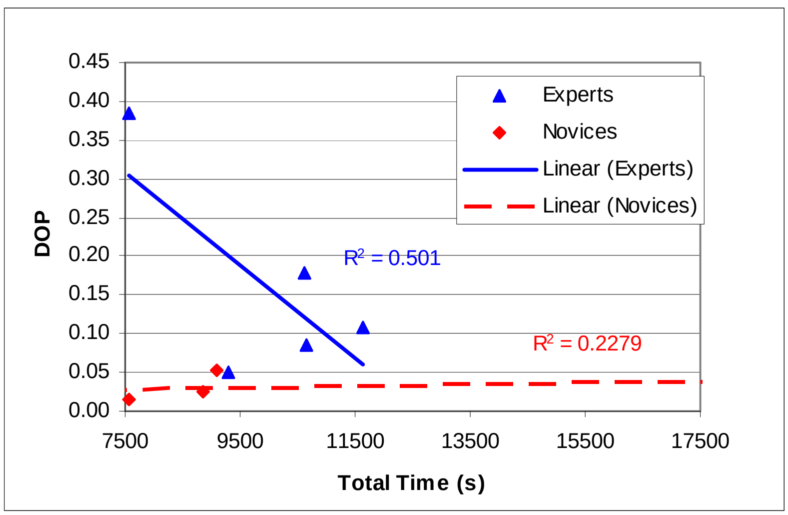

Figure 3.3-7. Experts and novices - DOP versus total time.

3.3.2 Ordnance

a. The average P_d for each ordnance type/depth and orientation for all the operators without instrumentation is presented in Table 3.3-2. All operators achieved 100 percent detection rates on the 40mm, both horizontally and vertically oriented. Operators had the lowest detection rates on the 81mm, both horizontally and vertically oriented. Overall, vertically oriented ordnance had higher P_d than horizontally oriented ordnance. Ordnance type and depths were codependent (table 3.3-2); that is, since each ordnance type was buried at a certain depth, no information can be deduced about ordnance type or depth separately.

Table 3.3-2. AVERAGE P_d OF ALL OPERATORS WITH INSTRUMENTATION BY ORDNANCE TYPE/DEPTH AND ORIENTATION

Type	Depth	Horizontal	Vertical	Total
40mm	6 in.	100.0%	100.0%	100.0%
60mm	12 in.	86.0%	97.1%	92.5%
81mm	18 in.	83.3%	85.7%	84.6%
105mm	24 in.	90.0%	100.0%	96.2%
155mm	30 in.	96.7%	91.4%	93.8%
Total		**90.8%**	**94.7%**	**92.7%**

b. The P_d by ordnance orientation and type for both novices and experts is presented in Table 3.3-3. Novices had 100 percent P_d with all ordnance buried vertically. They also performed equal to or better than the experts in every category with the exception of two, the 60mm horizontally and vertically.

TABLE 3.3-3. EXPERTS VERSUS NOVICES WITH INSTRUMENTATION - P_d BY ORDNANCE ORIENTATION AND TYPE

	Type	Novices	Experts	Total
Horizontal	40mm	100.0%	100.0%	100.0%
	60mm	92.0%	80.0%	86.0%
	81mm	96.7%	70.0%	83.3%
	105mm	100.0%	80.0%	90.0%
	155mm	93.3%	100.0%	96.7%
	Total	**96.2%**	**85.4%**	**90.8%**
Vertical	40mm	100.0%	100.0%	100.0%
	60mm	100.0%	94.3%	97.1%
	81mm	100.0%	71.4%	85.7%
	105mm	100.0%	100.0%	100.0%
	155mm	100.0%	82.9%	91.4%
	Total	**100.0%**	**89.4%**	**94.7%**

3.3.3 Audiological Analysis. For all participants, hearing status was not expected to have a significant impact on performance in the study for three reasons. First, the signals from the magnetic locators presented to the listeners were provided through headphones to both ears. Therefore, hearing loss in only one ear should not impact overall performance, as the better ear would be able to compensate for the loss in the poorer ear. Second, the signals provided to the listeners were of a level high enough to be above their hearing thresholds as shown in the graphs. Third, the signals emitted from the magnetic locators were broad in their frequency spectrum, so that an individual with a bilateral high frequency hearing loss should have been able to use the lower frequency.

3.3.4 Lane Orientation Analysis. A statistical analysis was done to compare performance data from lanes 1 through 20 (north-south lanes) with the data from lanes 21 through 33 (east-west lanes). P_d was tested using the chi-square test at 0.05 significance level, while the number of false alarms, distance measurement, and total time were tested using the Mann-Whitney test at the 0.05 significance level. The performance measurements that were significantly different between experts and novices are presented in Table 3.3-4. With instrumentation for all lanes, the novices had significantly better P_d and significantly shorter DOP. Without instrumentation for all lanes, the novices and experts performed similarly. The significant difference between lanes 1 through 20 data and lanes 21 through 33 data (total time was not addressed in these comparisons because the area covered was not the same) are presented in Table 3.3-5. For experts and novices both with and without instrumentation, significantly more false alarms were found for lanes 1 through 20 than lanes 21 through 33. CFA are false alarms in which four or more operators detected a false alarm within a 0.25-meter radius circle. For the operators with instrumentation (38 CFA), 89 percent occurred in lanes 1 through 20.

TABLE 3.3-4. SUMMARY OF SIGNIFICANCE TESTING OF EXPERTS VERSUS NOVICES

		Pd[a]	# FA[b]	DOP[b]	Total Time[b]
with Inst	Lanes 1-33	SIG	--	SIG	--
	Lanes 1-20	SIG	SIG	SIG	--
	Lanes 21-33	SIG	--	SIG	--
without Inst	Lanes 1-33	--	--	--	--
	Lanes 1-20	--	--	SIG	--
	Lanes 21-33	--	--	--	--

[a]Chi-square distribution, one-sided test, at 0.05 significance level.
[b]Mann-Whitney test, one-sided test, at 0.05 significance level.

TABLE 3.3-5. SUMMARY OF SIGNIFICANCE TESTING OF DATA FROM LANES 1 THROUGH 20 VERSUS LANES 21 THROUGH 33

		P_d[a]	#FA[b]	DOP[b]
with Inst	Experts	--	SIG	--
without Inst	Novices	--	SIG	--

[a]Chi-square distribution, one-sided test, at 0.05 significance level.
[b]Mann-Whitney test, one-sided test, at 0.05 significance level.

3.3.5 Stress Analysis. See appendix M.

3.3.6 Dynamic Data

a. The basis for providing dynamic tracking ability for the detector head stems from a desire to understand its effect on operator performance. Ultimately, the tracking system provided sufficient data to allow for analysis of average detector head height, detector head velocity, lane velocity, and percent area covered.

b. A comparison of P_d versus the four characteristics is shown in Figures 3.3-8 through 3.3-11; FAR versus the four characteristics is shown in Figures 3.3-12 through 3.3-15. A comparison of the distance DOP versus the four characteristics is shown in Figures 3.3-16 through 3.3-19.

c. The novices' performance as measured by P_d was closely grouped (fig. 3.3-8 through 3.3-11), so the dependency upon the performance characteristics was difficult to discern. However, for the experts, P_d performance suffered as the height and velocity of the detector head increased. In addition, though the correlation was not as significant, P_d performance also decreased as the lane velocity increased.

d. The number of false alarms by both experts and novices' generally decreased as the lane velocity, detector head height, and detector head velocity increased (fig. 3.3-12 through 3.3-15). However, the data are widely scattered, and the linear regression does not closely match the data, with the exception of the data for the novices and lane velocity.

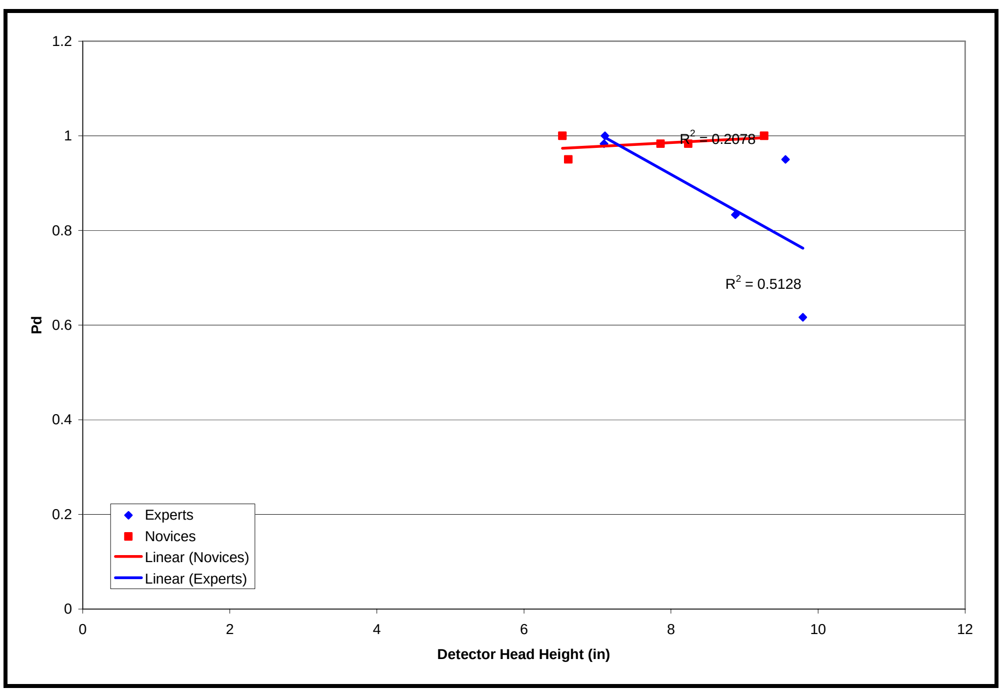

Figure 3.3-8. Experts and novices - P_d versus detector head height.

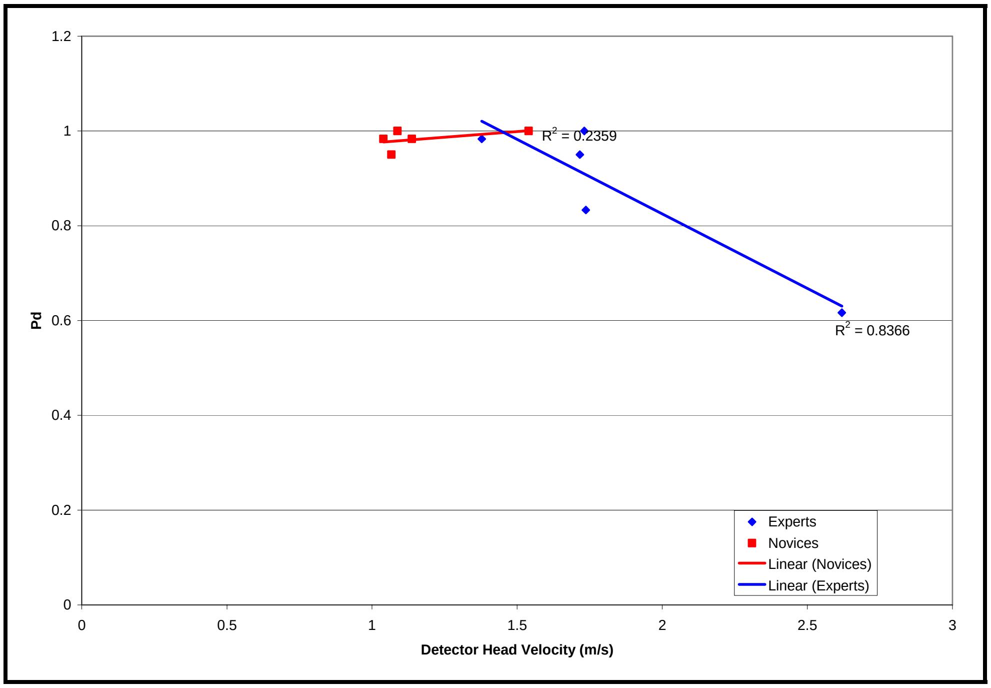

Figure 3.3-9. Experts and novices - P_d versus detector head velocity.

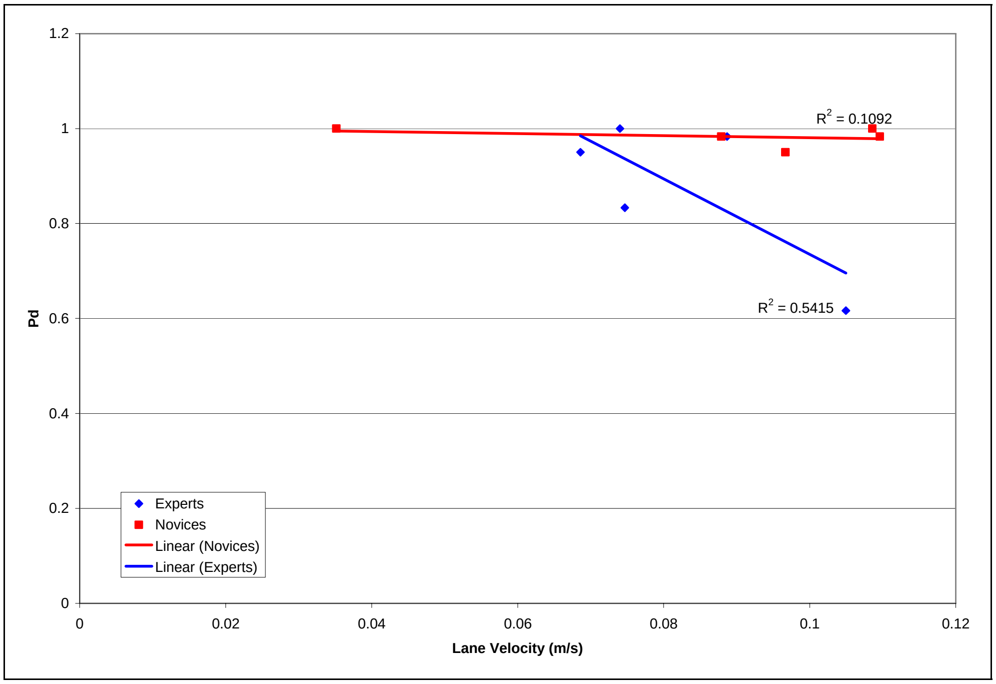

Figure 3.3-10. Experts and novices - P_d versus lane velocity.

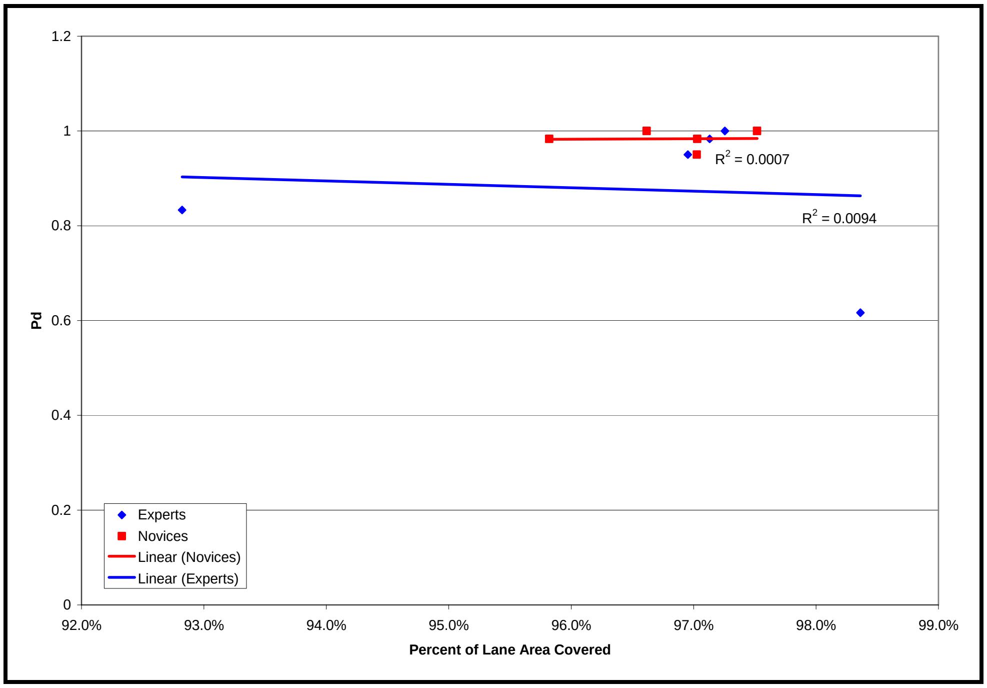

Figure 3.3-11. Experts and novices - P_d versus percent of lane area covered.

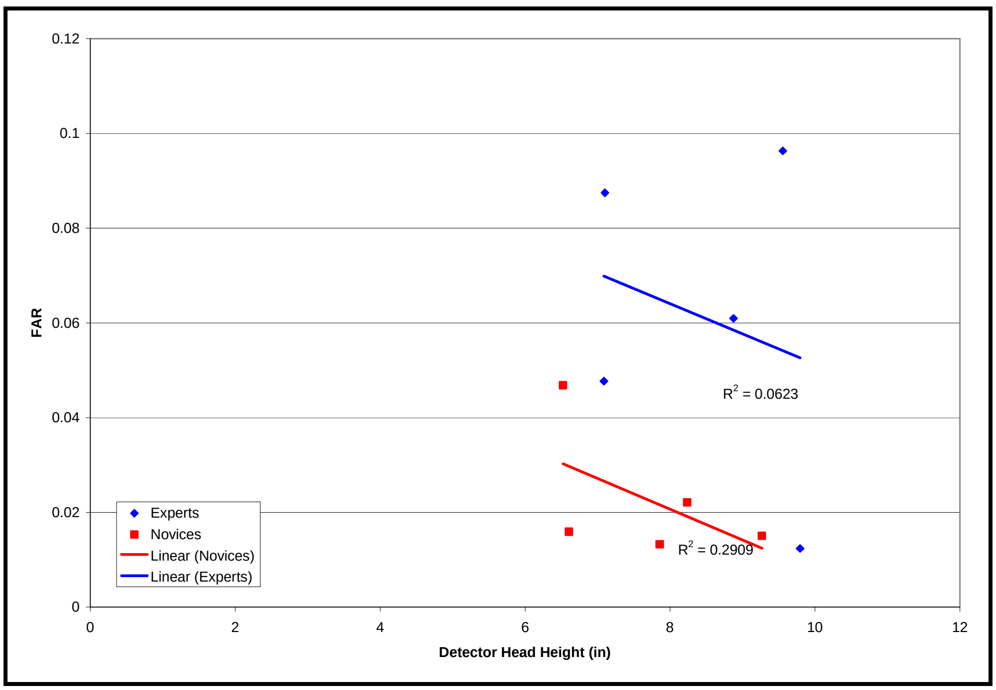

Figure 3.3-12. Experts and novices - FAR versus detector head height.

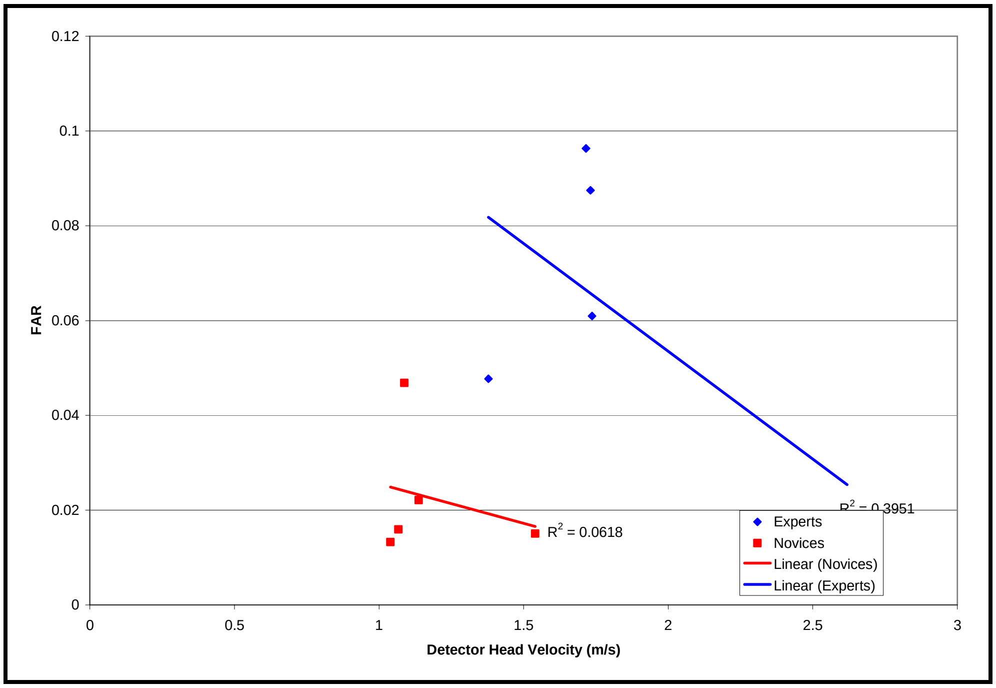

Figure 3.3-13. Experts and novices - FAR versus detector head velocity.

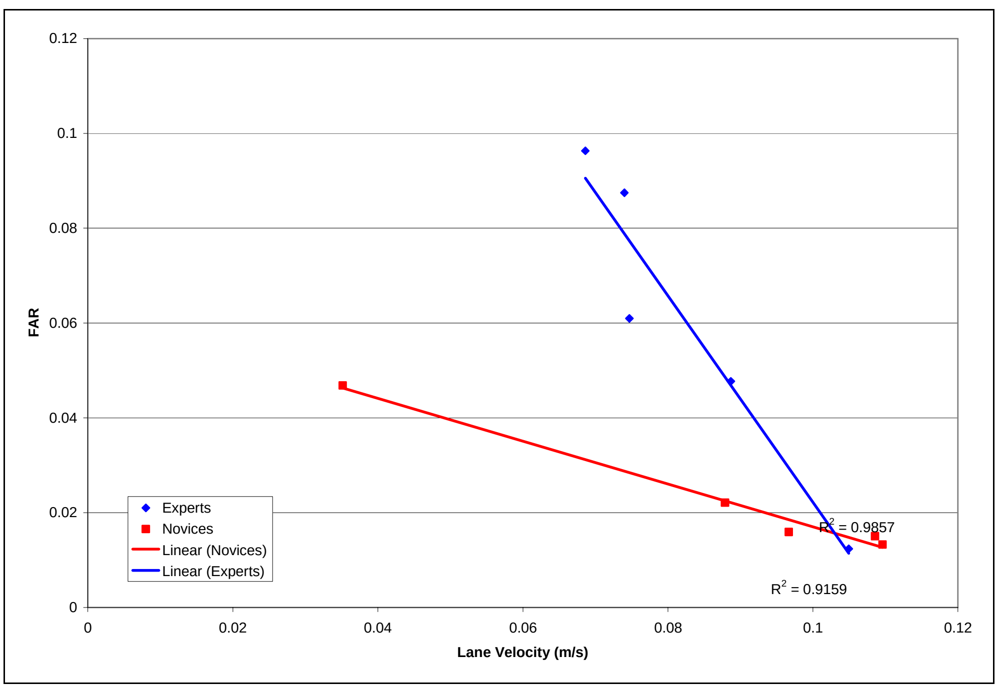

Figure 3.3-14. Experts and novices - FAR versus lane velocity.

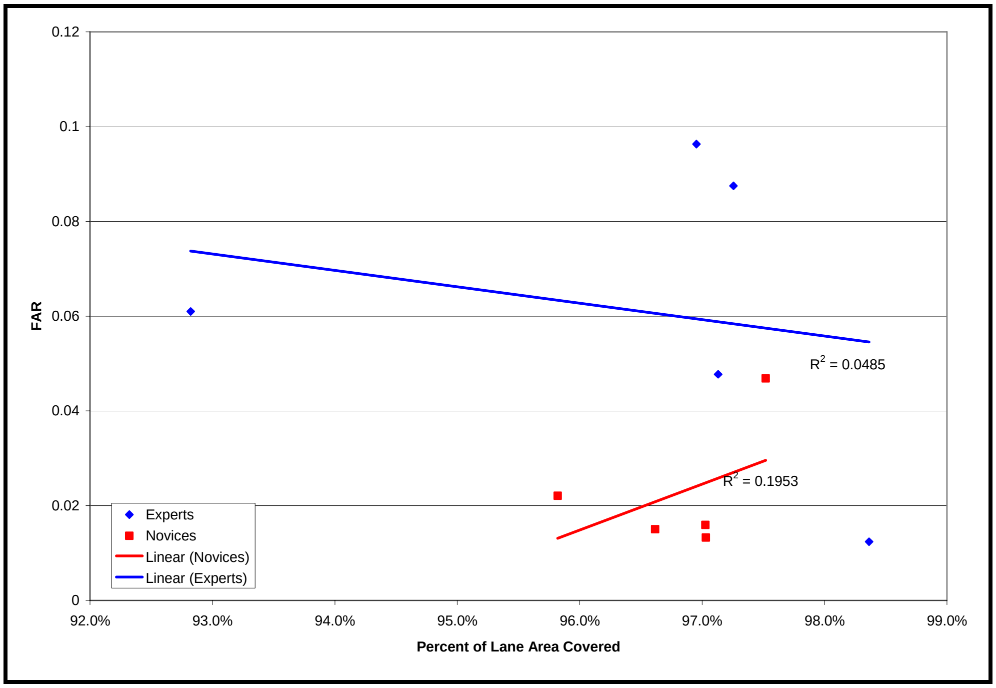

Figure 3.3-15. Experts and novices - FAR versus percent of lane area covered.

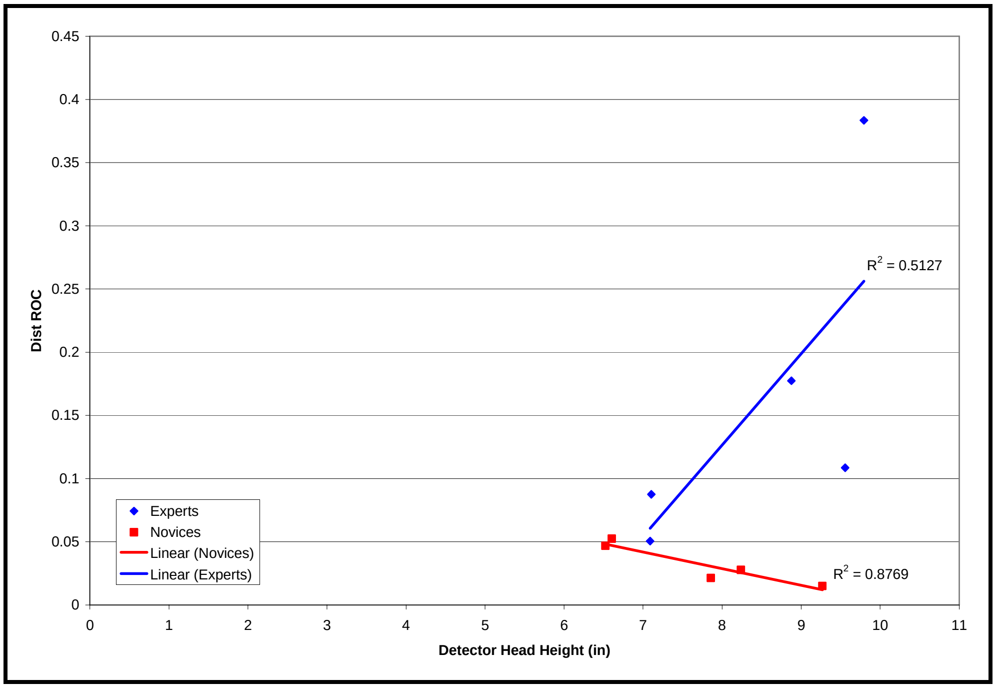

Figure 3.3-16. Experts and novices - distance ROC versus detector head height.

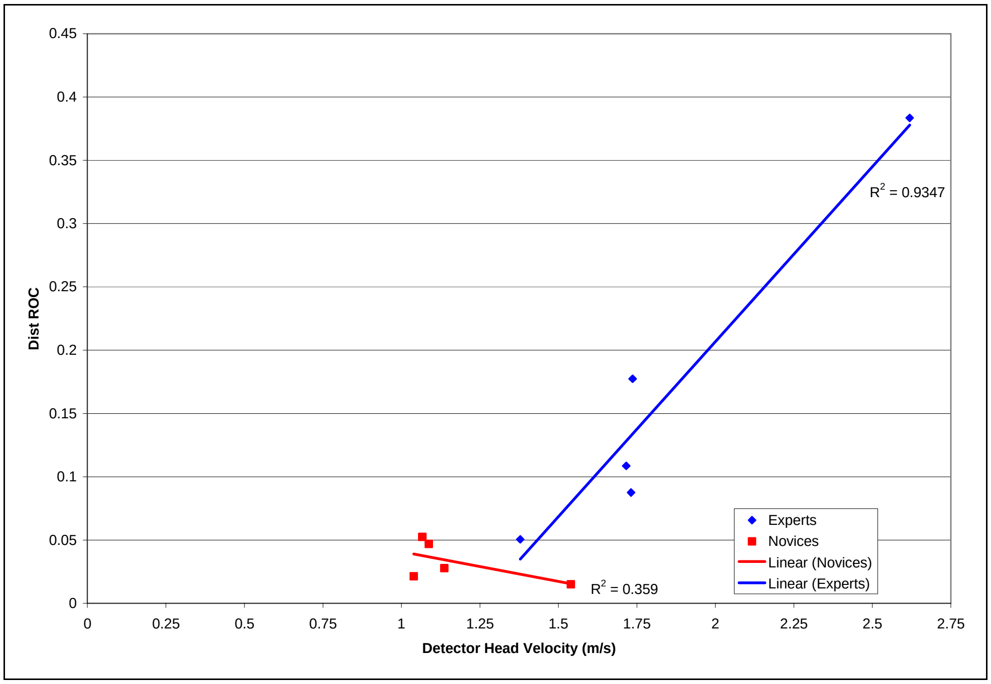

Figure 3.3-17. Experts and novices - distance ROC versus detector head velocity.

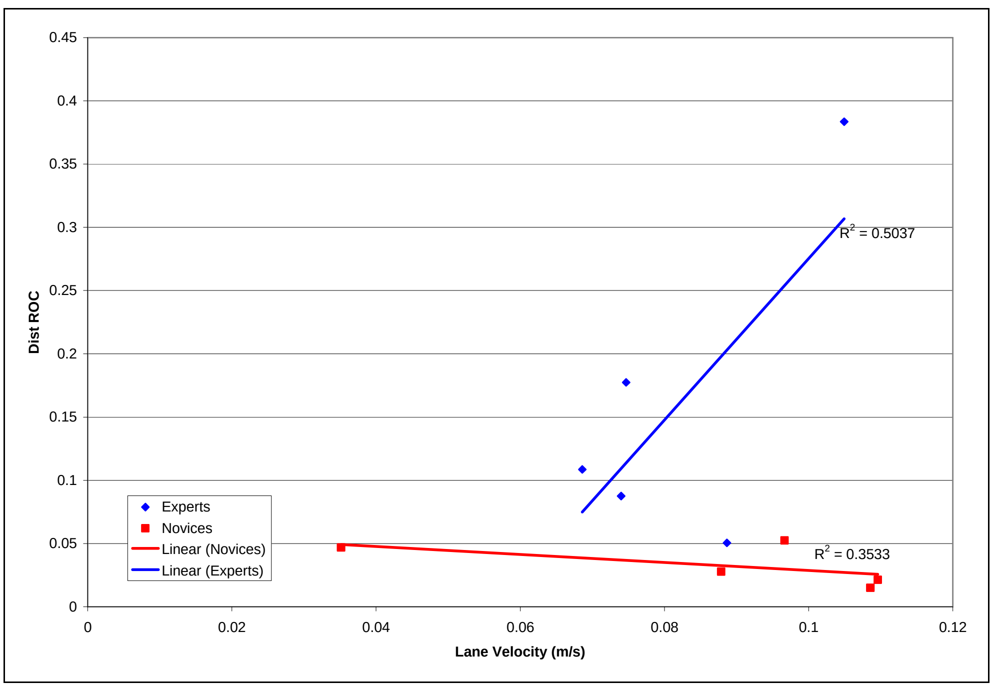

Figure 3.3-18. Experts and novices - distance ROC versus lane velocity.

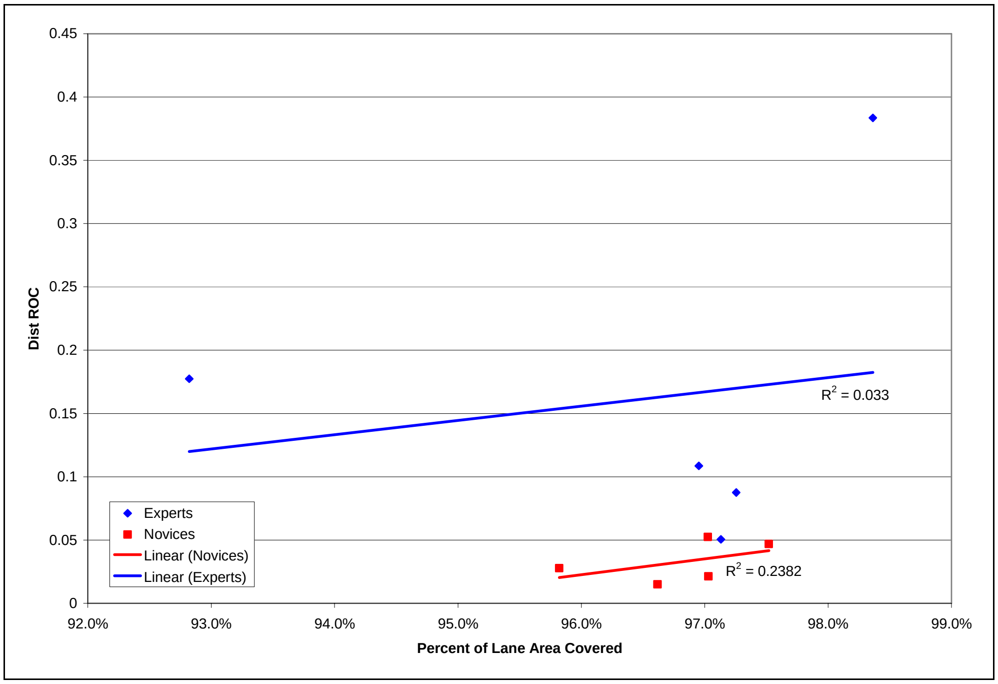

Figure 3.3-19. Experts and novices - distance ROC versus percent of lane area covered.

e. Once the two performance measurements were combined into the distance ROC, differences between the experts and novices appeared. The novices performed better as the detector head height increased, while the experts' performance deteriorated as the detector head height increased (fig. 3.3-16). This should be true only for the novices up to a critical detector head height value, after which performance should decrease because of reduced received signal strength. A similar result is shown in Figures 3.3-17 through 3.3-18, but the coefficients of determination (R^2 values) do not indicate a close fit for the linear regressions, with the exception of the line for the experts and detector head velocity (fig. 3.3-17). The closer the R^2 values are to 1.00, the greater the correlation of the *x* and *y* axis data.

f. Both the novices and the experts covered the lane area fairly equally with little variation. This translated into no significant correlation between that characteristic and P_d, FAR, and distance ROC (fig. 3.3-11, 3.3-15, and 3.3-19). The performance measurements and characteristics for each operator and the groups are presented in Table 3.3-6.

TABLE 3.3-6. SUMMARY OF DATA FOR EXPERTS AND NOVICES

	Operator	P_d	FAR, $1/m^2$	ROC Distance	Lane Velocity, m/s	% Lane Area Covered	Detector Head Height, in.	Detector Head Velocity, m/s
Experts	E-1	98.33%	0.0477	0.0506	0.09	97.13%	7.09	1.38
	E-2	83.33%	0.0610	0.1775	0.07	92.82%	8.88	1.74
	E-3	100.00%	0.0875	0.0875	0.07	97.26%	7.10	1.73
	E-4	61.67%	0.0124	0.3835	0.10	98.36%	9.79	2.62
	E-5	95.00%	0.0963	0.1085	0.06	96.95%	9.56	1.72
	Mean	**87.67%**	**0.0610**	**0.1615**	**0.08**	**96.50%**	**8.48**	**1.84**
	St. Dev.	**0.159**	**0.034**	**0.132**	**0.016**	**0.021**	**1.311**	**0.463**
Novices	N-1	98.33%	0.0221	0.0277	0.09	95.82%	8.24	1.14
	N-2	98.33%	0.0133	0.0213	0.11	97.03%	7.86	1.04
	N-3	95.00%	0.0159	0.0525	0.10	97.03%	6.61	1.07
	N-4	100.00%	0.0468	0.0468	0.04	97.52%	6.52	1.09
	N-5	100.00%	0.0150	0.0150	0.11	96.62%	9.27	1.54
	Mean	**98.33%**	**0.0226**	**0.0327**	**0.09**	**96.80%**	**7.70**	**1.17**
	St. Dev.	**0.020**	**0.014**	**0.016**	**0.031**	**0.006**	**1.157**	**0.208**

g. All results indicate that the position and speed of the Schonstedt detector head impact the performance measurements. To investigate this further, the detector head height and velocity data were plotted against the performance measurements without the novice, experts, and groups classifications. Since the range of mean heights and velocities of the best and worst groups indicated the curves may be parabolic, either a linear or parabolic regression was inserted to fit the data as best as possible. The results are shown in Figures 3.3-20 through 3.3-25.

h. As shown in Figure 3.3-22, the relationship between the detector head height and the distance ROC data may be approximated by a parabolic curve, with the better distance ROC measurements achieved in the 7- to 8-inch range. When the distance ROC measurement is broken into its individual parts (fig. 3.3-20), the detector head height correlates to the P_d measurement more than the FAR measurement, as shown in Figure 3.3-21. This suggests that operators may improve their P_d by maintaining the Schonstedt detector head between 7 and 8 inches off the ground; however, this will not necessarily improve their FAR.

i. With the high coefficient of determination, the parabolic curve in Figure 3.3-25 fits the data well. The curve suggests that the best performance can be achieved by swinging the Schonstedt so that the detector head travels at a velocity between 1 and 1.25 m/s. The curves in Figures 3.3-23 through 3.3-25 imply that the correlation was related more to P_d performance than FAR performance, but both may be optimized by maintaining a velocity in this range.

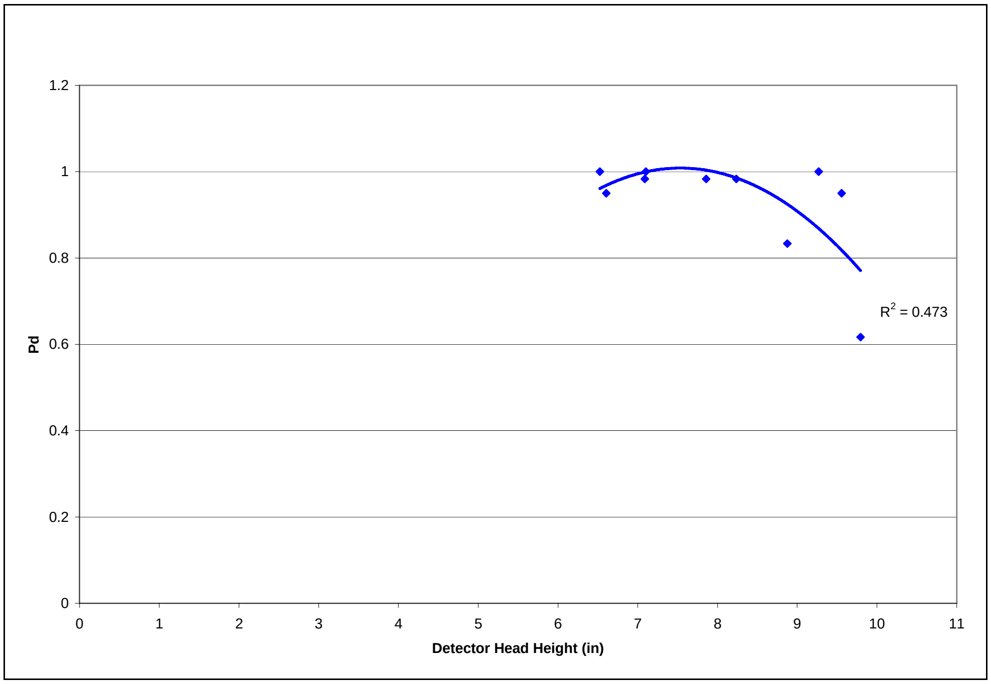

Figure 3.3-20. P_d versus detector head height, all participants.

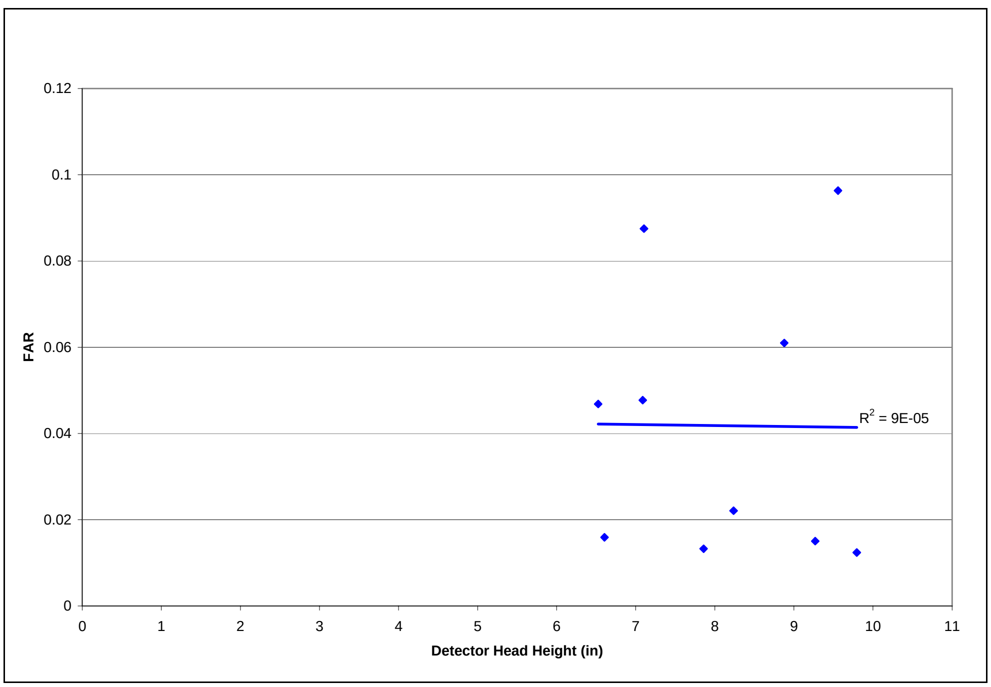

Figure 3.3-21. FAR versus detector head height, all participants.

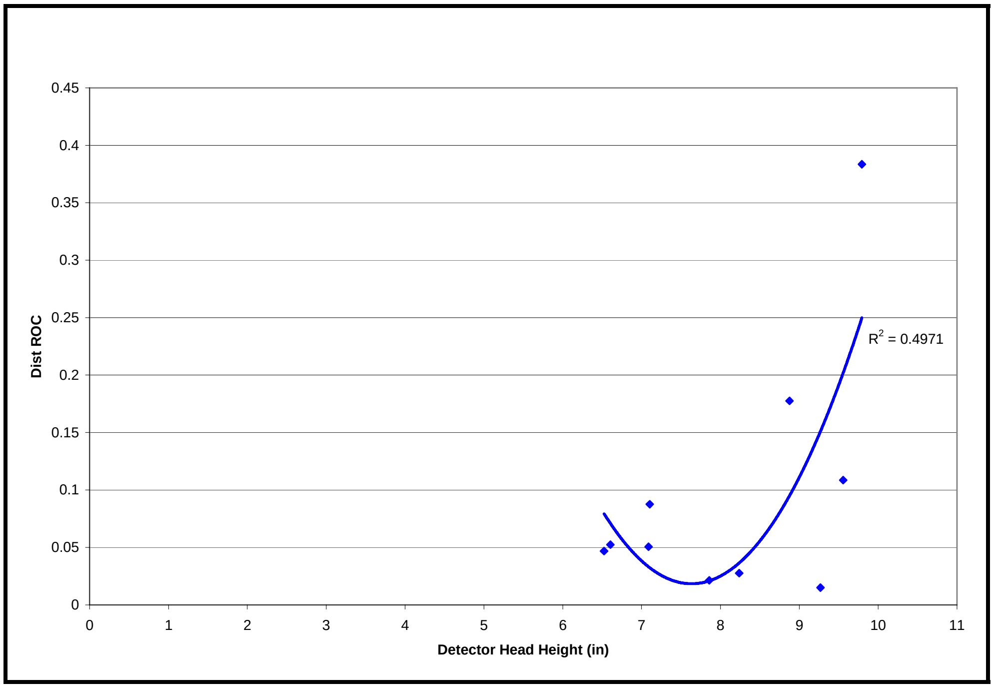

Figure 3.3-22. Distance ROC versus detector head height, all participants.

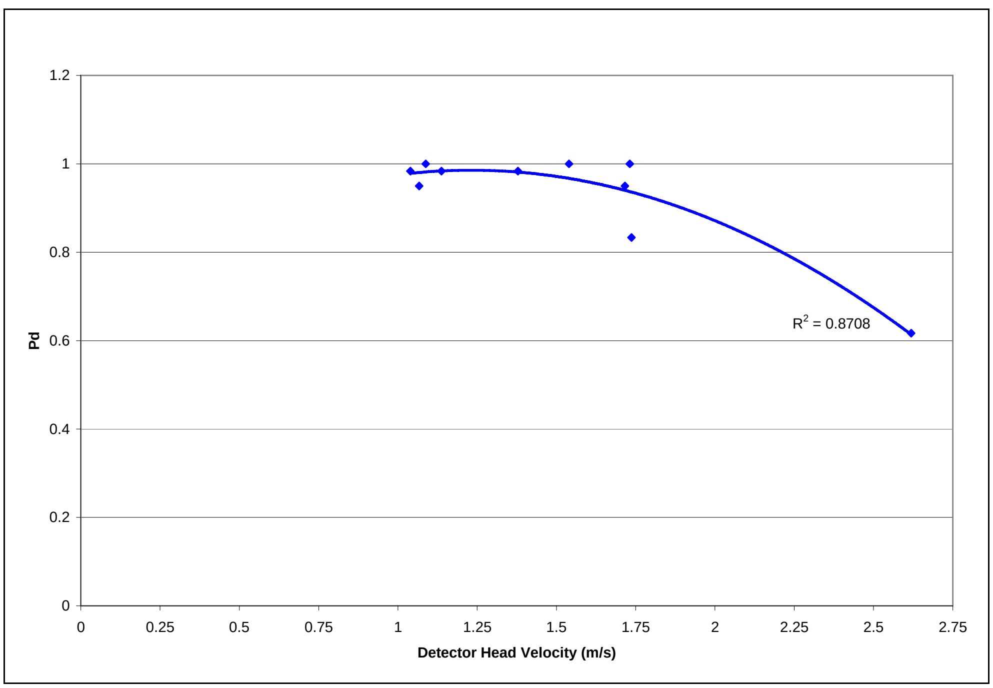

Figure 3.3-23. P_d versus detector head velocity, all participants.

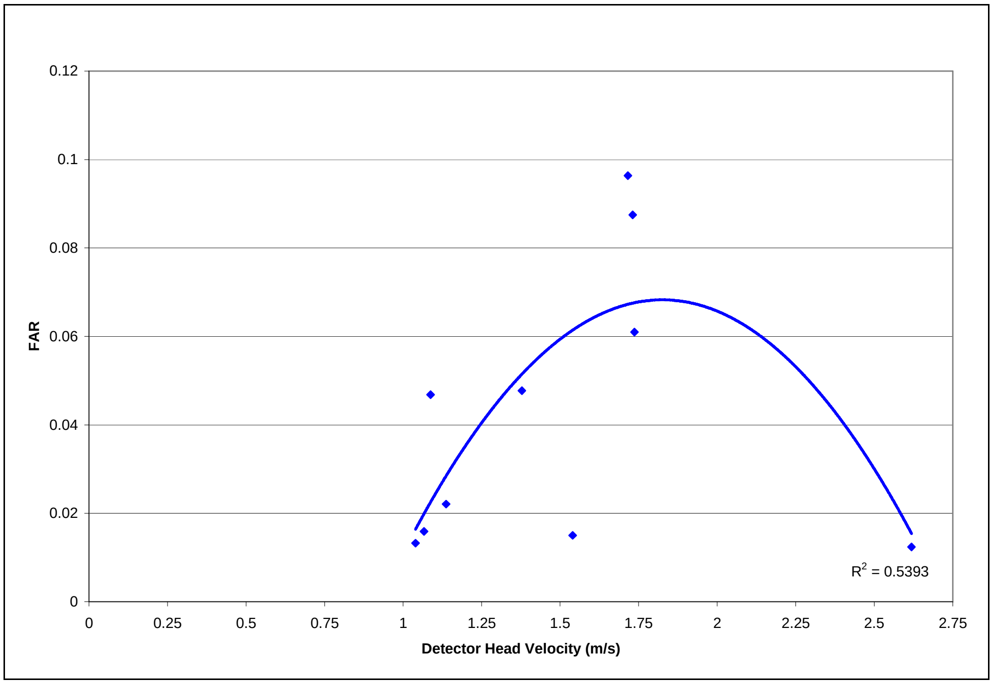

Figure 3.3-24. FAR versus detector head velocity, all participants.

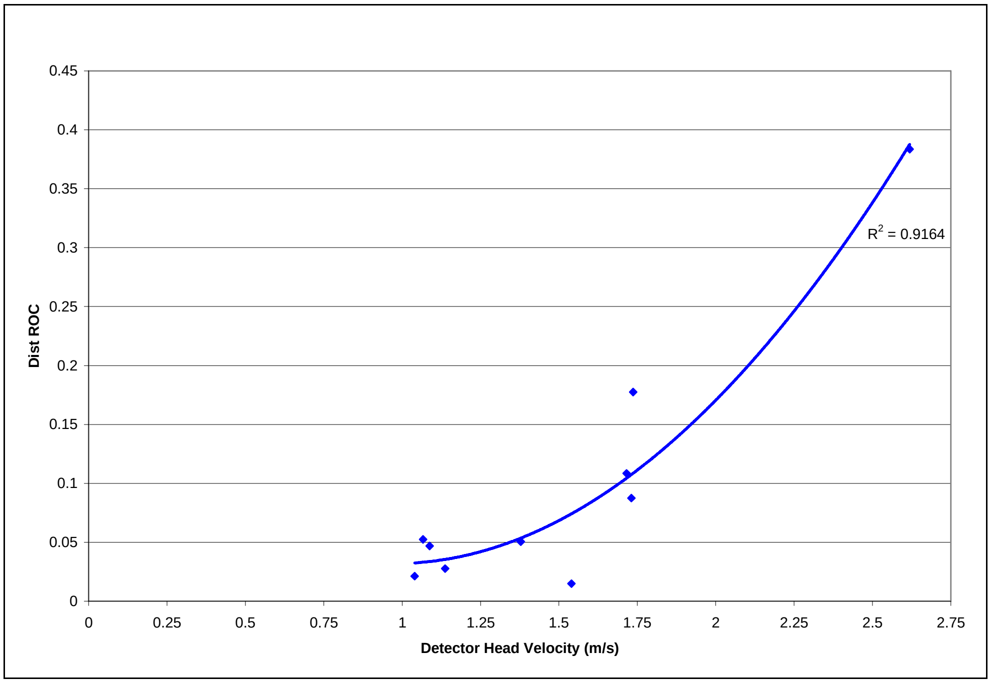

Figure 3.3-25. Distance ROC versus detector head velocity, all participants.

3.3.7 Observations

a. Overall, the novices had higher P_d and lower FAR within the instrumented subgroup. Consequently, it was not expected that DOPs for the novice's were also considerable lower (factor of five times), on average, than those for the experts. The novices had a very low P_d standard deviation (0.0204) compared with the experts (0.1593). The P_d versus FAR figure strongly depicts novices in a tight upper left-hand corner formation, while experts were loosely grouped more to the right and lower on the P_d axis. This matches the results from the DOP calculations presented in Table 3.3-6. The novices also exhibited FARs generally one-third lower than those of the experts.

b. Two trends can be seen from the expert versus novice comparison plots (fig. 3.3-14 and 3.3-18): the quicker the novices traversed the lanes, the fewer false alarms they indicated, and they also had a better overall performance (low DOP). Also, the experts and novices both had similar lane velocities (0.08 and 0.09 m/s). It is interesting to observe that P_d suffered only as the experts increased lane velocities, whereas the novices tended to not be affected by lane velocity.

c. When reviewing performance characteristics, some observations were clear with regard to the time domain presented in Table 3.3-6. Consistent with average lane velocity, the experts had less variation among themselves then the novices for total time; however, the experts' time was slightly higher than that of the novices. In addition, the standard deviation of experts P_d was quite high compared with that of the novices (0.159 versus 0.020).

d. Overall, vertically oriented ordnance had higher P_d than the horizontally oriented ordnance. The novices located 100 percent of the targets with a vertical position. The experts were able to detect only the 155mm target in the horizontal orientation better than the novices. Both novices and experts had difficulty locating the 61mm and 81mm mortar targets. This may have been because of their distinctive profile of the latter targets compared with the 40mm, 105mm, and 155mm targets, which share a simple projectile geometry. It was unexpected that both experts and novices located (P_d rates of 1) the 40mm projectile despite the predominantly aluminum alloy composition, albeit this target was positioned at a mere 6-inch burial depth. Overall, the novices averaged approximately 10 percent higher P_d rates than the experts.

e. Experts showed an overall lower average total time of 2.7 hours, whereas the novices reported an average total time of 3.1 hours. Novice 4 is an outlier in this data set and accounts for the difference in average total time. It is assumed that if novice 4 performed in a similar manner to his novice counterparts, this average would be lower. Novice 4's time performance also accounts for the considerably large standard deviation within the novice data set of 1.9 hours. This number is considered significant, considering the expert standard deviation was 26 minutes.

f. The demographics of experts and novices seemed to provide a wide range of individuals. Ages, races, and marital status seemed vary with no conclusive pattern. The majority of the participants (9 of 10) were male, with only one female in the expert group. education levels seemed to be higher in the novice group, with two participants having obtained a bachelor degree. The experts all held high school diplomas, with 1 or 2 years of additional study. It is possible that expert participants interpreted their military training as education, and this may account for the differences. All experts, but only one novice, reported prior military experience. Of that military experience, the experts had an average of 11.8 years of military, 4.5 years of UXO, and 2.3 years of Schonstedt specific experience. One novice reported 1.5 months of UXO and Schonstedt experience; however, this was assumed to be a subjective answer as he had graduated from the UXO program 1.5 months before participation in this study. In addition, this novice had not worked on a UXO site between graduation from the UXO training program and participation in this study. It was determined that these data would be valid for inclusion for analysis.

g. The heaviest expert was consistent with the individual greatest in height, and the lightest expert was the shortest. No physical outliers were observed in either set.

h. It is interesting that most experts (four of five) reported having excellent health, whereas all novices reported having good health. All experts were nonsmokers, and only one novice reporting using tobacco products.

i. The dynamic data provided a first-ever look into detector motion characteristics. Within the expert and novice groups, the novices held, on average, the detector head approximately three-quarters of an inch lower than the experts. Also, the novices had detector head velocity rates approximately 40 percent slower than the experts. Overall, the data revealed that operators may improve their P_d by maintaining the Schonstedt detector head between 7 and 8 inches off the ground; however, this will not necessarily improve their FAR. In addition, it was observed that best performance can be achieved by swinging the Schonstedt so that the detector head travels at a velocity between 1 and 1.25 m/s.

SECTION 4. DISCUSSIONS

4.1 UN-INSTRUMENTED VERSUS INSTRUMENTED DATA

4.1.1 Analysis. A statistical analysis was done to compare performance data with instrumentation and without instrumentation. P_d was tested using the chi-square distribution at 0.05 significance level, while the number of false alarms, distance measurement, and total time were tested using the Mann-Whitney test at the 0.05 significance level. The performance measurements that were significantly different between operators, with and without instrumentation, are presented in Table 4.1-1. For all lanes, the experts had a significantly higher P_d without instrumentation, and the novices had a significantly greater number of false alarms and greater DOP without instrumentation. The differences between the operators with versus without instrumentation for P_d, FAR, DOP, and time are shown in Figures 4.1-1 through 4.1-4.

TABLE 4.1-1. SUMMARY OF SIGNIFICANCE TESTING OF OPERATORS WITH INSTRUMENTATION AND WITHOUT INSTRUMENTATION

		P_d[a]	FAR,[b] no.	DOP,[b] no.	Total Time[b]
Lanes 1 to 33	Expert	SIG	-	-	-
	Novice	-	SIG	SIG	-
Lanes 1 to 20	Expert	SIG	-	-	-
	Novice	-	SIG	SIG	-
Lanes 21 to 33	Expert	SIG	-	-	-
	Novice	-	-	-	-

[a]Chi-square distribution, one-sided test, at 0.05 significance level.
[b]Mann-Whitney test, one-sided test, at 0.05 significance level.

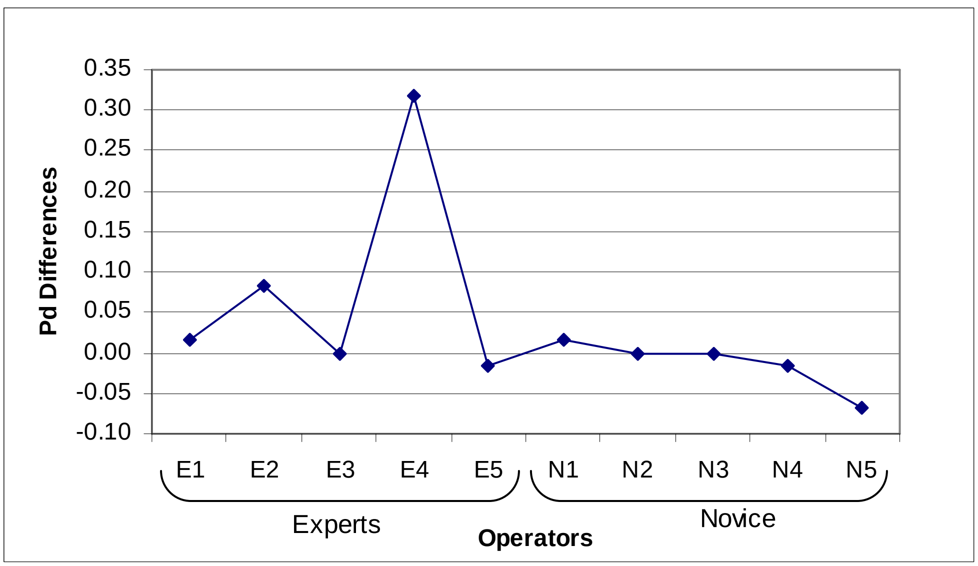

Figure 4.1-1. Difference in P_d between operators without instrumentation and with instrumentation.

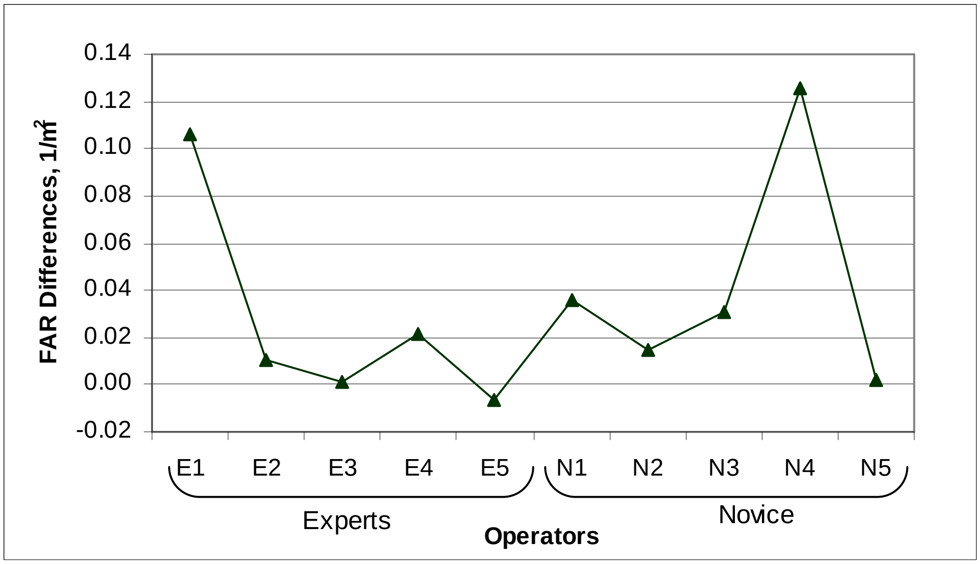

Figure 4.1-2. Difference in FAR between operators without and with instrumentation.

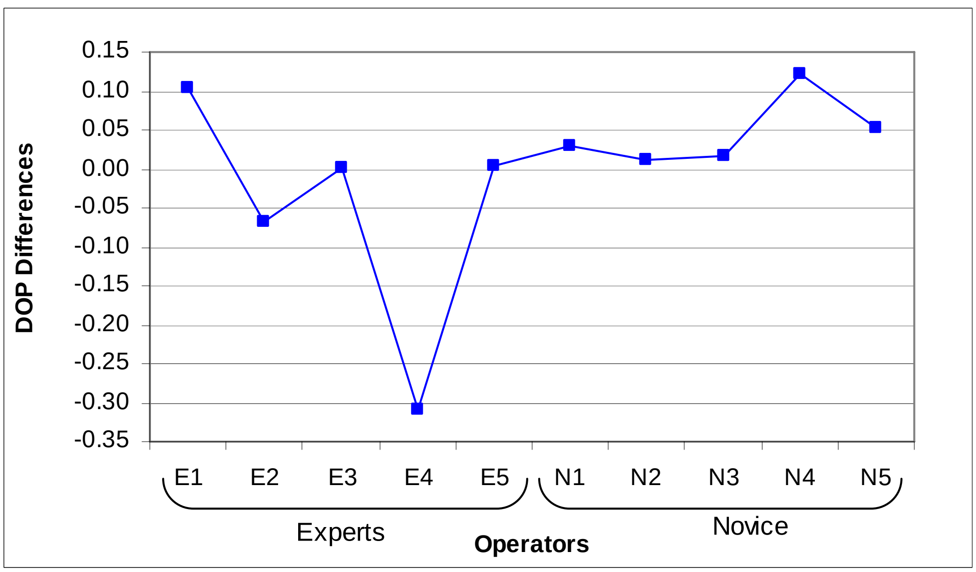

Figure 4.1-3. Difference in DOP between operators without and with instrumentation.

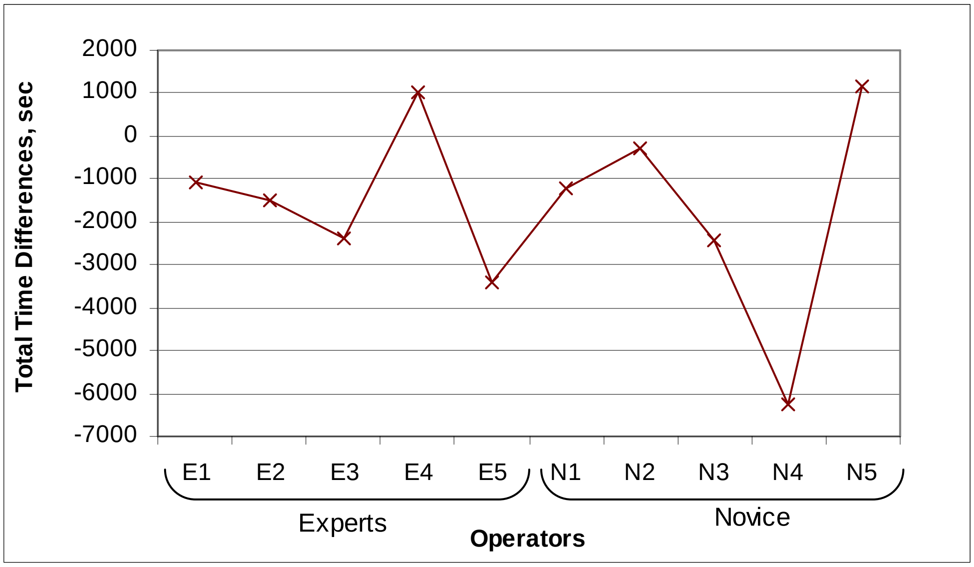

Figure 4.1-4. Difference in total time between operators without and with instrumentation.

4.1.2 <u>Discussion</u>

a. This investigation allowed for two independent testing scenarios that included changes to boundary conditions of basic experimental design. The un-instrumented variant provided a scenario, fairly close to true UXO sweep conditions, consistent to what one would find if contracted to perform such a mission. The instrumented variant provided a scenario with the sole purpose of obtaining critical human motion data while allowing working conditions similar to the un-instrumented variant.

b. Clear indicators of P_d differences are shown in Figure 4.1-1 when comparing expert and novice participants. Despite expert 4's signs of outlier status, it seems that data points show greater variability in the expert versus novice group. The larger slopes and variation between data points shows that P_d rates were highly variable in the un-instrumented versus instrumented set. This supports the argument that the instrumentation had a greater effect on expert versus novice participants.

c. In addition, when comparing the basic P_d versus FAR figure of both data sets, it is clear that experts performed substantially less with the instrumentation.

d. FARs were scattered within both groups with no clear, distinctive pattern, as shown in Figure 4.1-2.

e. The differences in DOP measurements (fig. 4.1-3) showed greater variability among the experts compared with the novices. Again, expert 4 was the primary indicator of this variability.

f. The differences in total time (fig. 4.1-4) show that instrumentation times were greater then without. It is hypothesized that this difference is due to the three main components with the added instrumentation equipment:

(1) Extra mass to the Schonstedt.

(2) Unfamiliar Schonstedt response due to change in localized magnetic field around detector shaft.

(3) Cumulative stress originating from those discussed above.

g. Expert 4 is an outlier in both the instrumented and un-instrumented data sets. It is interesting that this participant also had high P_d rates in both testing scenarios and scored the highest FAR in both scenarios. Expert 4 was noted by field observers to be conservative in pacing and slower compared with other participants in the study. Based on the observations, taking an exceptionally slow pace while executing a UXO sweeping, may result in high P_d rates; however, FAR will suffer as a result. This observation is needed to be further studied for confirmation.

4.2 CONCLUSIONS AND FUTURE STUDY

4.2.1 General

a. Prior hypotheses generated notions that experts would lead the sample population in performance; data collected within this investigation's boundary conditions proved differently. In general, experts scored worse in two rudimentary metrics: P_d and FAR. This was true in both un-instrumented and instrumented test scenarios.

b. Target detection trends showed that vertically oriented ordnance had overall higher P_d rates than horizontal ordnance. Ordnance with geometries of cylinders containing ogives also presented higher P_d rates. Participants had difficulty locating mortar-shaped targets in both the vertical and horizontal orientations. The horizontal orientation of mortars specifically proved difficult for all participants, whereas all other ordnance geometries positioned horizontally had the highest P_d rates.

c. Lane orientation analysis showed that in both test scenarios, a significantly higher FAR was found in north-south lanes versus lanes situated east-west. Over 86 percent of common false alarms were observed in the north-south lanes. North-south lanes accounted for 36 percent of the total test grid area.

d. The capture of human and detector motion provides perspective into maximizing operator performance via continual improvements regarding operator actions during UXO sweeps. Within the boundary conditions, the investigation determined that maintaining the detector head at a height of 7 to 8 inches above grade, and concurrently swinging the device between 1 and 1.25 m/s, provided the highest probability for increased performance.

e. Differences in performance measurements were found between the instrumented and un-instrumented variants. Expert participants were affected by telemetry equipment attached to the detector and themselves. This could account for the performance discrepancy between the expert and novice data set in the instrumented variant. The novices, however, performed in a similar manner as the un-instrumented variant and continued to outperform the experts. This occurrence could have been due to the standardized and recent training received from the UXO Technician Level I training curriculum. Furthermore, this could explain the variations in expert performance, as their backgrounds, military service, UXO and Schonstedt experience, and other UXO training was diverse in nature. Despite these differences, data suggest that continued education in what the UXO community identifies as "experts" may benefit overall performance.

4.2.2 Anecdotes

When considering all forms of data from this investigation, several caveats must be mentioned to provide a review of the results presented.

a. The un-instrumented variant of this test provided a realistic scenario that mimicked conditions encountered by UXO technicians in the field. The results provide the best (within all data generated) results in terms of quality for the purposes of reviewing operator trends for implementation into the training curriculum.

b. The instrumented variant of this investigation was the first look into detector motion trends in the UXO arena. While several sources of error must be included with the data, it is suggested that improvement of the tracking system in a manner that reduces error will result in higher quality data. As a tertiary concern, the sample size of five participants limited the results of an analysis based on descriptive statistics. Observations included are valid only for the population observed within the boundary conditions. Although extrapolating to a larger population of UXO technicians is theoretically possible, this approach is discouraged until a larger set of participants is observed.

4.2.3 Future Study

a. The current data set would benefit most from an increase in overall population, specifically, one that satisfies minimum sample size requirements. Therefore, it is suggested that testing continue to confirm original data observations and increase data quality in an effort to present logical and cogent UXO operator observations. While the dynamic data captured during the initial phase of testing provided insight into detector and human motion, it is suggested that this phase of testing be continued when a technology is available to track motion with less invasive telemetry. Sensors with limited mass and ferrous content would provide a reduced amount of stress and unfamiliar detector operation, increasing data value. Continued testing would only encompass analog methods of data capturing with a focus on two to three parameters of the initial investigation.

b. It is critical to identify how the results will benefit the UXO community in the future. An international effort encompassing the current UXO detection process is under way to incorporate quality assurance while emphasizing process efficiency in current system planning. The process may benefit by absorbing certain characteristics from the continuous improvement of methodologies. Direct application of observed trends into training curricula, in an effort to increase operator performance and decrease overall cost, would benefit the UXO community. This investigation is the first step in the discovery of trends that show promise of increasing overall “MAG and flag” effectiveness.

SECTION 5. APPENDIXES

APPENDIX A. EXPECTED RECOVERY DEPTHS AND EMPLACEMENT DATA

TABLE A-1. EXPECTED RECOVERY DEPTHS

Ordnance	Maximum calculated depth, m	Maximum recovered depth, m (99% of UXO were found)
37-mm Projectile	0 to 2.400	0 to 0.76
40-mm Projectile	0 to 3.600	0 to 0.66
57-mm Projectile	0 to 1.680	0 to 0.91
60-mm Mortar	0 to 0.910	0 to 0.46
75-mm Projectile	0 to 3.020	0 to 1.22
81-mm Mortar	0 to 1.650	0 to 1.06
105-mm Projectile	0 to 5.380	0 to 0.67
155-mm Projectile	0 to 8.700	0 to 0.91
3-in. Stokes Mortar	0 to 2.100	0 to 0.91
61-mm Mortar	0 to 0.660	0 to 0.91
81-mm Mortar	0 to 1.650	0 to 1.22
M9 Rifle Grenade	0 to 0.076	0 to 0.61
35-mm Rocket	0 to 0.305	0 to 0.76

TABLE A-2. EMPLACEMENT DATA

Ordnance	Depth, m	Delta (maximum recovery), m
40-mm Projectile	0.152	0 to .41
60-mm Projectile	0.305	0 to .15
81-mm Projectile	0.541	0 to .60
105-mm Projectile	0.715	0 to .06
155-mm Projectile	0.917	0 to .15

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APPENDIX B. TEXAS A&M (TEEX) TRAINING SCHEDULE

Day	Subject	Location
1	Introduction	IUTP, Riverside
	UXO Environmental Remediation Overview	IUTP, Riverside
	Mathematics, Electricity and Physics	IUTP, Riverside
2	Explosives and Explosive Effects	IUTP, Riverside
3	Fuze Functioning	IUTP, Riverside
4	Ordnance Safety Precautions	IUTP, Riverside
	Ordnance Identification (Surface Ordnance)	IUTP, Riverside
5	Progress Test 1	IUTP, Riverside
	Ordnance Identification (Surface Ordnance)	IUTP, Riverside
6	Ordnance Identification (Surface Ordnance) (ID Application)	IUTP, Riverside
7	Ordnance Identification (Air Ordnance) (ID Application)	IUTP, Riverside
8	Ordnance Identification (Air Ordnance) (ID Application)	IUTP, Riverside
9	Ordnance Identification (Air Ordnance)	IUTP, Riverside
	Ordnance Identification (Chemical Ordnance) (ID Application)	IUTP, Riverside
10	Ordnance Identification (Underwater Ordnance and Pyrotechnics)	IUTP, Riverside
	Ordnance Identification Application	Practical Area
11	Progress Test 2	IUTP, Riverside
	Demolition Materials	IUTP, Riverside
12	Firing Systems (ID Application)	IUTP, Riverside
13	Disposal Procedures (ID Application)	IUTP, Riverside
	Storage, Handling, and Transportation of Explosives	IUTP, Riverside
14	Nonelectric Firing Systems Application	Demolition Range
15	Nonelectric Firing Systems Test	Demolition Range
	Shock Tube Firing Systems Application	Demolition Range
16	Electric Firing Systems Application	Demolition Range
17	Electric Firing Systems Test	Demolition Range
18	Detection Equipment Application (ID Application)	IUTP, Riverside
19	Detection Equipment Application (ID Application)	Practical Area
20	Detection Equipment Application (ID Application)	Practical Area
21	Detection Equipment Application (ID Application)	Practical Area
22	Professional Development and Industry Seminar	IUTP, Riverside
23	Equipment Inventory and Maintenance	IUTP, Riverside
	Course Review (ID Application)	IUTP, Riverside
24	Comprehensive Test	IUTP, Riverside
25	Course Critiques and Graduation	IUTP, Riverside

IUTP = International Unexploded Ordnance Training Program.

TEST ASSIGNMENT CHART

Test	Type	Topics Covered	Minimum passing
1	Written	Math, Electricity, Physics, Explosives and Explosive Effects (EEE), Fuze Functioning	80
2	Written	Ordnance Safety Precautions, Ordnance Identification	80
3	Practical	Nonelectric Firing Systems	85
4	Practical	Electric Firing Systems	85
5	Written	Comprehensive Course Exam	80

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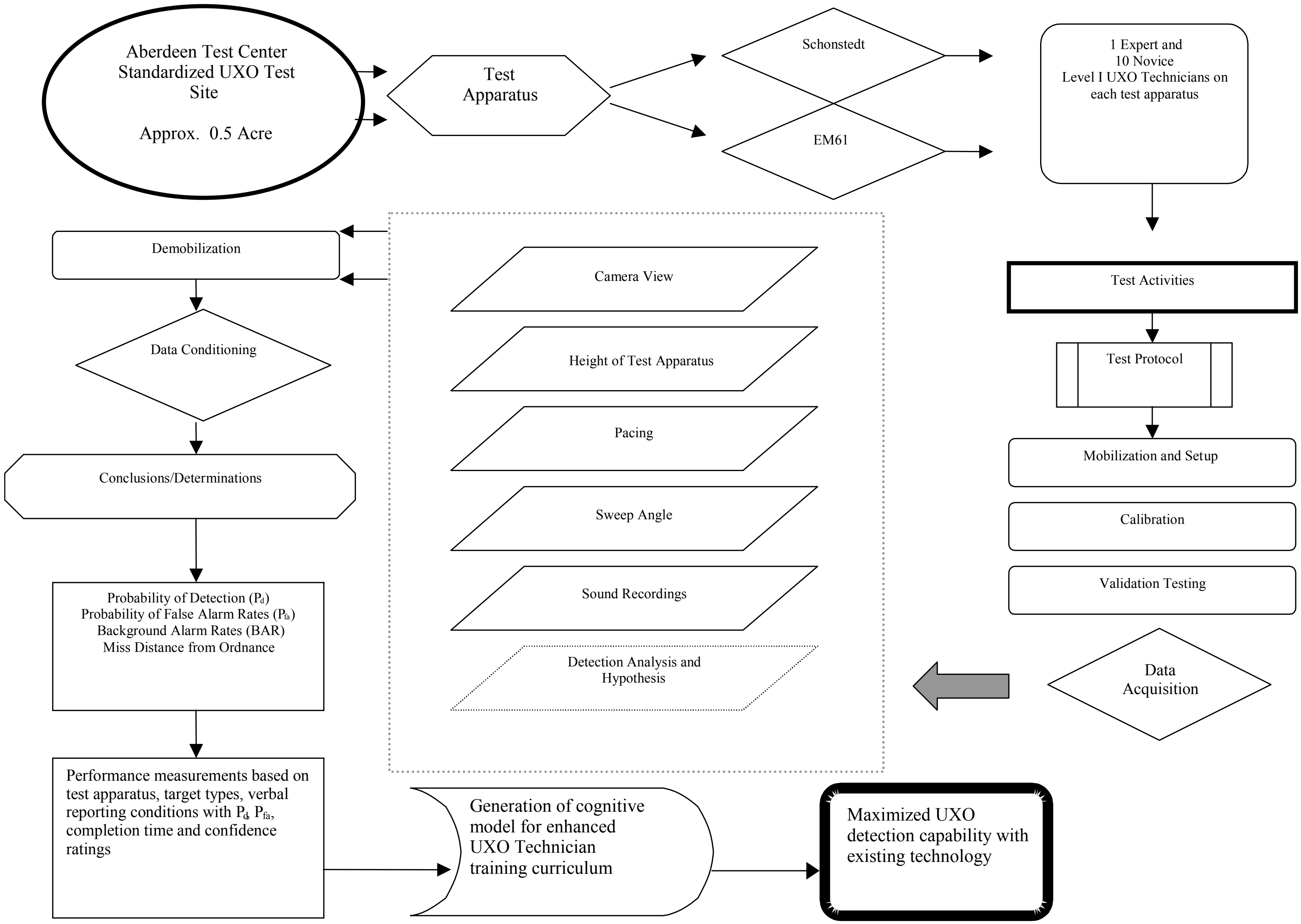
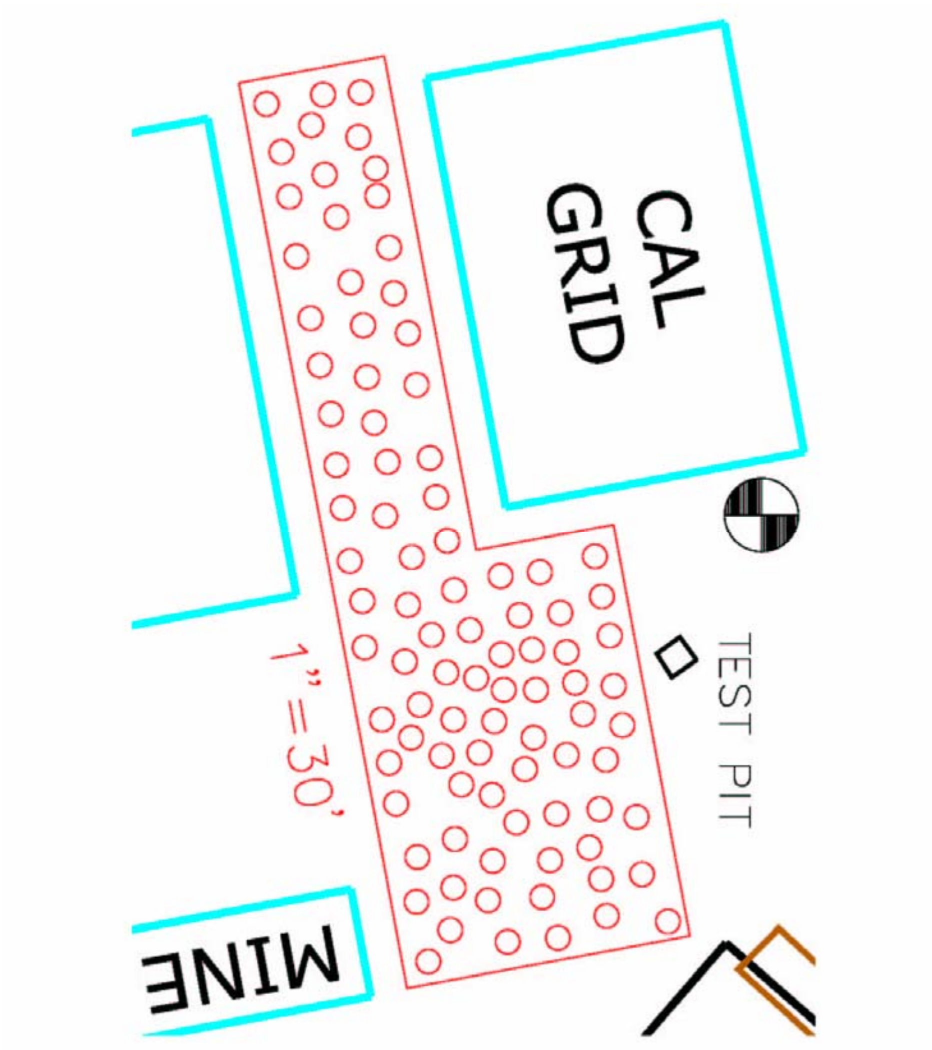
APPENDIX C. FLOW CHART



APPENDIX D.   TEST BED



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APPENDIX E. DATA ANALYSIS DETAILS

Recorded data will be reviewed for any patterns of observable trends. Statistical modeling or regression calculations will be performed when relevant correlation situations are identified.

In general, operators will be divided into distinct sample sets, depending on their UXO background. For the purposes of this study, *expert* operators are those individuals with prior military experience and a minimum of 5 years experience performing MAG and flag operations. *Novice* operators are those individuals that are direct graduates of the Texas Extension Service (TEEX) UXO Level I certification course. These designations will also be made in accordance with experience related to the Geonics EM61 and Schonstedt detectors.

The following are descriptions of data reviewed:

P_d.

UXO technicians are given the task of locating items buried under the surface of the ground. The results of their actions can be graded by asking a simple question: "Did the UXO technician find subsurface targets?" This can mathematically be described and simplified into a true/false scenario. A probability of detection can be calculated that will represent that of the UXO technician locating UXO in a given area. Equation 1 shows how the probability of detection or P_d is calculated:

$$P_d = \left(\frac{t_{\det}}{T_{total}} \right) \quad \text{Equation 1}$$

where t_{det} is the number of targets detected per lane and T_{total} represents the total number of targets possible per lane.

P_d will be calculated with information recorded by the TMS system and will then be compared with ground truth data. Each target will have an imaginary 1-meter safe-halo. If the UXO technician declares a target within that halo, it counts as a detected target. If multiple declarations are made within a targets halo, only one will count as a detected target. The other "excess" declarations will not count against the P_d score.

FAR.

When a UXO technician declares a target position that lies outside the 1-meter halo of a validated target, a false alarm is recorded. Equation 2 defines the false alarm rate as

$$FAR = \left(\frac{F_A}{Area} \right) \quad \text{Equation 2}$$

where F_A is the number of false alarms recorded and "area" is the lane area in m^2. If an operator declares multiple targets outside of the 1-meter halo, each multiple target counts as a recorded false alarm.

Forward velocity.

The operator's average forward velocity can be defined as

$$\bar{v} = \left(\frac{\mathrm{T}_{total} - \tau_{delays}}{Lane_{length}} \right) \quad \text{Equation 3}$$

where T_{total} is the time recorded from start to finish of lane, tau_{delays} is any obvious delays incurred during the course of the lane and $Lane_{length}$ is the length of the lane in meters.

Detector Height.

Detector height can be defined as the distance from the lowest possible point on a detector head to the ground directly under the detector when raised. This will be captured over the course of each lane via laser positional data and subtracted from ground topography. Real-time kinematic surveying technology was used to achieve sub-centimeter z-axis accuracy. Detector height can therefore be defined as

$$H_d = Detector_{abs} - topography_{abs} \quad \text{Equation 4}$$

where H_d is the detector height above the ground, $Detector_{abs}$ is the absolute height of the detector in the 3-d TMS environment and $topography_{abs}$ is the absolute grade elevation recorded.

Average detector Height.

The average detector height can be defined as

$$\overline{H}_d = \left(\frac{\sum H_d}{samples} \right) \quad \text{Equation 5}$$

where H_d is defined in equation 4, and samples is an arbitrary number of samples taken during the period investigated. The number of detector height samples will be limited based on the resolution of the TMS laser tracking system. Anticipated sampling rate is 10 Hz.

Sweep rate.

The number of sweeping motions that an operator makes per unit time is defined as the sweep rate. A sweep is a full range motion from left to right, or right to left. The motions an operator makes just before locating a target does not count toward this value. This value is found by replaying the TMS data file and plotting detector motion. Full sweep motions are then summed and recorded. The sweep rate can alternately be defined as

$$S_r = \left(\frac{\sum sweeps_{lane}}{\left(\mathrm{T}_{total} - \tau_{delays} \right)} \right) \quad \text{Equation 6}$$

where $sweeps_{lane}$ is the number of full sweeps per lane and the denominator is take from equation 3 for total corrected time to complete the lane.

Sweeps per meter.

The number of sweeps per meter is the average sweeps per unit distance. It can be found by

$$S_m = \left(\frac{\sum sweeps_{lane}}{Lane_{length}} \right) \quad \text{Equation 7}$$

where $sweeps_{lane}$ and $Lane_{length}$ were described in equations 6 and 3, respectively.

Total time.

Total time is the total UXO mag and- lag time required for full coverage of the test grid.

Average lane time.

Average lane time is a statistical average of an operators lane times for lanes 1 through 33. This can be calculated as:

$$\overline{\mathrm{T}}_{total} = \left(\frac{\sum \mathrm{T}_{total}}{33} \right) \quad \text{Equation 8}$$

where T_{total} is decribed in equation 3 and the denominator will be the number of lanes covered in the test. In this case, we have 33 lanes.

Percentage of area covered.

By assuming that each detector will have a radius of effective detection, we can map the detector's coverage of each lane with the TMS tracking system. TMS data files are viewed in an AutoCAD format and a detection halo is projected around the given TMS detector head point. The TMS file is replayed and the % area covered is calculated as

$$\left(\frac{Area_{covered}}{Area}\right)\times 100 \quad \text{Equation 9}$$

where $Area_{covered}$ is the area covered by the movement of the detector and Area is described in equation 2.

APPENDIX F. DATA GRID

		Acquisition Method		*How obtained*					
VARIABLES	**Parameter**	**Manual**	**TMS**	**Post Processed**	**Hearing Tests**	**MACCL-R**	**Spit Tests**	**SRE**	**NASA TLX**
Detection Results	Pd	X	X						
	FAR	X	X						
Operator	Forward Velocity	X		X					
Performance	Detector Height		X	X					
	Sweep Rate		X	X					
	Sweeps per Meter		X	X					
	Total Time	X		X					
	Average Lane Time	X		X					
	% Area covered		X	X					
Ordnance	Type	X	X						
	Depth	X	X						
	Orientation	X							
	Azimuth	X							
Stress	Anxiety					X			
	Depression					X			
	Hostility					X			
	Positive Affect					X			
	Dysphoria					X			
	Salivary Amalase						X		
	Workload								X
	Cortisol						X		

		Acquisition Method		*How obtained*					
VARIABLES	**Parameter**	**Manual**	**TMS**	**Post Processed**	**Hearing Tests**	**MACCL-R**	**Spit Tests**	**SRE**	**NASA TLX**
Hearing	Pure Tonal Average (PTA)				X				
Demographics	Age							X	
	Gender							X	
	Education							X	
	UXO Experience							X	
	Detector Experience							X	

APPENDIX G.   TEST PIT

Figure G-1.   40mm projectile vertical orientation.

Figure G-2.   40mm projectile horizontal orientation.

Figure G-3. Nine bucket calibration area.

Figure G-4. Bucket calibration test in progress.

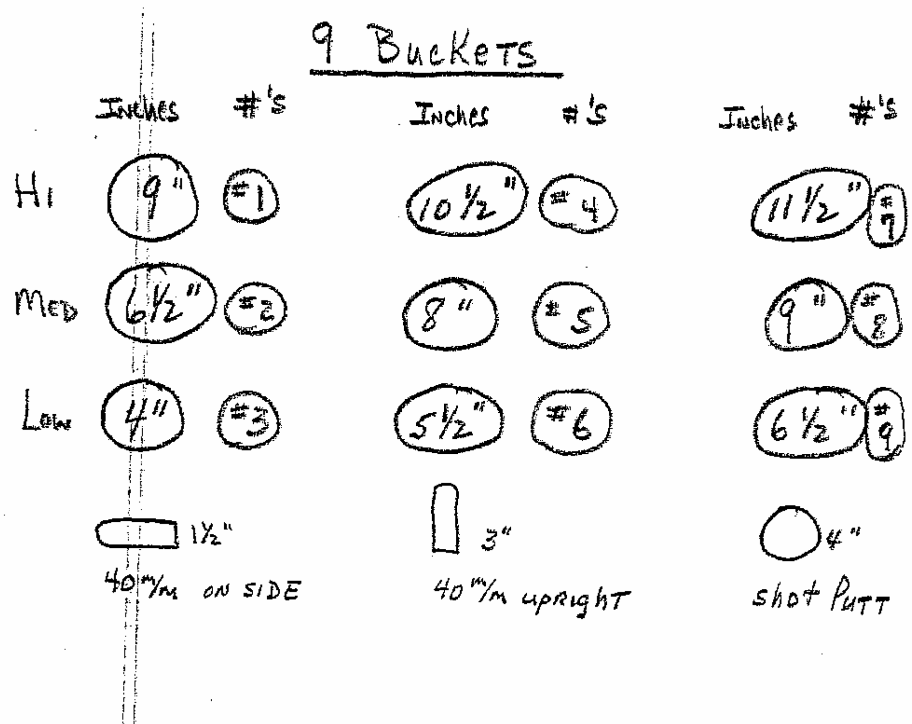

Figure G-5. Field notes of bucket/test pit layout.

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APPENDIX H. TARGET DESCRIPTIONS

CARTRIDGE, 40MM, TP, M781

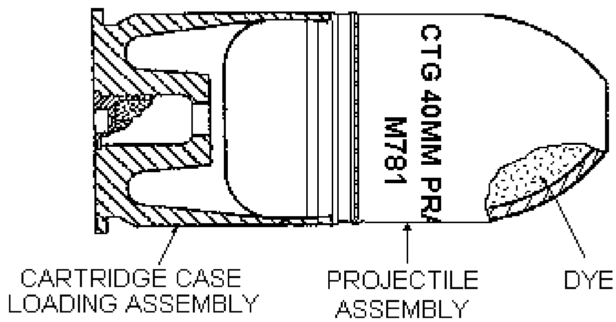

Figure H-1. 40mm, TP, M781 Projectile with cartridge case.

CARTRIDGE, 60MM TP, M49 SERIES

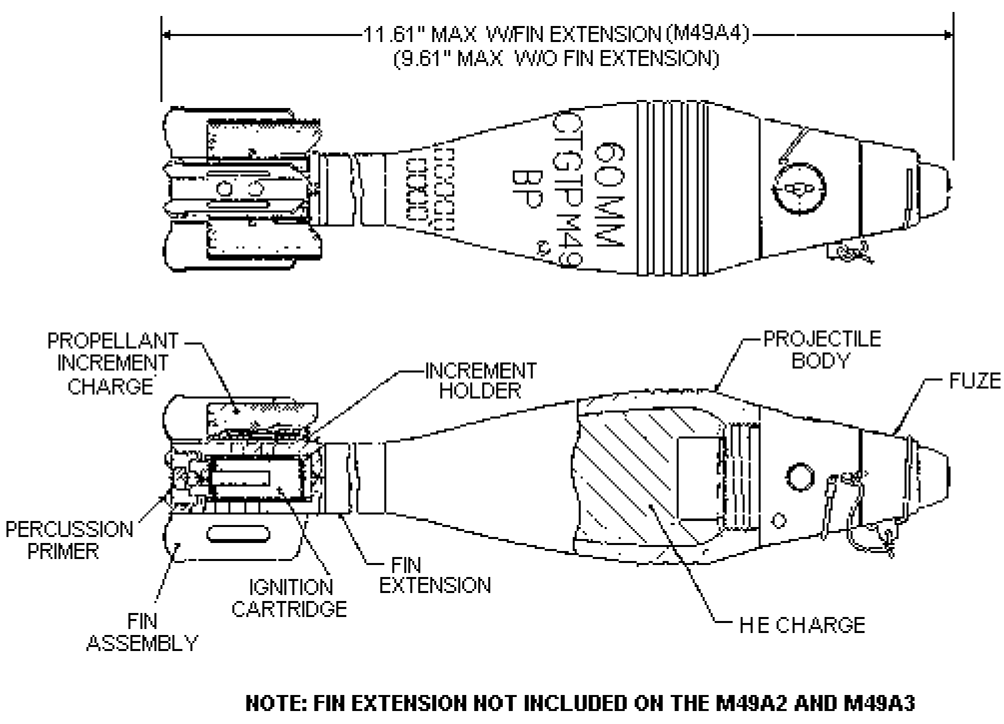

Figure H-2. 60mm TP, M49 Mortar.

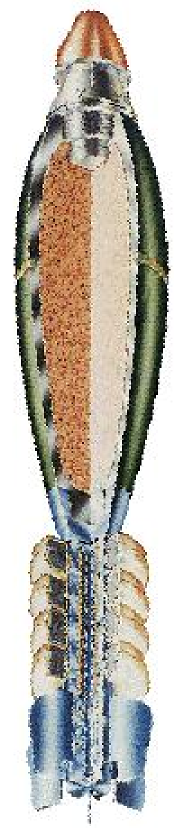

Figure H-3. 81mm M821 Mortar with propelling charge, zone 4.

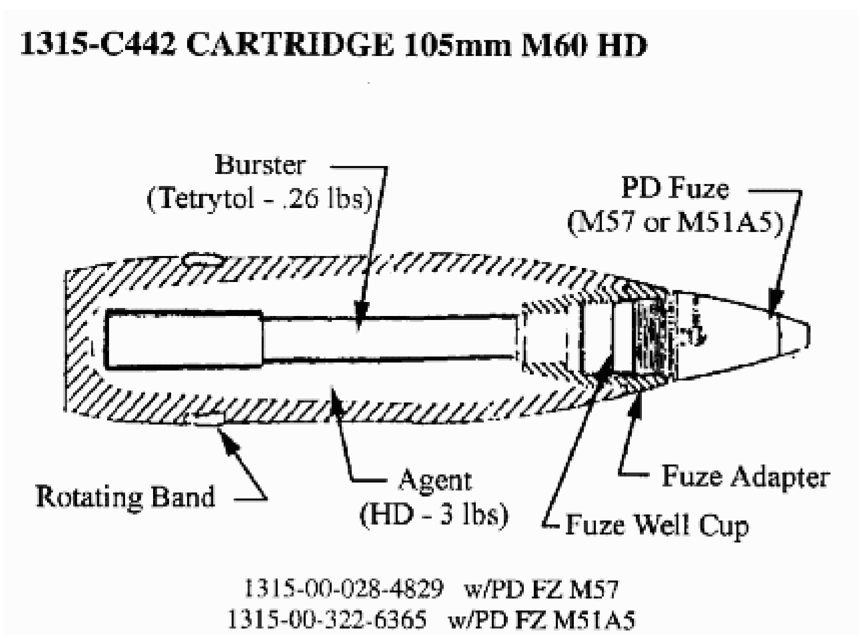

Figure H-4. 105mm M60 HD Projectile.

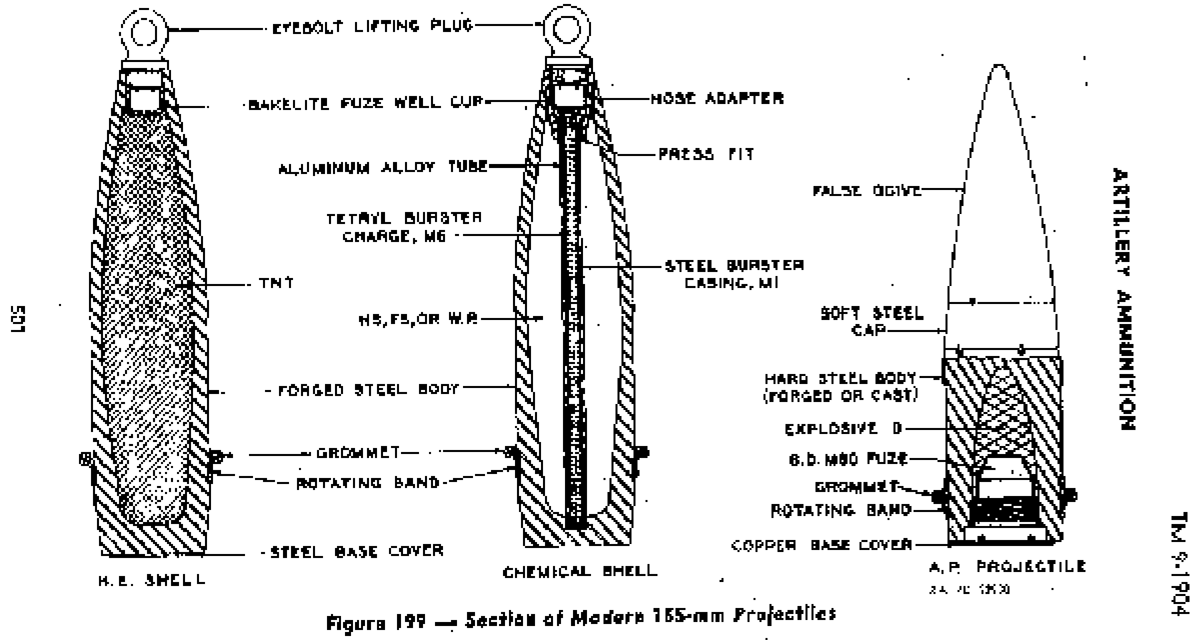

Figure H-5. 155mm Howitzer Projectile.

APPENDIX I. THREAT MANAGEMENT SYSTEM (TMS)

SYSTEM USERS MANUAL
FOR THE THREAT MINEFIELD SYSTEM
(Phase II)

CONTRACT NO. DAAH01-00-C-A107/0028/0029

CDRL#A031

8 January 2004

Prepared for:

Threat Systems Management Office
AMSTI-ITTS-SSC
Redstone Arsenal, AL 35898-7461

Monitored By: Mr. John Vanderwilt

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DOCUMENT CHANGE RECORD

DOCUMENT TITLE:	***DOCUMENT IDENTIFICATION & DATE:***
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Revision ID	Date	Approval Authority	Reference
-	30 May 2003		Initial release
A	27 August 2003		TMS ECN 0TM0007-12
B	8 January 2004		TMS ECN 0TM0009-12

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Scope

Identification

Scientific Research Corporation (SRC), under Contract DAAH01-00-C-A107 Technical Direction Orders (TDOs) 0010 and 0018 of the US Army Threat Systems Management Office (TSMO) program, was contracted by the TSMO to develop the Threat Minefield System (TMS). This System Users Manual (SUM) describes in sufficient detail the provided interfaces and procedures necessary for the operation of the Phase II (version 2.0) implementation of the TMS. This document serves as CDRL A031 of TDOs 0010 and 0018 and as partial satisfaction of the TMS task order requirements. This users manual pertains to the following computer software configuration items applications:

Operator Client (OpCli) version 1.1.0

Threat Minefield System Master (TMS Master) version 2.1.0

TMS Data Communications/Digital Signal Processing (TMS DataComms) version 2.1.0

Mine Interactive Simulation Program (MISP) version 2.1.0

Countermine Test Management System version 2001.503

Countermine Test Management System Host (CTMS Host) version 1.0.0

3DiWorkbench version 1.0.1405

System Overview

TSMO is an office under the Project Manager - Instrumentation, Targets, and Threat Simulators (PM-ITTS) within the Program Executive Office for Simulations, Training, and Instrumentation (PEO STRI). TSMO is developing a Distributed Interactive Simulation/High Level Architecture (DIS/HLA) compatible threat node that will provide distributed users with validated operator-in-the-loop (OITL) simulations of current and emerging threat systems. Providing OITL and hardware-in-the-loop radar simulators through the threat representations available in the threat node reduces the costs associated with testing and training in threat environments compared to tactical combat training and operations at open-air ranges.

The TMS system facilitates demining testing and training in either real or virtual environments. The system provides resources necessary to function as a test bed for demining instrumentation development. Additionally, TMS provides virtual mines for inclusion into HLA exercises. This manual applies to the entire TMS system.

This system represents Phase II of the TMS effort. Phase I, executed under a separate contract, facilitated the initial Evaluator Workstation architecture on a single personal computer (PC) running the Microsoft (MS) Windows 2000 operating system (OS). In Phase II, additional subsystems were added to accommodate necessary position measurement hardware, mine detector instrumentation, mine detector operator instrumentation, virtual exercises, and an extensible hardware and software framework to support multiple simultaneous exercises. Software configuration management is performed for the US Government by SRC using the MS configuration management tool Visual SourceSafe.

TSMO sponsored the original Phase I and this Phase II implementation of TMS. The intended initial users of the system are the US Army Countermine (CM) office at Ft. Belvoir, VA and the Engineering School within the US Army Training and Doctrine Command (TRADOC) although the system can be conceivably used by other agencies performing similar tasks such as unexploded ordinance (UXO) and ground remediation training. The Night Vision and Electronics Systems Directorate (NVESD) works closely with the CM office at Ft. Belvoir for the purpose of humanitarian demining and other technology development related activities.

Phase I Software Contributors

SRC was tasked by TSMO to develop a TMS that would operate in conjunction with mine detection instrumentation such as the U.S. Army Program Manager – Close Combat Systems (PM-CCS) Countermine (CM) office Handheld Standoff Mine Detection System (HSTAMIDS) and the Ground Standoff Mine Detection System (GSTAMIDS). BRTRC and Riggs Consulting supported SRC through subcontracts. BRTRC authored the original Countermine Test Management System (CTMS) software primarily under NVESD funding that has been used by the CM community and was adopted as part of the TMS workstation capability. Dr. Lloyd Riggs of Auburn University and sole proprietor of Riggs Consulting aided in data collection and statistical model developments.

Phase II Capability Improvements

TMS generates synthetic signal returns for the mine detection instrumentation operator based upon the simulated interaction between detectors and a set of Virtual Mine Models (VMMs) developed by SRC. The following four operational goals have been realized by TMS:

1. The TMS Survey function, in conjunction with the Geo-location Wand, provides a rapid, cost-effective method of surveying the "ground truth" of a minefield area.
2. TMS also provides an effective means of indicating to the exercise evaluator whether a detector operator target detection alarm was valid or not.
3. The TMS False Alarm Assessment function aids an evaluator in the determination of whether a false target detection was due to detector equipment or operator error.
4. The TMS CM Test Analysis functions will further reduce the difficulty of analyzing CM Test data.

TMS can be divided into functional units to describe the modular approach to the system:

1. Survey equipment used to survey a minefield to supply "ground truth" to the workstation using either:
    a) Conventional surveying equipment, which stores its survey results in a ground truth file
    b) New equipment, known as a Geo-location Wand, that transmits its data
2. Operator/detector instrumentation used to collect and transmit position and alarm data
3. A workstation, used by the exercise evaluator, which interfaces with the survey equipment, mine detection instrumentation and its operator, and the DIS/HLA network
4. A simulation program which adapts the position and alarm data from the detector and its operator, computes and displays their interaction with a real and/or virtual minefield
5. A library of VMMs

Exclusive of the survey and operator instrumentation, all of the above capability will be resident within what is described as the workstation. The workstation may or may not be composed of multiple computers or platforms. The modular approach to the system allows the form to match the system requirements for a particular application. Below in Figure 1-1 is shown the top-level functions of the TMS workstation. All modules under the control of the TMS Master executable (shown within the TMS Master box) are resident on the workstation.

This system is intended to find application at all TRADOC Engineering School demining training sites across the United States including Yuma, Ft. Leonard Wood, Ft. A. P. Hill, Aberdeen, Hawaii and others. The system currently supports handheld detection devices but is intended to be retrofitted to support vehicular based mine detection assets as well. The initial handheld demining equipment that TMS was developed for is the US Army issue AN/PSS-12 detector manufactured by Scheibel and the newly developed Handheld Standoff Mine Detection System (HSTAMIDS) in development by Cyterra Corporation of Orlando, FL under the direction of the CM/NVESD offices.

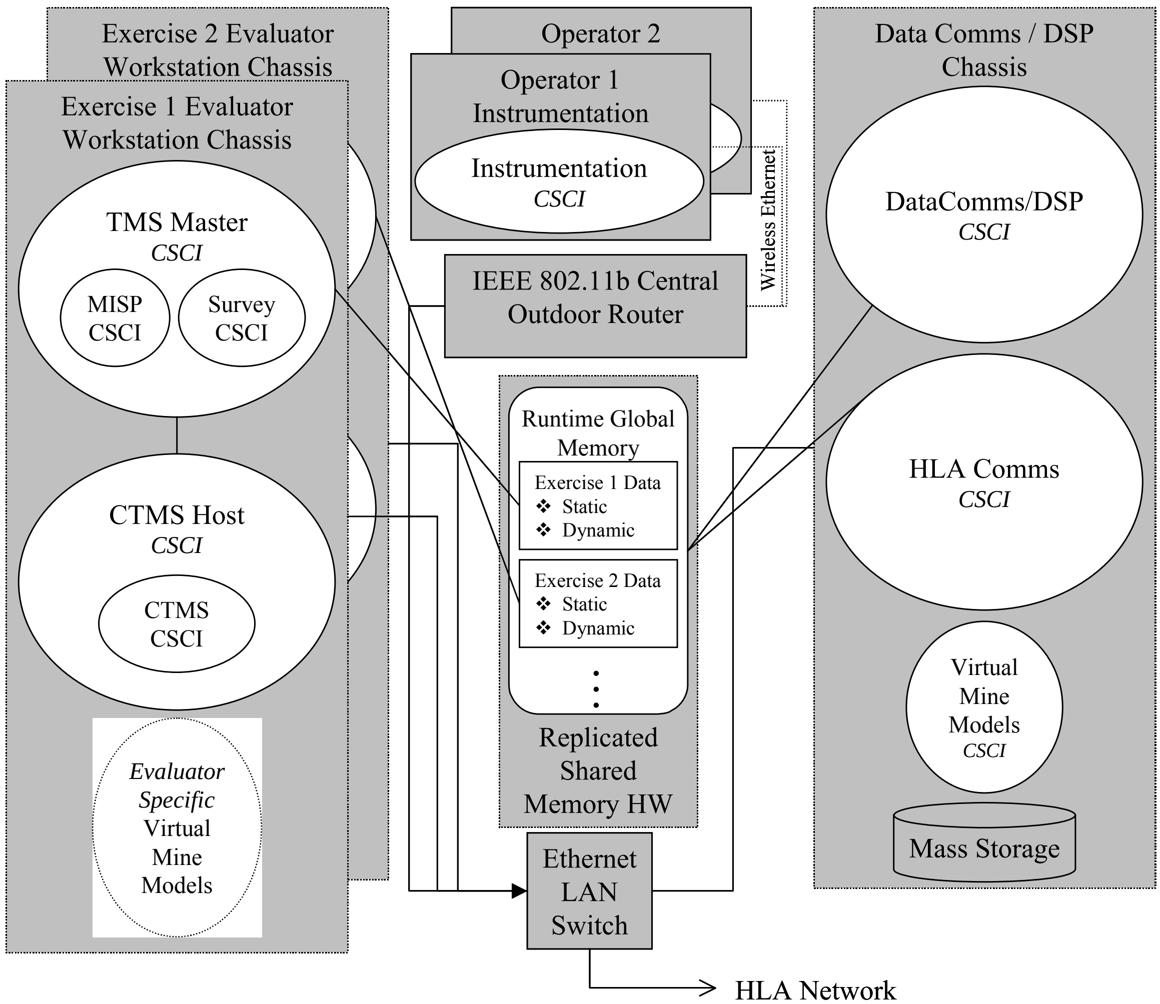


Figure 1-1. TMS Top Level Functions

The Threat Minefield System includes the following.

- Position, Locating and Tracking (PLT) Equipment
- Operator Instrumentation

The TMS Operator instrumentation includes position sensing gear, instrumented mine detection hardware, and the Operator Client (OpCli) subsystem. OpCli includes data acquisition, signal injection, data communication and control software.

- Data Communications, HLA Communications and Digital Signal Processing (DataComms/DSP) Equipment
- Evaluator Workstation Equipment

The TMS Evaluator Workstation subsystems consist of the TMS Master, and the Mine Interactive Simulation Program (MISP) evaluation tools, Survey, the Countermine Test Management System (CTMS) Host, and CTMS itself.

- Shared Memory Equipment

The replicated shared memory (RSM) component provides common data availability across all evaluator workstations served by the DataComms/DSP machine. This component is generically called Runtime Global Memory (RGM). In the mobile version of the TMS system, RGM is facilitated through software.

Document Overview

This SUM was developed in accordance with the TMS task description and DI-IPSC-81443. There are no security or privacy considerations associated with its use.

The purpose of this document is to present the instruction for correct operation of the TMS System including the Hardware Configuration Items (HWCIs) and the TMS Computer Software Configuration Items (CSCIs). It describes the operations necessary to exploit the TMS system capabilities and demonstrate compliance with the program requirements. The SUM is used as the basis for describing the correct system operational procedures. It provides an overview of the system with sufficient background to understand the functions. Table 0-1 provides an overview of this document. This document contains only unclassified information.

Table 0-1. Overview of SUM

Section	Title	Description
1	Introduction	Provides a full identification of the system, the software and this document.
2	System Overview	Provides a list of documents referenced within this SUM.
3	Software Summary	This section describes the system and associated software applications, inventory, environment, organization, operational overview, any contingencies and assistance and problem reporting contacts.
4	Access to the Software	This section introduces the software to the first time user, describes session initialization and session controls.
5	Processing Reference Guide	This section describes the system capabilities, procedures, and any related processing procedures.
6	Notes	This section provides an acronym list.
7	Appendices	This section describes the Arc Second positioning system set-up procedures.

Referenced Documents

The following documents of the exact issue shown are a part of this manual to the extent specified herein. In case of conflict between the documents referenced herein and the contents of this manual, the contents of this manual shall be considered the superseding document.

Table 2-1. Referenced Documents

Ref #	Identification #	Date	Title
1	JT&E Contract F08635-97-D-0017 Task Order 0031	4/11/00	TMS Task Description
2	DI-IPSC-81438	12/5/94	Software Test Plan (STP) Data Item Description
3	JT&E Contract F08635-97-D-0017 T.O. 0031 (CDRL B001)	6/22/00	Threat Minefield System Software Requirement Specification (SRS)
4	N/A	6/22/00	Contract F08635-97-D-0017 T.O. 0031 Threat Minefield System Preliminary Design Review (PDR)
5	N/A	10/11/00	Contract F08635-97-D-0017 T.O. 0031 Threat Minefield System Critical Design Review (CDR)
6	JT&E Contract F08635-97-D-0017 T.O. 0031 (CDRL B002)	10/18/00	Threat Minefield System Software Design Description (SDD)
7	Contract Number DAAK70-92-D-0003 Task Order 0056	1/25/98	Countermine Test Management System Draft User's Guide and Technical Report V2.0
8	Contract Number DAAK70-92-D-0003 Task Order 0056	Apr. 2000	Countermine Test Management System 2000
9	Threat Systems Management Office Contract DAAH01-00-C-A107/010	5/24/01	TMS Statement of Work
9	Threat Systems Management Office Contract DAAH01-00-C-A107/018	7/08/02	TMS Statement of Work
10	Threat Systems Management Office Contract DAAH01-00-C-A107/010/018 (CDRL A018)	4/3/03	Conceptual Design Drawings and Associated Lists
11	Threat Systems Management Office Contract DAAH01-00-C-A107/010/018 (CDRL A005)	5/6/03	Acceptance Test Plan for the Threat Minefield System
12	Threat Systems Management Office Contract DAAH01-00-C-A107/018 (CDRL A009)	5/15/03	Acceptance Test Procedures for the Threat Minefield System
13	Threat Systems Management Office Contract DAAH01-00-C-A107/010/018 (CDRL A010)	5/31/03	Threat Minefield System Phase II System Development Final Report

Software Summary

TMS may be setup in multiple configurations. One optional system configuration intended for permanent facility installations consists of a single DataComms/DSP component residing on a dedicated computer providing instrumentation data in real-time to multiple distributed evaluator workstations through a RSM network. Another optional system configuration suitable for single evaluator use includes a single computer on which a DataComms/DSP component is co-resident with the evaluator components, with which it communicates through local shared memory. For both system configurations, there are options on the setup of other components as well. The software components of TMS reside on three or more different computers, depending upon the configuration in use. One or more software applications perform the processing required to implement the capabilities of TMS on each computer. These applications are listed and described briefly in the following sections.

Software Applications

The following custom applications implement or initiate the processing required for TMS. Data acquisition and communication processing on the field instrumentation unit (FIU) is performed by the Operator Client application. Data communication between evaluator workstations and the FIU(s) as well as any data conversion and translation processing is performed on the DataComms/DSP component by the TMS DataComms application. Operation specification, configuration, and execution at an evaluator workstation are performed by the TMS Master application. VMM implementation, operator performance evaluation, and mine detonation prediction are performed by the MISP at an evaluator workstation. CTMS performs exercise scoring and area coverage analysis. Data transfer between an evaluator workstation and an external workstation executing CTMS is facilitated by the CTMSHost application. Additionally, several commercial applications perform some TMS functionality, either as a stand-alone application or under the control of one of the custom TMS applications.

Software Inventory

The files required to execute each of the TMS software applications are listed in the following sections. A TMS software installation utility will install all of the custom components necessary for a particular computer/configuration. Commercial components will be installed by either the TMS installation utility or an installation utility provided by the component developer, as required.

Operator Client

TMS custom components

- OpCli.exe – the Operator Client application
  - ws_dll.dll – WinSock communications processing
  - StartApp.exe – process start-up application

Commercial components

3DiWorkbench.exe – Arc Second control application
Conductor.dll – Primary assembly containing the core objects that make up a 3Di system
MsgTransport.dll – Network library
PositionData.dll – Position calculation algorithms
MathLibCS – Mathematic and geometric calculation library
Symantec PCAnywhere (multiple files)

TMS DataComms

TMS custom components

TMSDataComms.exe – the TMS DataComms application
dc_net_io.exe – IP network communications processing
dc_serial_io.exe – serial interface processing
dc_proc.dll – TMS DataComms/comm. processing shared memory
ws_dll.dll – WinSock communications processing
serial_buff.dll – serial interface physical layer processing
rgm_p2.dll – Phase 2 shared memory API and implementation
datacomms_help.hlp – online help documentation file
datacomms_help.cnt – online help contents file

Commercial components

DMSO RTI HLA support package (multiple files)
VR-Link HLA support package (multiple files)
Pnpscr.dll – Systran SCRAMNet replicated shared memory device driver
UART.dll – ICP DAS low level serial communications driver for Demo Unit controllers (See Appendix B.)
I7000.dll – ICP DAS high level serial communications driver for Demo Unit controllers (See Appendix B.)
Symantec PCAnywhere (facility configuration, multiple files)

TMS Master

TMS custom components

TMSMaster.exe – the TMS Master application
Ctmstt.mdb – augmented CTMS targets database
SurveyTmplt2.exe – survey session data database template
Ws_dll.dll – WinSock communications processing
rgm_p2.dll – Phase 2 shared memory API and implementation

Commercial components

StripM.ocx – strip chart display ActiveX control
Mscomct2.dll – date/time display ActiveX control
Pnpscr.dll – Systran SCRAMNet replicated shared memory device driver
TechSmith SnagIt screen capture package (multiple files)
Symantec PCAnywhere (single evaluator configuration, multiple files)

TMS MISP

TMS custom components

TMSMISP.exe – the MISP application

Avg_user.mdb – average user statistics database

MineResponse.mdb – mine detector response value database

rgm_p2.dll – Phase 2 shared memory API and implementation

Commercial components

StripM.ocx – strip chart display ActiveX control

Pnpscr.dll – Systran SCRAMNet replicated shared memory device driver

CTMS/ CTMSHost

TMS custom components

TMSCTMSHost – the TMS CTMS Host application

Ws_dll.dll – WinSock communications processing

CTMS 2001.503 package for TMS (multiple files)

Commercial components

MS Access 2000 database management package (multiple files)

Software Environment

All TMS software components run in a MS Windows 2000 or MS Windows XP environment. Furthermore, it is recommended that TMS DataComms run under MS Windows 2000 Server when installed on a dedicated server-type computer as part of the distributed, fixed site configuration

Software Organization and Overview of Operation

The organization of the TMS software components is specific to the corresponding computer and configuration. All TMS custom components are installed to a \TMS_Home\TMS_Bin folder on the corresponding computer. Commercial components are installed to either the same folder or a folder specified by the installation utility provided by the developer, as required. The operation of each component is also specific to the functionality of the corresponding computer.

Field Instrumentation Unit

The software on the FIU includes the Operator Client application as well as the Arc Second 3DiWorkbench application. During field exercise execution, no direct operator interaction occurs with the executing software. Rather, the FIU is configured so that the StartApp application launches on system power-up, then starts each of the required individual processes. The 3DiWorkbench application functions as a data server, providing position data to the Operator Client application, which sends the position data, along with acquired mine detector output, to the DataComms/DSP component. During the calibration of the Arc Second PLT system, the user will interact with the 3DiWorkbench application via a remote system control session. Refer to Appendix A for further information on the Arc Second calibration process.

DataComms/DSP

The TMS DataComms application performs the processing for the DataComms/DSP component. The user interacts with TMS DataComms to configure communications interfaces to FIUs and assign field entity types to each communications interface. The user may also monitor system status information pertaining to inter-component communications using various facilities of TMS DataComms. If no changes to the communications interface and entity assignment configurations are required, no interaction with TMS DataComms may occur during normal system operation. In the facility configuration, TMS DataComms resides on the dedicated DataComms/DSP computer. In the single evaluator configuration, TMS DataComms resides on the single evaluator workstation. In this configuration, the TMS Master application will launch the TMS DataComms application if it is not already running.

Evaluator Workstation

The TMS Master application and MISP together perform the processing required for the operations of the Evaluator workstation. The TMS Master application is the primary focus of user interaction for normal system operation. It performs the processing required for setup and execution for live field and HLA exercises as well as exercise playback and survey operations. It also exchanges data and status messages with the CTMS workstation, if CTMS is in use during exercise execution. During live, HLA, or playback exercise execution, MISP processes position data against exercise ground truth data and VMM data to predict detonations, detector response to virtual mines, and operator performance.

CTMS Workstation

The CTMS workstation is included to provide a dedicated environment for CTMS real-time processing during an exercise due to the high level of processor activity required to perform the CTMS display and analysis function. The use of CTMS during an exercise, either live or playback, is optional and is specified by the evaluator during exercise setup at the Evaluator workstation. The CTMS Host application facilitates the transfer of exercise data and status messages between CTMS and the Evaluator workstation. The user interacts to some degree with both applications, generally in response to prompts triggered by status messages from the Evaluator workstation. The CTMS Host application will launch CTMS as necessary. The CTMS Host application also provides access to the CTMS Reports Manager.

Contingencies and Alternate States and Modes of Operation

This paragraph has been tailored out, as it is not applicable.

Security and Privacy

TMS does not contain or generate or provide any special provisions for operating on classified data. Also, TMS has no functional requirement for operating within a secure environment.

Assistance and Problem Reporting

For assistance with the operation and configuration of TMS or to report a problem encountered while using TMS, contact:

Prime System Developer:
Scientific Research Corporation

Bill Brothers, Program Manager/Senior Systems Engineer
(256) 428-9222
bbrothers@scires.com

Government Technical Representative:
TSMO (AMSTI-ITTS-SSC)
John Vanderwilt
(256) 876-9656, ext. 222 (commercial)
476-9656 (DSN)
John.Vanderwilt@tsmo.redstone.army.mil

Access To the Software

First Time User of the Software

Each of the TMS applications involving user interaction adheres to the familiar MS Windows user interface paradigm. All user controls are laid out and arranged in the conventional manner. For TMS DataComms, the first steps for a new user are to create one or more communications interfaces and associate those interfaces with field entities of the appropriate type. For TMS Master, the first steps for a new user are to configure and execute an operation of the appropriate type. For CTMS Host, the new user will follow the prompts resulting from status messages received from the Evaluator workstation. Refer to Section 5 for more details on the specific user interactions with each application.

Equipment Familiarization

TMS Workstations

All of the TMS workstation applications run on standard IBM PC-style computers. For the facility configuration, each workstation, including the dedicated DataComms/DSP computer, must include a Systran SCRAMNet RSM board. Also in this configuration, each workstation must include 2 network interface controllers (Ethernet ports.) It is recommended that the dedicated DataComms/DSP computer be a server-type PC with significant processing capability to better handle the network communications and signal processing calculations.

FIU Processor

The TMS FIU processor is custom-built to meet the requirements of TMS. It contains a fully functional embedded Intel Pentium-based single board computer running the MS XP Professional operating system. Wireless Ethernet and an Analog-to-Digital converter (ADC) are provided via Personal Computer Memory Card International Association (PCMCIA) form factor. The FIU also contains four Arc Second position calculation engine (PCE) cards and the interconnections required between the embedded computer and the PCEs. Figure 4-1 shows the front panel of the TMS FIU.

Figure 4-1. FIU Front Panel

The FIU is water resistant to 1m. All connectors on the front panel are water resistant. The RF IN connector is a water resistant SMA connector and the remaining connectors are auto-locking cylindrical connectors produced by Fischer Connector, Inc. The front panel Fischer connectors and their mates on the provided cabling are color-coded. In addition to being color-coded, each port type (Power, Sensor, Video, etc.) has a different number of pins to prevent accidental connection mistakes. The connectors, however, are not keyed differently so some care must still be exercised to not force connectors. If the connectors are forced, significant damage may occur.

FIU Input/Output Connection Ports

Power

Power is supplied to the FIU though the PWR IN port. This is a 6-pin Fischer connector that is color-coded red. The mating cable provides two connectors for connecting to rechargeable batteries. Either one or two batteries may be connected. Additionally, the two battery connectors are diode-separated inside the FIU, allowing for “hot swapping” of the batteries. Each 15V, 11Ah battery will provide at least 5 hours of service. Each battery has a charge indicator on top to determine approximate percentage charge remaining. Connecting a fully charged battery to the FIU with a depleted battery will generally only draw current from the fully charged battery.

The power and reset buttons are both water resistant. The power button, labeled PWR, will be illuminated red while power is applied to the FIU and it is turned on. Pressing the power button while the FIU is on has no effect. Pressing the reset button at any point will cause the embedded computer to perform a hard shutdown, and power to the FIU to be turned off. Operation of the reset button is not standard, as the power button must be pressed to restore power to the FIU. "Graceful" shutdowns are accomplished remotely. However, typically, there are no consequences from a hard shutdown. Shutdowns of any type should not be performed during an exercise.

PS2 – Keyboard/Mouse

The keyboard/mouse port allows a PS/2 keyboard and/or a PS/2 mouse to be connected to the embedded computer. This connector is a 12-pin Fischer connector labeled KB/M and color-coded green. The mating cable provides two standard PS/2 connectors. Also provided is a Twiddler handheld keyboard/mouse input device (also called a chording device). During normal operations, the keyboard connector of the Twiddler (or replacement handheld keyboard device if desired) will be connected to the keyboard PS/2 connector to allow the operator to input alarm information. Normally, the mouse connector will not be used because it is not necessary for operations in the current configuration. During configuration, or other operations that require comprehensive access to the embedded computer, the keyboard and mouse connectors may be used to provide input from standard PS/2 input devices. PS2 connections are not plug and play and therefore must be present upon FIU power application for PS2 device recognition by the OS.

Video

The Video port is a 19-pin Fischer connector that is color-coded blue. The mating cable provides a standard 15-pin video graphics array (VGA) connector. During normal operations, the FIU is headless and the video connector will not be used. It provides access to the embedded computer video port and will be used for configuration and other operations where a video monitor is required.

Ethernet

The Ethernet port is a 5-pin Fischer connector that is color-coded gray. This port provides 10/100 Ethernet-connectivity to the embedded computer. The mating cable provides a standard RJ-45 connector. During normal operations, there will be no connection made to this port.

Sensors

The FIU has four laser PLT system sensor ports. Each provides connectivity to one of the internal PCE boards. The sensor ports are 4-pin Fischer connectors color-coded yellow. The four ports are labeled LEFT, RIGHT, UPPER, and LOWER and are intended to be connected to specific sensors on the operator and the mine detector. The LEFT port must be connected to the sensor on the operator's left foot and the RIGHT port to the sensor on his right foot. The UPPER port should be connected to the upper sensor on the mine detector shaft and the LOWER port should be connected to the lower sensor on the mine detector shaft. The Sensor port mating cables mate to the sensor ports on one side and the detector housings on the other side. All Sensor port mounting cables are identical, so care must be taken to attach the correct sensor to each port.

Universal Serial Bus (USB)

The USB port provides access to the embedded computer USB interface. The USB port is a 10-pin Fischer connector color-coded white. The mating cable provides two standard USB connectors. During operation, one connector is allocated for the optional camera attached to the mine detector shaft (a USB extension cable has been provided to give the operator full range of motion). The second USB connector is used for a USB-to-serial (this extra port is necessary when RS-232 data is being collected using the Minelab F3 mine detector).

DAQ

The Data Acquisition port, labeled DAQ, is a 10-pin Fischer connector color-coded white. This port provides connections to the FIU's data acquisition ADC subsystem. The mating cable provides a standard 9-pin D connector. There are four single ended analog input channels provided. The input range for these channels is +10V to –10V. There is also a single digital-to-analog converter output channel. This channel provides output from +10V to –10V and can be used to inject signals into a properly instrumented mine detector. During TMS operations, this port is used to collect data from and provide signals to an instrumented AN/PSS-12. The instrumented AN/PSS-12 has a 9-pin D connector that the other end of the DAQ mating cable plugs into.

RF/Wireless Ethernet

The RF port is an SMA female connector. To facilitate 802.11b communications, an antenna must be connected to this port. The provided 802.11b antenna may be attached directly to this connector for short-range communications (~100m). For longer-range communications (up to 1 mile), a provided 4-foot mast may be attached using the provided clamps. A cable with SMA male ends on both sides is used to connect the RF port to the bottom of the antenna mast. The provided antenna is then connected to the top of the mast. This raises the antenna above the operator so that the operator's body does not shadow the 802.11b signals (attaching the antenna mast is only necessary if 802.11b connectivity cannot be achieved without it).

Audio

The Audio port is a 7-pin Fischer connector color-coded black. It provides access to the audio output of the embedded computer. This port is currently unused. In the future, the Audio port may be used to provide audio or other feedback to the operator.

Integrating the FIU, the Handheld Mine Detector and the Operator

This section lists the necessary equipment and the steps required to outfit a handheld mine detector operator with an FIU prior to conducting an exercise. The AN/PSS-12 is cited as an example mine detector.

Equipment List

- TMS FIU
- TMS FIU mounting bracket, shoulder straps, and belt
- Ultralife 15V lithium ion battery
- Battery pouch
- 802.11b antenna
- 2 Arc Second sensors with foot mounts
- 2 Arc Second sensors with mine detector shaft mounts
- USB camera
- Instrumented AN/PSS-12
- Twiddler handheld input device
- Associated cabling

Integration Steps

- Mount the FIU to its mounting bracket and attach the belt and shoulder straps. Put the battery in the battery pouch and attach the battery pouch to the belt.
- Attach the 802.11b antenna to the RF port of the FIU.
- Attach the battery cable to the battery.
- Put the FIU on the operator and adjust the belt and shoulder straps until the processor is secure and the operator is comfortable. The FIU weight should rest on the hips of the operator and not on his shoulders. The shoulder straps are provided for stability and should not be weight bearing.
- Attach the two Arc Second sensors to the shaft of the AN/PSS-12. Also attach the USB camera to the mine detector shaft between the two sensors.
- Attach an Arc Second sensor to each of the operator's feet using the foot mounts.
- Place the AN/PSS-12 electronics over the operator's shoulder such that the electronics are on the opposite side of the operator from the hand holding the AN/PSS-12 during operation.
- Using the provided cables, attach each sensor to the appropriate sensor port on the FIU. Take care with the routing of the cables to avoid impairing the operator's range of motion with the detector or with his feet.
- Attach the USB camera to the FIU USB port using the provided USB adapter cable. Follow the same cable routing as was used for the detector shaft sensor cables.
- Attach the DAQ port to the AN/PSS-12 using the provided cable.

- Attach the Twiddler to the KB/M port using the provided cable. Only the keyboard connector of the Twiddler should be used. The operator should attach the Twiddler to the same wrist as the arm swinging the mine detector. In this fashion, the other hand is free to adjust the AN/PSS-12 sensitivity control and press the appropriate buttons on the Twiddler for alarm and clutter enunciations.
- Insert the battery into the provided FIU mounting belt pouch. Attach the battery cable to the battery and the FIU PWR IN port. Press the PWR button to turn on the FIU.

Access Control

No access control beyond the standard MS Windows user login process is provided or required for any TMS computer or application. Normal FIU operation is headless and requires no user interaction beyond the indication of alarms during an exercise.

Installation and Setup

The procedures required for the installation and setup of TMS components are dependent upon the specific component and the desired overall system configuration. The following sections address these types of installation and setup issues for all TMS components.

DataComms/DSP Software Installation and Setup

In the distributed, facility configuration, the DataComms/DSP component resides on a separate computer that also includes the shared system-wide Mass Storage archive volume. This configuration uses a Systran SCRAMNet RSM board to implement system RGM. The installation of the RSM board and its support software is the first step in the setup of the distributed configuration of DataComms/DSP. The next step for the distributed configuration (or the first step for the mobile single evaluator configuration) is the installation of the TMS software, and optionally, the third party HLA interface support software. Finally, the network interface configuration parameters must be set and networking support software loaded. All of this software is provided and installation procedures are described in the following sections.

Replicated Shared Memory Installation and Setup

Note: this procedure is required only for the distributed, facility installation.

- Install the RSM board in the computer following the instructions in the Systran hardware reference manual. When appropriate, connect the fiber optic cables between the board in the DataComms/DSP computer and those in all workstation computers following the instructions in the same manual. (Note: all cables must be connected for the RSM network to function properly.)
- Install the RSM support software for the appropriate version of Windows following the instructions in the Systran programmer's reference manual.
- Launch the WINInst application from the SCRAMNet program group in the Programs submenu of the Windows Start menu. Click the Edit button on the initial dialog. In the board configuration dialog, enter 1 as the Node ID. Leave the default values for all other settings. Click OK to save the new value.
- Exit WINInst. Restart Windows.

DataComms/DSP TMS Software Installation

The specific installation of the TMS software for the DataComms/DSP component is dependent upon the system configuration and the requirement for HLA interface support. HLA interface support is optional because it is implemented using third party components under a per-platform license.

Distributed, Facility Configuration

- From the TMS Software Installation CD, if HLA support is required, run the Facility_DC_HLA_Setup installation utility. If HLA support is not required, run the Facility_DC_NoHLA_Setup installation utility.
- The installation utility will create a folder named ‘Archive_Storage’ at the root of the G: drive. Under Windows, designate this folder as Shared.
- The installation utility will create a folder named ‘TMS_DB’ within a ‘TMS_Home’ folder that is at the root of the F: drive. Under Windows, designate this folder as Shared.

Single Evaluator Configuration

The software for the DataComms/DSP component in the single evaluator configuration is installed together with all other TMS software. See Section 4.1.3.2.3.2.

HLA Interface Software Installation

The HLA interface implemented within TMS DataComms/DSP incorporates 2 third party components, the runtime infrastructure (RTI) and VR-Link. Each component is installed separately as described in the following sections.

RTI Installation

The RTI is government-owned software that facilitates the communication between the federates in an HLA federation. TMS uses the Defense Modeling and Simulation Organization (DMSO) 1.3NG version 4 RTI (RTI1.3NGv4). The RTI was originally downloaded from the DMSO web page; however, DMSO no longer provides/supports the RTI. The necessary version is included on the TMS Software Installation compact disc (CD). Execute the RTI-1.3NGv4-Win2000.exe installation utility and install the RTI software to the folder C:\Program Files\DMSO\RTI1.3NG-v4/Win2000-vc6. Associated with the RTI is a configuration file used by DataComms/DSP named RTI.rid. This file contains settings specific to the particular installation of DataComms/DSP and the network on which DataComms/DSP is an HLA federate. This file is installed as part of the TMS software installation in the ‘TMS_Bin’ folder.

VR-Link Installation

VR-Link is a product of MÄK Technologies that provides a programming interface to the RTI. Each installation of VR-Link requires a separate runtime license. Therefore, VR-Link must be installed from an installation package purchased for a specific installation. Refer to the instructions included with the VR-Link installation package. VR-Link uses the FLEXlm runtime license manager. FLEXlm is included in the VR-Link installation. Before you can run an application that employs VR-Link, a valid license file must be obtained from MÄK Technologies. The license file is keyed to the host ID of the TMS DataComms/DSP computer. The license file must reside in the 'TMS_Bin' folder within the 'TMS_Home' folder. It will be named 'host.lic,' where 'host' is the host name of the computer. The TMS DataComms application automatically executes the license manager by invoking the TMSRUNLM batch file located in the 'TMS_Bin' folder. This file should be edited to reference the correct license file. In addition to the license file, the environment variable, MAKLMGRD_LICENSE_FILE, must be defined on the TMS DataComms/DSP computer as @host where 'host' is the host name of the computer. Refer to the VR-Link users manual for more information on the installation and usage of the runtime components of VR-Link.

Network Interface Parameter Settings and Support Software Setup

DataComms/DSP uses Ethernet networks to exchange data with FIUs (as IEEE 802.11b Wireless Ethernet,) to connect to HLA simulations, and to share locally resident data files and exercise archive files with distributed workstations. In addition, third party support software must be installed along with the Wireless Ethernet hardware. The exact configuration of the Ethernet network interfaces used by DataComms/DSP is dependent upon the requirements of the specific installation.

Field Instrumentation Network Interface Parameter Settings and Support Software

The field instrumentation network is implemented as Wireless Ethernet. If DataComms/DSP is installed on a desktop or workstation computer, an external access point is used to connect to the field instrumentation units. For increased network capacity, the access point may actually be a central outdoor router (COR) that supports 2 simultaneous channels. If necessary to support a large number of field units simultaneously, a second COR could be added. DataComms/DSP is connected to the access point through a built-in network interface. The IP address of this network interface on DataComms/DSP must be consistent with the IP address assigned to the access point. Support software supplied with the access point is used to configure the IP address and network operating parameters of the access point. One network parameter will indicate that the network is operating through an access point. If DataComms/DSP is installed on a notebook computer, a Wireless Ethernet interface card may be installed directly in a PC-Card slot. A different set of support software is used to configure the interface card and network operating parameters. One network parameter will indicate that the network is operating among peers. (The IP addresses assigned to field instrumentation units, as well as the network operating parameters, must also be consistent with those assigned to the instrumentation network interface of the DataComms/DSP computer and the access point. These settings are assigned locally to each instrumentation unit.) Refer to the user manual of the appropriate support application for details on configuring the network interface and operating parameters, including IEEE 802.11b channel assignment.

In the distributed facility configuration, each distributed evaluator workstation is also connected to the field instrumentation network (using an appropriate network connection device, such as a hub or switch) in order to receive video directly from associated instrumentation units. This network connection is also used to connect shared drives located on DataComms/DSP in which reside data files and exercise archive files. Therefore, the IP addresses assigned to the corresponding network interfaces on the evaluator workstations must be consistent with those of DataComms/DSP and the instrumentation units. The following address assignment scheme is recommended for the instrumentation network. This scheme requires that the leading address component (octet 0) is 150 or greater.

Table 4-1. Recommended Instrumentation Network Address Assignment

IP Address (Y >= 150)	Unit
Y.X.X.1	Access Point/COR 1
Y.X.X.2	(Reserved: Access Point/COR 2)
Y.X.X.3	DataComms/DSP
Y.X.X.4 -7	Distributed Evaluator Workstation 1 - 4
Y.X.X.8 -21	Field Instrumentation Unit 1 -14

Note: the current facility configuration of TMS provides for up to 4 evaluator workstations. This number corresponds to the number of 802.11b channels that could be used simultaneously without potential interference from frequency overlap. Additional workstations could be added to the current configuration with minor modifications to some software components, and, potentially, the use of replicated shared memory boards with greater capacity. Such an addition, however, may require the use of channel sharing among simultaneously active field units. This could require a trade-offs in some operational capabilities, such as not transmitting video from a field unit sharing a channel.

HLA Network Interface Parameter Settings

DataComms/DSP uses a built-in network interface to connect to an Ethernet local area network (LAN) to exchange data within an HLA simulation. The configuration parameters for this interface must match those specified for the LAN and for other simulation federates. In addition, configuration files used to configure the RTI residing on DataComms/DSP and other federates may need to be edited to specific operating parameters unique to each federate network interface. For instance, if DataComms/DSP uses 2 network interfaces, the IP address and port number for the computer executing the RTI must be specified in the ‘RTI.rid’ file in the ‘TMS_Bin’ directory as:

(RtiExecutiveEndpoint X.X.X.X:N)

where X.X.X.X is the IP address of the network interface of the computer executing the RTI and N is the port number. The information in this file may be modified for each simulation in which DataComms/DSP is a federate. (Note: a complete description of all parameters and settings necessary to participate as a federate in an HLA simulation is beyond the scope of this document.)

Evaluator Workstation Software Installation and Setup

In the distributed, facility configuration, the evaluator workstation components reside on up to 4 separate platforms. This configuration uses Systran SCRAMNet RSM to implement system RGM in hardware. The installation of the RSM board and its support software is the first step in the setup of the distributed configuration. The next step for the distributed configuration or the first step for the single evaluator configuration is the specification of the network interface configuration parameters. The final step is the installation of the TMS software and third party support software.

Replicated Shared Memory (RSM) Installation and Setup

Refer to Section 4.1.3.1.1 and follow the same procedures, except that the board Node ID assigned for each evaluator workstation should be the workstation ID number + 1 (e.g., board Node ID for Workstation 1 is 2.)

Network Interface Parameter Settings

In the distributed, facility configuration each evaluator workstation is connected to the field instrumentation network in order to receive video directly from associated instrumentation units. This network connection is also used to connect shared drives located on DataComms/DSP in which reside data files and exercise archive files. In both the distributed and single evaluator configurations, an evaluator workstation includes a separate Ethernet network interface dedicated to communications with the external CTMS workstation. In addition, if HLA interface support is required in the single evaluator configuration, an HLA network interface must be configured as described in Section 4.1.3.1.4.2.

Field Instrumentation Network Parameter Settings

Refer to Section 4.1.3.1.4.1 for information on setting the field instrumentation network parameters for an evaluator workstation network interface.

CTMS Network Interface Parameter Settings

An evaluator workstation uses a built-in network interface dedicated to exchanging data during an exercise with an external computer executing CTMS. As this is a private, dedicated network, the IP address of this network interface should be set as 10.X.X.Z. Correspondingly, the IP Address of the associated network interface on the external CTMS workstation will be set as 10.X.X.Z + 1.

Evaluator Workstation TMS Software Installation

The specific installation of the TMS software for the evaluator workstation components is dependent upon the system configuration and the requirement for HLA interface support. HLA interface support is optional because it is implemented using third party components under a per-platform license.

Distributed, Facility Configuration

The distributed, facility configuration supports up to 4 evaluator workstations. Follow these procedures at each workstation.

- From the TMS Software Installation CD, run the Facility_Eval_Setup installation utility.
- The installation utility will create a folder named 'TMS_GroundTruth' within a 'TMS_Home' folder that is at the root of the C: drive. Under Windows, designate this folder as Shared.
- Launch Windows Explorer. From the 'Tools' menu select the 'Map Network Drive' item. Set the drive letter to 'Y:'. Enter as the Folder '\\DCHOST\ARCHIVE_STORAGE' where 'DCHOST' is the host name of the DataComms/DSP computer. Check the 'Reconnect at logon' box. Click the 'OK' button.
- Again using Windows Explorer, from the 'Tools' menu select the 'Map Network Drive' item. Set the drive letter to 'Z:'. Enter as the Folder '\\DCHOST\TMS_DB' where 'DCHOST' is the host name of the DataComms/DSP computer. Check the 'Reconnect at logon' box. Click the 'OK' button.

Single Evaluator Configuration

The software for all TMS components is installed in one operation for the single evaluator configuration. From the TMS Software Installation CD, if HLA support is required, run the Single_Eval_HLA_Setup installation utility. The HLA support software must then be installed following the procedures in Section 4.1.3.1.3. If HLA support is not required, run the Single_Eval_NoHLA_Setup installation utility.

Evaluator Workstation Third Party Support Software Installation and Setup

One or more third party software packages may be used on the TMS evaluator workstation to facilitate various system capabilities. This section addresses installation and setup issues of these packages.

TechSmith SnagIt

TechSmith Corporation's SnagIt is used to capture the video displayed in the video session window of TMS Master during a live exercise to an '.AVI' video file. To install SnagIt, follow the instructions in the corresponding installation CD. After the installation process completes and SnagIt is launched for the first time, a configuration wizard allows the specification of application settings. In the 'Select Input' dialog select 'Region.' In the 'Select Output' dialog select 'Graphics file.' In the 'Hotkey' dialog accept the default value. In the 'Preview' dialog select 'Off.' On the application main window, click on the 'Video Capture' tool button. Under the ‘Input’ menu, select ‘Fixed Region’ and then select the ‘Properties’ item. In the ‘Input Properties’ dialog, enter 240 as the Width and 200 as the Height (the dimensions of the TMS Master video session video display area.) Under the ‘Options’ menu select the ‘Compact View’ item. Exit SnagIt. These settings will be retained for subsequent SnagIt sessions.

Symantec PCAnywhere

Symantec PCAnywhere is used to facilitate a remote session between a TMS workstation and an FIU to allow the user to perform certain configuration and setup operations local to the FIU prior to initiating an exercise. The remote session requires an active Wireless Ethernet connection between the TMS workstation and each FIU. In the facility configuration, PCAnywhere should be installed on the DataComms/DSP workstation. In the single evaluator configuration, it should be installed on the Evaluator workstation. PCAnywhere is distributed to include installations for both a “host” node and a “remote” node. The FIU installation should be designated as the “host” and the workstation installation as the “remote.” Refer to the PCAnywhere documentation for detailed instructions on installation, configuration, and use.

CTMS Workstation Software Installation and Setup

The external CTMS workstation provides a dedicated computer for performing CTMS analysis and display processing during a TMS exercise without affecting the real-time processing of the TMS evaluation and simulation components. The software installation and setup of the CTMS workstation involves loading the CTMS software, the specification of the network interface configuration parameters, loading the TMS software, and, finally, loading third party support software.

CTMS Installation

Insert the TMS Software Installation CD and open the CTMS 2001.503 Install folder. Launch the Setup application. Accept all default entries. (Note: Only CTMS version 2001.503 is currently fully compatible with TMS.)

Network Interface Parameter Settings

The CTMS workstation uses a built-in network interface dedicated to exchanging data during an exercise with the TMS evaluator workstation. As this is a private, dedicated network, the IP address of this network interface should be set as 10.X.X.Z. Correspondingly, the IP Address of the associated network interface on the TMS evaluator workstation will be set as 10.X.X.Z - 1.

CTMS Workstation TMS Software Installation and Setup

The TMS CTMSHost application facilitates the exchange of exercise information between the TMS evaluation and simulation components and CTMS. This section describes the installation and setup required for this application.

- From the TMS Software Installation CD run the CTMS_Host_Setup installation utility.

- Launch Windows Explorer. From the 'Tools' menu select the 'Map Network Drive' item. Set the drive letter to 'Z:'. Enter as the Folder '\\10.X.X.X\TMS_GroundTruth' where '10.X.X.X' is the IP address of the CTMS network interface on the TMS evaluator workstation computer. Check the 'Reconnect at logon' box. Click the 'OK' button.

CTMS Workstation Third Party Support Software Installation and Setup

MS Access 2000 must be loaded on the CTMS Workstation in order to run the CTMS Reports Manager. Follow the installation instructions provided with the Microsoft Access installation CD. Accept all default entries during installation.

Field Instrumentation Unit Software Installation and Setup

Operating System Installation

The FIU is a headless system that does not contain a CD-ROM or diskette drive. There are, however, pinned interfaces that are exposed on the FIU's NetCard II backplane/motherboard that facilitate CD-ROM and diskette drive connectivity (consult the NetCard II System Manual for further information).

Before installing a Windows OS, there are some BIOS parameters that must be configured. They are listed below (the items listed are assuming a PhoenixBIOS 4.0 Release 6.0):

- Main → Boot Feature (optional)

  Item: QuickBoot Mode

  Setting: Enabled

  Description: Enables Quick Boot, which reduces the amount of time that it takes for the processor to boot

- Advanced → PCI Configuration → PCI/PNP ISA IRQ Resource Exclusion

  Items: IRQ 10
IRQ 11

  Settings: Reserved
Reserved

  Description: Reserves IRQs 10 and 11 so that the 4 RS-232 ports needed for the Arc Second PCE cards will have adequate IRQ resource allocation

- Advanced

  Item: Installed O/S

  Setting: Other

  Description: Specifies that installed operating system is not Windows 95 or Windows 98 (Windows XP Professional is installed)

Upon completion of the BIOS configuration, refer to the Windows “Getting Started Manual” for instructions on installing Windows.

Instrumentation Software Installation

From a network connection, run the Instrumentation_Package_Setup installation utility.

Field Instrumentation Network Interface Parameter Settings and Support Software

Refer to Section 4.1.3.1.4.1.

Initiating a Session

An execution session for the FIU is initiated at power-on of the unit. A session on the DataComms/DSP component in the facility configuration is initiated by launching the TMS DataComms application. The user may select to add TMS DataComms to the Startup program group of the Programs item of the Windows Start menu to launch TMS DataComms at power-on. A session on the Evaluator workstation is initiated by launching the TMS Master application, which in turn launches MISP when appropriate. Also, in the single evaluator configuration, TMS Master will launch TMS DataComms. In this configuration, TMS DataComms may be launched individually for communications and entity configuration tasks. A session on the CTMS workstation is initiated by launching the CTMS Host application, which in turn launches CTMS or the CTMS Reports Manager, as appropriate.

Stopping and Suspending Work

The user may terminate a session in TMS DataComms, TMS Master, and CTMS Host at any time using any of the standard Windows methods for normal application shutdown. Each application will display a prompt if it is necessary to save any modifications and as well as that shutdown is the action intended by the user. The FIU should be sent a “Shutdown” command from TMS Master (at the conclusion of an exercise) or TMS DataComms prior to power-down of the system.

Processing Reference Guide

Capabilities

The capabilities of each of the TMS workstation applications are accessed using the standard user interaction techniques of the MS Windows desktop environment.

Conventions

No unique conventions beyond those of the MS Windows environment are included in any TMS software applications.

Processing Procedures

The following sections describe the procedures used for operation of each of the TMS software applications.

TMS DataComms

The TMS DataComms application provides user access to and display of the configuration and status data of the TMS Data Communications/Digital Signal Processing (DataComms/DSP) component. DataComms/DSP combines hardware and software that facilitate the transfer of sensor data, position data, simulation data, and system commands between the TMS evaluation and simulation components and the TMS remote field instrumentation units. DataComms/DSP also provides any intermediate processing of the exchanged data between the sender and the user of the data. In addition, DataComms/DSP generates and stores archive files of the data received from field units during a live exercise and accesses these files during playback exercises configured at the evaluator workstations. DataComms/DSP also receives and processes the data sent by survey equipment in support of ground truth data generation and manual exercise scoring using the TMS Survey operation.

DataComms/DSP exchanges various types and formats of data with the TMS remote field instrumentation units through two types of communication interfaces. The first is a TCP/IP based mechanism over Wireless Ethernet (IEEE 802.11b). The second is a serial interface to RS-232 compliant wireless modem devices. DataComms/DSP also serves as a gateway that allows the TMS evaluation and simulation components to function as a federate in HLA simulations. DataComms/DSP exchanges HLA simulation data over an Ethernet Local Area Network (LAN) interface.

In the distributed (facility) configuration, DataComms/DSP exchanges system data and information with the evaluation and simulation components using two connection methods. System data and operation control information is exchanged through a system-wide RGM component accessible simultaneously by DataComms/DSP and the evaluation and simulation components. These exchanges occur between the system components in real-time as an exercise is configured and executed. In this configuration, RGM is implemented through a hardware RSM network. A LAN interface provides access to files stored on the Mass Storage volume resident on the DataComms/DSP computer to the distributed components. In the mobile, single evaluator configuration, RGM is implemented through software, and all processes share access to the local Mass Storage volume.

Getting Started

The TMS DataComms application ("TMS DataComms") is intended to require little to no user interaction to perform normal operations in support of workstation activities. However, some configuration parameters must be entered and other activities performed before TMS DataComms is prepared to provide data processing and transfers between workstations and field units.

Connections

Before powering on the DataComms/DSP computer, make sure all necessary cables and devices are connected properly. The RSM fiber optic cables of the DataComms/DSP computer and all active workstation computers should be connected in a circular, daisy-chain fashion. The DataComms/DSP computer should be connected from Network Interface 1 using a standard CAT-5 Ethernet cable with RJ-45 connectors at each end to the appropriate HLA LAN interface connection. The computer should be connected from Network Interface 2 to the instrumentation network switch unit using a standard CAT-5 Ethernet cable with RJ-45 connectors at each end. All active evaluator workstations should be similarly connected to the switch unit. An Ethernet cable with RJ-45 connectors at each end should connect the switch to the Wireless Ethernet (IEEE 802.11b) Central Outdoor Router (COR). Each active interface card in the COR should be connected from the card's antenna connection to the antenna splitter. The connectors at each end of the cables for this connection will depend upon the type of each device in use. The antenna splitter is connected to the antenna's coaxial cable. (An optional RF signal amplifier may be inserted at the splitter-antenna cable junction. If present, the amplifier will have an A/C power connection.) Also, any serial devices should be connected to the proper COM port on the computer with the appropriate cabling. All external devices should be powered on before or simultaneously with the computer.

Startup

TMS DataComms may be configured to start-up automatically upon power-up of the DataComms/DSP computer or the user may launch it as a conventional Windows application. Upon start up of TMS DataComms, the configuration data from the last execution session is accessed and used to determine the start up configuration. This information specifies communications interfaces and the field entities associated with the interfaces, if any. The current configuration is displayed in the application's main window, shown in Figure 5-1. After this window opens, the initialization of the current configuration will commence. Also at start-up, when DataComms/DSP is configured to serve as an HLA gateway, TMS DataComms will launch an external software license manager process in a command console window. This process must not be terminated while TMS DataComms is running.

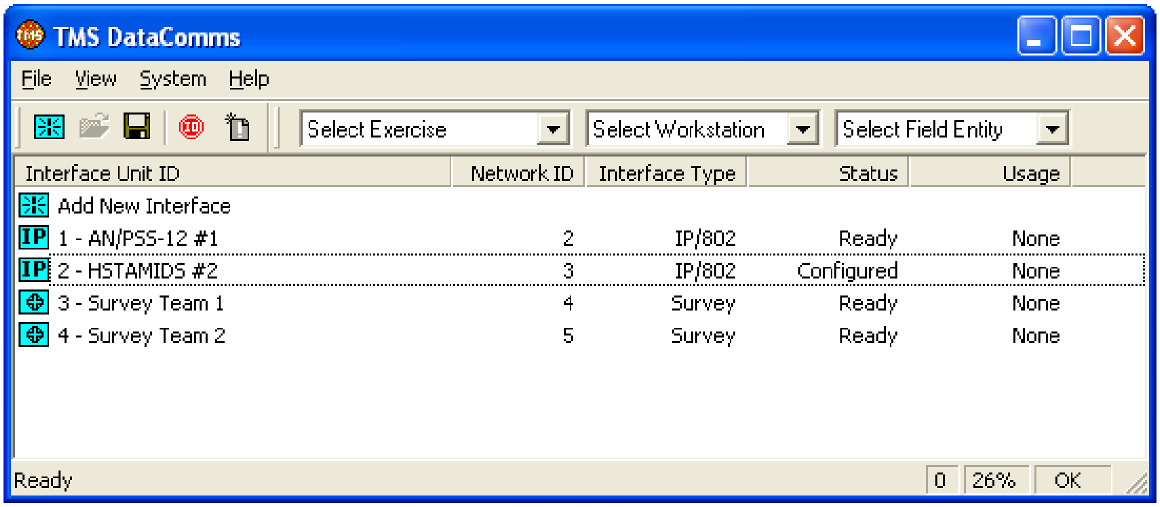


Figure 5-1. TMS DataComms application main window.

The first time TMS DataComms is started after installation, the user will be prompted to identify the default exercise file archive directory and to locate the database file containing the virtual mine model data. The archive directory is the 'Archive_Storage' folder and the database file is in the 'TMS_DB' folder referred to in Section 4.1.3.1.2.1. This information is recorded and used during future execution sessions. (Note: even when installed as part of the single evaluator configuration, TMS DataComms should be launched directly to perform this configuration step.)

Initialization

After all the start up configuration data is obtained, TMS DataComms will commence the initialization of the configured communications interfaces. This process involves allocating the required local system resources for each interface and initiating the processing for each interface. No communication with the remote instrumentation unit associated with an interface is attempted or required as part of the initialization process. When an interface initializes successfully, its status is set to either Ready or Configured, depending upon the type of interface (see Interface Activity.) The initialization of a communications interface may fail if any of the required system resources cannot be allocated to the interface. When an interface initializes unsuccessfully, its status is set to Failed. No user action is required to start the initialization process nor can the user pause or terminate initialization. Figure 5-2 shows an interface with a status of Failed.

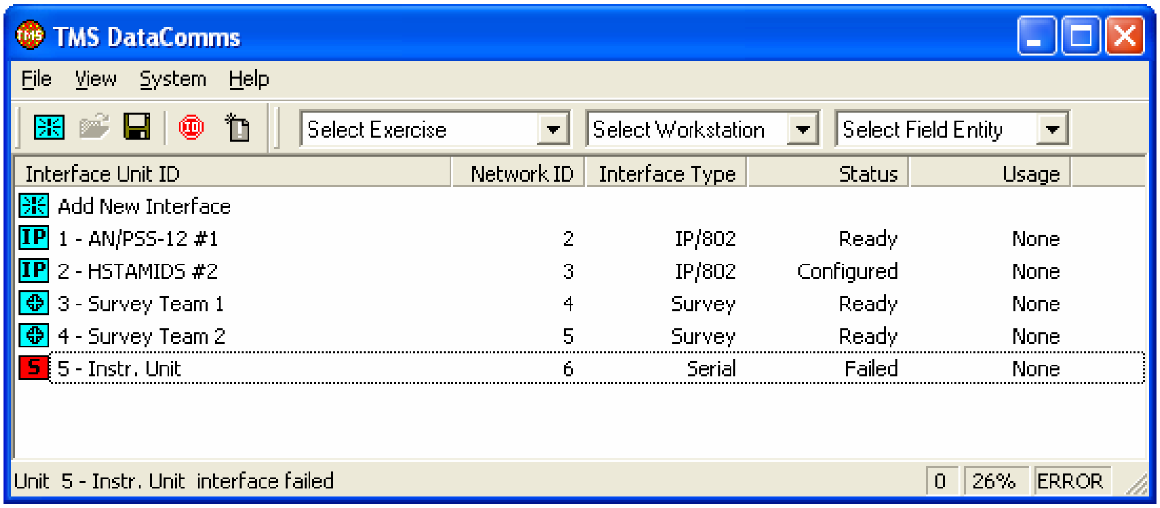


Figure 5-2. Example of a Failed Interface

Once the initialization of all of the configured communications interfaces has completed, TMS DataComms will attempt to attach to the RGM implemented through the RSM network. If successful, TMS DataComms will post to RGM its own status and that of all configured interfaces for access by the distributed TMS components. The final initialization status information for all configured elements is displayed in the appropriate locations of the main window. Any problems that occur during the initialization process are noted in the System Event Log. The System Event Log is accessible using the 'Show Event Log' item of the 'System' menu. Figure 5-3 shows the System Event log window.

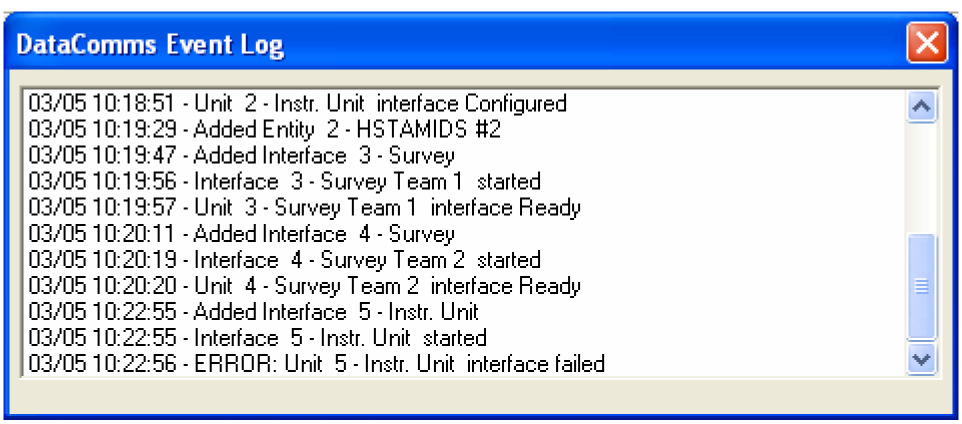


Figure 5-3. TMS DataComms System Event Log window

Interface Configuration

An interface represents a communications channel between DataComms/DSP and another TMS component. An interface to an instrumentation unit may be created or deleted by the user. When this type of interface, referred to as an instrumentation unit interface, is added, the user must provide a set of configuration parameters. Once the interface is created, the configuration data may not be modified. If any instrumentation unit interfaces are added or deleted by the user during an execution session, TMS DataComms will prompt the user to save the configuration data for the next execution session. Another type of interface is created automatically when a workstation is detected as online through RGM. This interface is referred to as a "playback" interface. It is the mechanism by which DataComms/DSP provides data through RGM from an exercise archive file during exercise playback at a workstation. The user cannot delete or provide any configuration parameters for a playback interface. In addition, a playback interface does not automatically persist across execution sessions. Figure 5-4 shows a playback interface corresponding to an online workstation. When DataComms/DSP is configured to serve as an HLA simulation gateway for an evaluation/simulation component functioning as a simulation federate, the corresponding playback interface for that workstation will be reconfigured automatically as an HLA interface to process HLA simulation data between the workstation and the simulation federation.

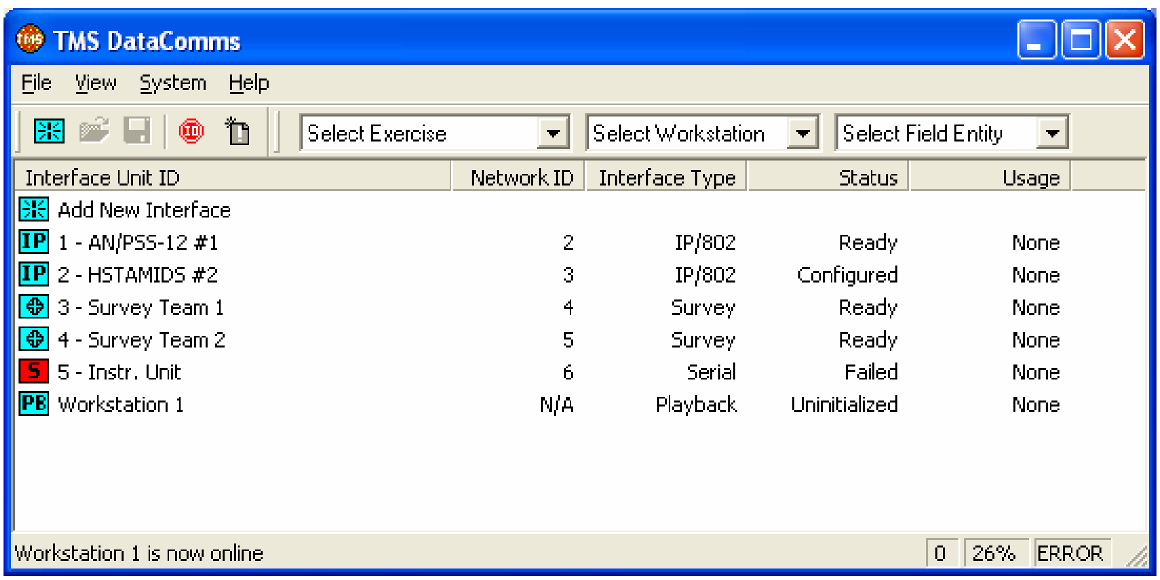


Figure 5-4. Example of a Playback Interface

Instrumentation Interface Parameters

When the user creates an interface to an instrumentation unit, the type of interface and an associated set of parameters must be specified. The types of instrumentation interfaces correspond to the types of communications devices used to facilitate the connection between DataComms/DSP and the instrumentation unit. The interface types are: IP/802 for TCP/IP over Ethernet (wired or wireless); Serial for binary data transfers over RS-232 compliant devices; P1 Serial for data transfers over RS-232 compliant devices using the ASCII-text format devised for TMS Phase 1; and Survey for transfers of ASCII-text data from survey equipment over RS-232 compliant devices. Two configuration parameters are common to all instrumentation interface types. The first is the Unit ID. This value identifies the instrumentation unit with which the interface links DataComms/DSP. The second is the Network ID. This value represents an "address" used by DataComms/DSP for transfers across the interface. Each of these values must be unique to a single interface. Figure 5-5 shows the Add New Interface dialog in which the user enters the required configuration parameters. The parameters specific to the type of interface are listed in the following sections. The configuration parameters required for each of the serial (RS-232) interface types are the same.

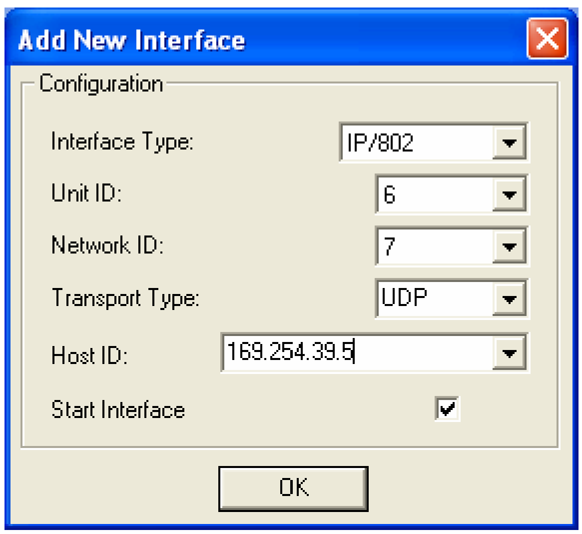


Figure 5-5. Add New Interface dialog

IP/802 Interface Parameters

The configuration parameters specific to IP/802 instrumentation interfaces are the Host ID and the Transport Type. The Host ID can be either the IP (Internet Protocol) address or the host name assigned to the instrumentation unit. The IP address should be used if it is known. The transport type can be one of UDP (User Datagram Protocol) or TCP (Transmission Control Protocol.) UDP should be selected as the default.

Serial Interface Parameters

The configuration parameters specific to serial instrumentation interfaces are the COM Port ID and the Baud Rate. The COM Port ID specifies which of the COM ports installed in the computer is to be physically connected to the communications device associated with the interface. For the interface to initialize successfully, the COM port must exist and be functional. The Baud Rate selection must match the configuration of the device connected to the COM port for communications to occur.

Creating an Instrumentation Interface

The user may create a new instrumentation interface using either the ‘New Interface’ item of the ‘File’ menu, the ‘New’ toolbar button, or by double clicking the ‘Add Interface’ item of the main window's list. Each of these methods will open the Add New Interface dialog, shown in Figure 5-5, in which the appropriate configuration parameters described previously may be entered. The user may also choose to immediately start the new interface by selecting the ‘Start Interface’ check box on this dialog.

Interface Activity

Interface activity includes any type of communications over an interface between DataComms/DSP and the associated system component. Before data transfer activity can occur over certain types of instrumentation unit interfaces, however, DataComms/DSP must first detect the presence of the instrumentation unit. This occurs when the instrumentation unit responds to a "ping" message sent automatically by DataComms/DSP. Prior to receipt of the ping response, the corresponding instrumentation unit interface is assigned a status of Configured. Upon the receipt of the ping response, the interface status will be set to Ready. When activity is detected on an interface with a status of Ready, the status of the interface is set as Active. An interface to an instrumentation unit need not be assigned to an exercise for activity to occur. Activity over a playback interface occurs only during the execution of a playback exercise. If the activity ceases, the status of the interface is set as Ready. After a period of inactivity, the status of an instrumentation unit interface initialized with a status of Ready will be set back to Configured, and DataComms/DSP will resume sending the ping message to the instrumentation unit.

Information on current interface activity and status is available to the user in the Interface Status dialog, shown in Figure 5-6. The user may view this dialog by selecting an interface in the list of the main window and then either selecting the ‘Open Interface’ item of the ‘File’ menu or clicking the ‘Open’ toolbar button, or by double clicking the interface list item. If the interface was not started previously, a ‘Start’ button will appear on this dialog to allow the user to start the interface. The status of the interface will be set to Starting at that time. The user may also terminate current and future instrumentation interface (but not playback interface) activity by either clicking the ‘Stop’ button on the Interface Status window or selecting the interface in the main window's list then clicking the ‘Stop Interfaces’ toolbar button. Upon the user performing either of these actions, the interface status is set to Terminated. The user may not terminate an interface that is assigned to a live exercise configured at a workstation.

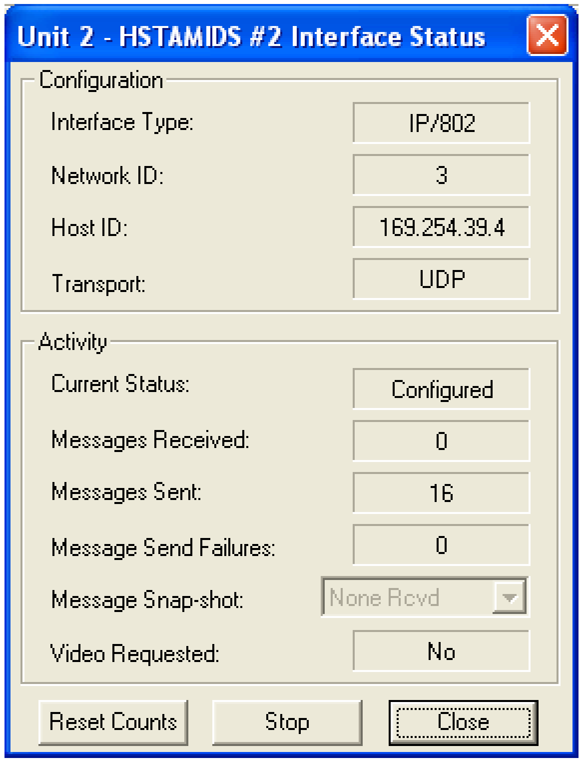


Figure 5-6. Interface Status dialog

Deleting an Instrumentation Interface

The user may delete an instrumentation interface with a status of either Terminated or Failed. To delete an interface, the user may either click the 'Delete' button on the Interface Status dialog (the 'Stop' button is replaced by the 'Delete' button for an interface with a status of Terminated or Failed) or select the interface in the main window list then select the 'Delete Interface' item of the 'File' menu.

Field Entities and Instrumentation Units

DataComms/DSP uses instrumentation interfaces to communicate with instrumentation units associated with field entities.

Field Entities

A field entity is an object that is tracked during a TMS exercise. This includes a platform that carries a detector system, such as an operator carrying a hand-held detector or a vehicle carrying a detector array; and any supporting platform(s), such as a control vehicle for a remotely operated detector vehicle, or a team member accompanying a hand-held system operator. An entity may have some number of distinct components that are individually tracked, such as the operator's feet and the detector head of a hand-held system. Associated with an entity is a set of characteristic information, including physical properties such as dimensions and weight, and the type of data collected from the entity during an exercise.

Instrumentation Units

An instrumentation unit is a TMS component attached to a field entity to collect sensor data from external sensors on the field entity and pass the data over a communications interface to DataComms/DSP. For live exercises involving one or more real field entities, the communications interface will typically be implemented using some type of wireless communications medium, such as Wireless Ethernet or wireless modems. The Test ID value associated with the configuration data for an interface specifies the particular instrumentation unit corresponding to the interface. When an interface is initially created, it is identified as linking DataComms/DSP to an instrumentation unit using the Test ID.

Assigning Interfaces to Entities

The user must identify the type of entity to which an interface (and its associated instrumentation unit) links DataComms/DSP. The user selects the 'Add Field Entity' item of the 'Field Entity' pop-up list in the toolbar area of the TMS DataComms main window. This opens the Add Entity Data dialog, shown in Figure 5-7. This dialog contains a pop-up list of all instrumentation interfaces that are not currently assigned to entities, and another pop-up list that contains a fixed set of entity types. The user selects from these lists an interface/instrumentation unit ID and an entity type, and then clicks the 'OK' button. The Interface Unit ID for the interface is then updated to indicate the specific entity assignment. An entity must be assigned to an interface at DataComms/DSP before it can be selected at a workstation for inclusion in a live exercise. The user may also use the Field Entity pop-up list in the toolbar area of the TMS DataComms main window to delete a current entity assignment. To do this, the user selects the desired entity from the Field Entity pop-up list, and then clicks the 'Delete' button on the resulting View Entity Data dialog. Entities that are currently assigned to a live exercise cannot be deleted. In addition, if an instrumentation interface associated with an entity is deleted, the Field Entity list entry is also deleted.

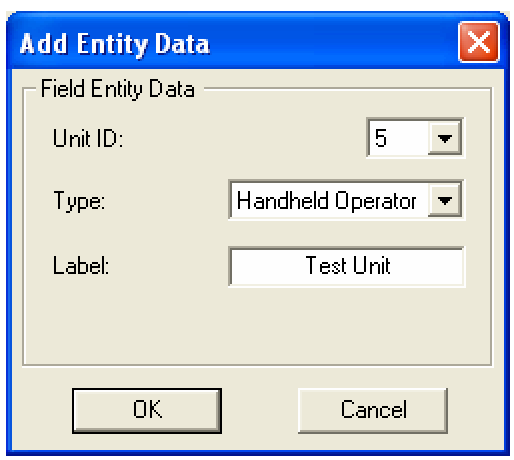


Figure 5-7. Add Entity Data dialog

Sending Commands to Instrumentation Units

The user may send Command messages to instrumentation units for a variety of purposes. Care should be taken in sending commands to an instrumentation unit, as some commands may shutdown or restart the instrumentation unit. Under normal circumstances, commands to instrumentation units assigned to an exercise should not be sent from DataComms/DSP. The user clicks on the 'Send Command' button of the toolbar to open the Send Command Message dialog, shown in Figure 5-8. The user then selects the instrumentation unit and command type using pop-up lists on this dialog. The command is sent when the user clicks the 'Send' button. The instrumentation unit sends a command acknowledgement if it successfully receives the command. TMS DataComms will indicate command send failure after an appropriate period if no acknowledgement is received.

Figure 5-8. Send Command Message dialog

Workstations and Exercises

DataComms/DSP sends data received over instrumentation interfaces from instrumentation units to workstations running exercises. It uses the same interfaces to send simulation and command data from workstations to instrumentation units.

Workstations

A workstation is a computer functioning as a distributed client of DataComms/DSP that hosts the TMS exercise control, evaluation and simulation components. DataComms/DSP provides to a workstation through RGM the processed data resulting from DSP applied to raw data received from field entities through instrumentation interfaces. DataComms/DSP also sends to an instrumentation unit simulation data accessed through RGM that was generated at a workstation. A workstation provides an indication of its presence to DataComms/DSP through RGM. The DataComms/DSP user may view the status information for any online workstation by selecting the corresponding entry from the Workstation pop-up list in the toolbar area of the TMS DataComms main window. This will display the Workstation status dialog, shown in Figure 5-9. When TMS DataComms first detects that a workstation is online, it will create a playback interface for the workstation. Upon creation, the status of a playback interface is set to Uninitialized. If a playback exercise is configured at the workstation, the playback interface status is set to Ready. While the playback exercise is in progress, the status is Active. If the workstation goes offline, the playback interface status is set to Terminated. If the workstation comes back online, the status is again set to Uninitialized. When a workstation is configured to participate in an HLA simulation, the corresponding playback interface is reconfigured as an HLA interface.

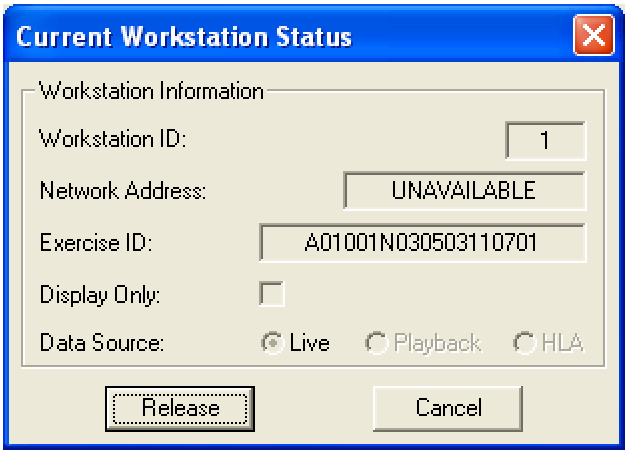


Figure 5-9. Workstation Status dialog

Exercises

The data transferred over the communications interfaces associated with one or more instrumentation units is ultimately processed within the context of an exercise. The exercise defines the entities of interest as well as the ground truth data (the geographical area of the exercise, the boundaries of the test lane, and the types and locations of mines (real or virtual) and other physical objects within that test lane,) the name of an archive file, if any, and a set of performance baseline data against which the performance of the entities under test will be evaluated. Exercises are configured and controlled at workstations running the TMS exercise control, evaluation and simulation components.

The raw data for an exercise can be generated live by field entities or extracted from an archive file from a previous live exercise during playback mode. In either case, TMS DataComms processes the raw instrumentation data in real-time and posts the processed data to RGM for access by the TMS exercise control, evaluation, and simulation components on a workstation. In turn, the TMS simulation component may generate data that is posted to RGM and, in the case of a live exercise, passed by DataComms/DSP to the appropriate instrumentation unit through an instrumentation interface. Once a workstation has defined an exercise, the exercise configuration and status data is available through RGM and may be viewed by the user of DataComms/DSP. The user may view the exercise configuration data using the Exercise Configuration Data dialog, shown in Figure 5-10. This dialog may be accessed by selecting an entry for an exercise from the Exercise pop-up list in the toolbar area of the TMS DataComms main window. The status of a configured exercise is indicated as part of the information displayed with each interface assigned to the exercise in the TMS DataComms main window list.

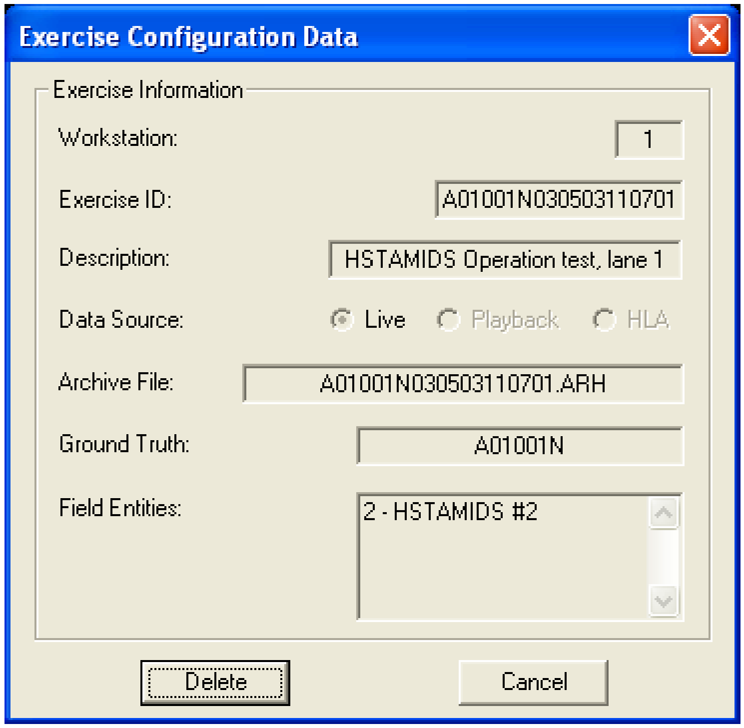


Figure 5-10. Exercise Configuration dialog

Displaying DataComms/DSP System Information

Various displays containing configuration and status information about DataComms/DSP are accessible using the System menu. These displays include the System Configuration display, the System Event Log, the Available Ground Truth Data display, and the Check Access Point utility display. In addition, panes in the status bar at the bottom of the main display continuously indicate several status values of interest. Each of these methods of displaying system information is described in the following sections.

System Configuration

The System Configuration display, shown in Figure 5-11, provides the user with information on configuration and status of a number of items. This display is accessed using the 'Show Configuration' item of the 'System' menu.

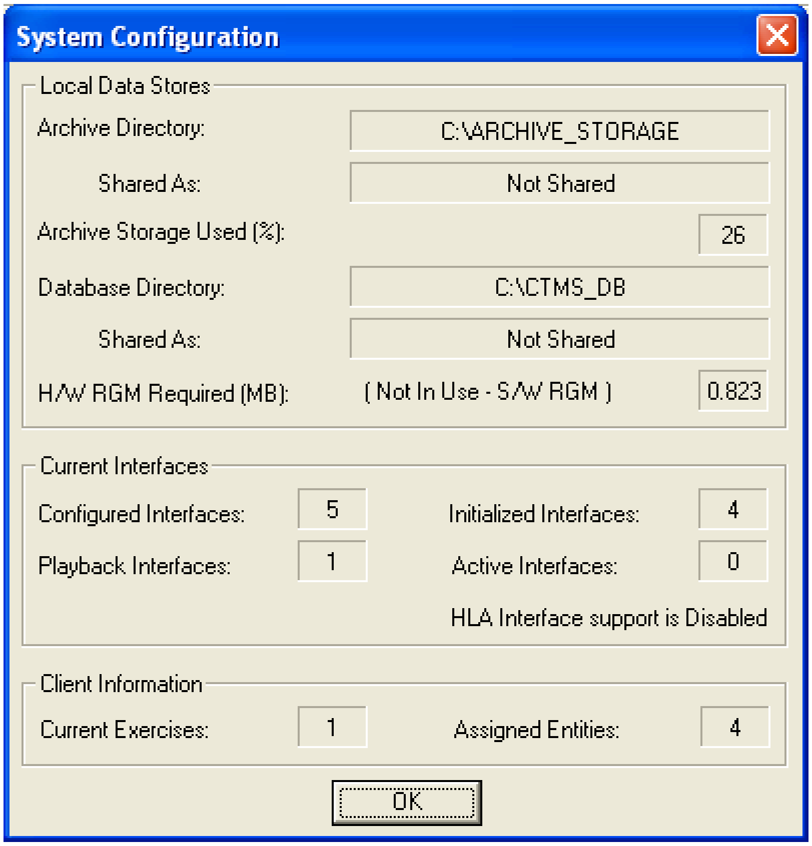


Figure 5-11. System Configuration display

System Event Log

The System Event Log, shown previously in Figure 5-3, provides the user with a running list of indications and descriptions of events of interest as they occur during a TMS DataComms execution session. The Event Log display is accessed using the Show Event Log of the System menu. This display maintains a list of the most recent system events. This display may remain open at any time during an execution session. System events that indicate operational errors will be tagged with "ERROR" and the system status pane of the status bar will also indicate ERROR. The status pane will be reset to OK after the user displays the Event Log to observe the error explanation.

Available Ground Truth Data

The Available Ground Truth Data display provides a list of the ground truth data files stored locally on the Mass Storage (archive) volume on the DataComms/DSP computer. By default, this is the set of ground truth data with which a user of an evaluation workstation will define an exercise. If the TMS DataComms user selects a file from this list, the Ground Truth Data display, shown in Figure 5-12, will open containing a list of the mines, landmarks and lane boundary markers composing the ground truth data. The ground truth data display is accessed using the 'Available Ground Truth Data' item of the 'System' menu.

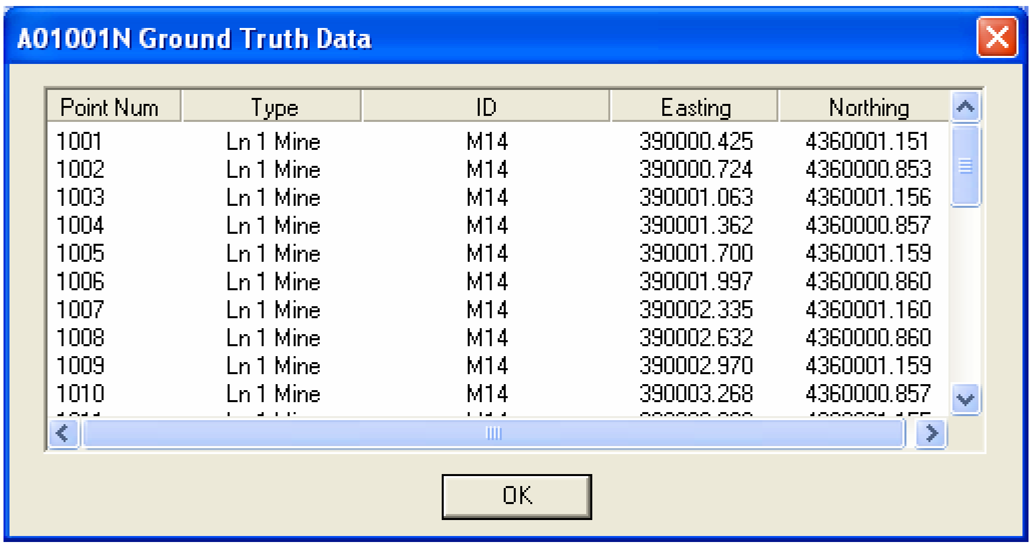


Figure 5-12. Ground Truth Data display

Check Access Point Utility

The Check Access Point utility is accessed using the 'Check Access Point…' item of the 'System' menu. This utility provides a means of checking on the operational status of a Wireless Ethernet (IEEE 802.11b) access point. An access point is basically a gateway onto the wireless network for a device with a standard Ethernet (IEEE 802.3) port. A Central Outdoor Router (COR) is a type of access point. Selecting the menu item will open the Check Access Point dialog, shown in Figure 5-13. This dialog contains a pop-up list of previously registered access point IP addresses, text fields for entering a new IP address, and buttons for adding a new address, deleting a previously registered address, and checking the status of an access point associated with an address. If the access point is powered on and connected to one of the Ethernet ports of the DataComms/DSP computer, it will send a reply to the check operation. If it is either off or disconnected, no reply will be received.

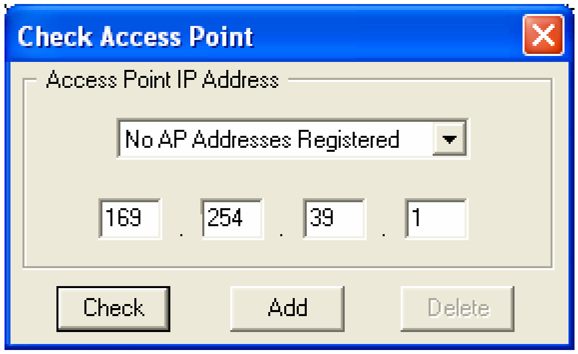


Figure 5-13. Check Access Point dialog

Status Bar Panes

The status bar panes at the lower right of the main window continuously indicate values for various system status items. The leftmost pane indicates the number of communications interfaces that are currently active (sending or receiving data.) The center pane indicates the percentage of space used on the Mass Storage (archive) volume. The rightmost pane displays "ERROR" if an operational error occurs of which the user should be made aware; nominally this pane displays "OK." Additional information on system operational errors appears in the system Event Log. Once the user views the Event Log, the contents of the system status pane will revert to "OK."

Exiting TMS DataComms

To exit TMS DataComms, the user may select any of the standard Windows application exit methods, including the 'Exit' item of the File menu and the Close box of the main window. Exiting TMS DataComms will also terminate all DataComms/DSP activity and clear all data in RGM posted by DataComms/DSP. After selecting an exit method, the user is alerted if there is any interface activity or if any exercises are currently configured at any workstations. If so, the user may elect to cancel the exit process. Also, the user is prompted to save any modifications made to the current interface and/or entity configurations. During the TMS DataComms exit processing, all workstations attached to RGM are notified that DataComms/DSP is unavailable, meaning no live exercises may be configured or executed. Upon exiting TMS DataComms, the DataComms/DSP computer may be shut down.

TMS Master

The TMS Master application is the evaluator's interface to the Threat Minefield System. The Master is a conventional Microsoft Windows application that provides the mechanism for configuring a TMS operation and displaying the data specific to each operation. The TMS operations are Exercise, Playback, Survey and HLA. The Master also controls the execution of MISP and communicates with the external CTMS workstation.

Startup

At startup, the Master checks for an executing instance of TMS DataComms thru RGM. If TMS DataComms is not detected, a dialog is launched that allows the evaluator to make a selection to wait for TMS DataComms, abort or startup in a standalone-processing configuration. Optionally, when installed as part of the single evaluator configuration, the user will be prompted to start up Master in Single Evaluator mode and can set this mode as the default for subsequent start-ups. In this mode, Master will launch TMS DataComms on the evaluator workstation if it is not currently executing.

The application main window, shown in Figure 5-14, is displayed after the Master is started. The value displayed in the right-most pane of the status bar is the percentage of used disk space on the system mass storage device. The fourth pane defines the system's operating configuration.

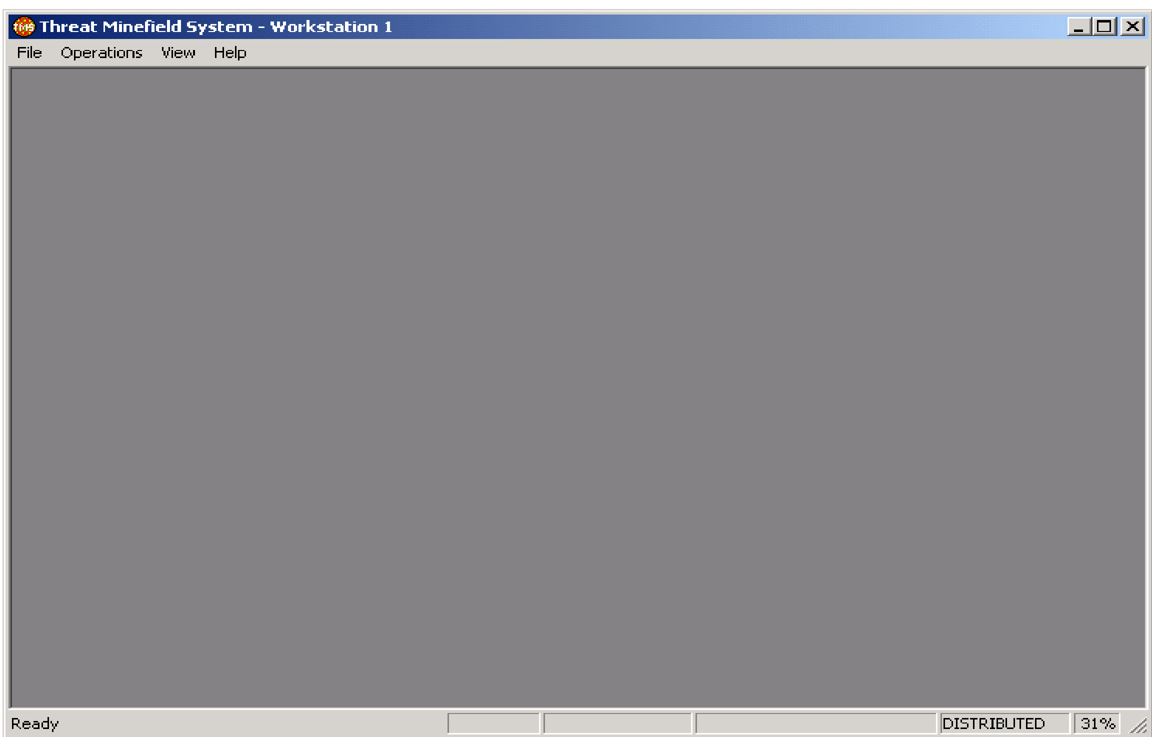


Figure 5-14. TMS Master application main window

Figure 5-15 shows the Master's menus at startup. The 'Exit' menu terminates the Master and, if appropriate, MISP, and sends an exit message to the CTMSHost application executing on the external CTMS workstation. The 'Operations' menu allows the evaluator to select the mode of operation and the 'TMS Master System Log' menu item on the 'View' menu opens a modeless dialog containing system event and error messages encountered by the Master.

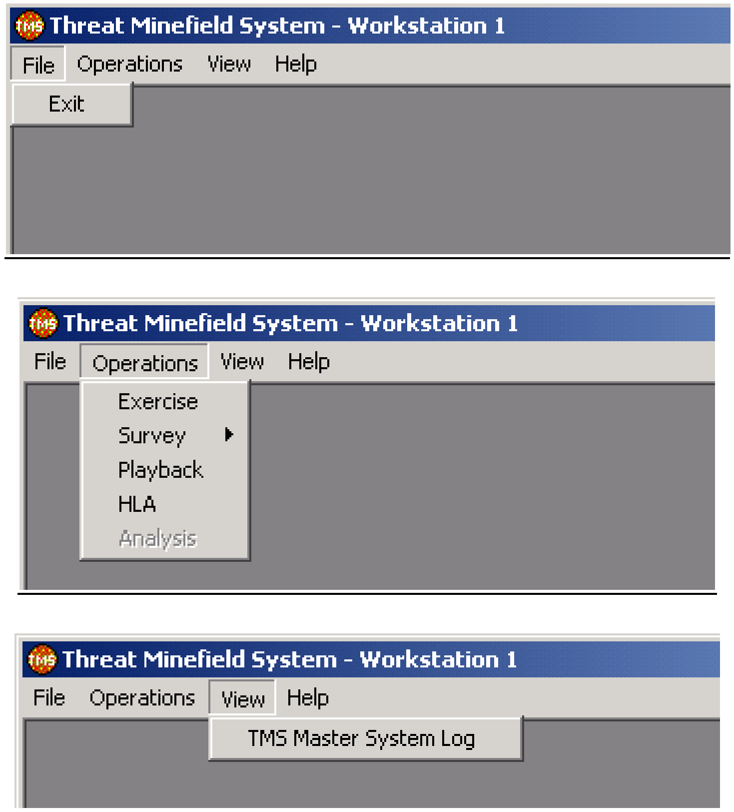


Figure 5-15. TMS Master Startup menus

Operations

The TMS Master application currently supports four system operations: Exercise, Survey, Playback and HLA simulation. The following sections provide overviews of the user interactions in each of these operations.

Exercise

To initiate an exercise, select the 'Exercise' item on the 'Operations' menu. This selection invokes the 'Exercise Setup' dialog shown in Figure 5-16. The setup dialog consists of 2 tabular dialogs, General and Entities.

The 'Display' section of the 'General' tab allows the evaluator to select the application(s) that will graphically display the exercise's position and ground truth data. TMS and CTMS are the system defaults, but a single application can be chosen. If both applications are selected, the 'Start', 'Pause' and 'Stop' actions can be manipulated from either application to control the exercise. If TMS is not selected, TMS Master displays the selected exercise ground truth data, but does not display received position data updates.

To archive an exercise, check the 'Archive Exercise' box. When an exercise is archived, all instrumentation data received while the exercise is running is written to a file in the workstation's archive directory. The exercise filename is the name of the exercise with the extension ".ARH." The exercise name is created using the fields in the 'Exercise ID' section of the ‘General’ tab. Using the pull-down lists under each field header, the exercise name can be changed.

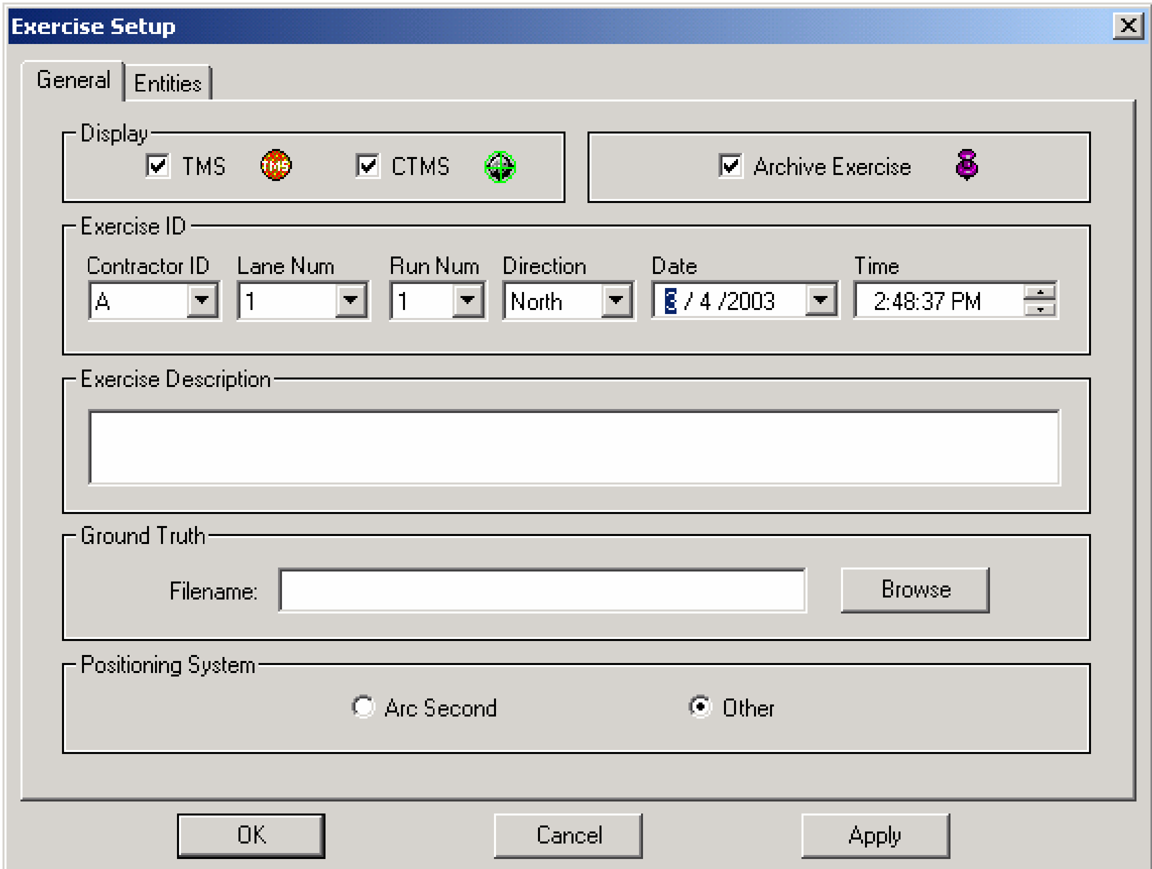


Figure 5-16. Exercise Setup dialog

‘Exercise Description’ is a section provided for entering a description or comment pertaining to an exercise. If the exercise is archived, the exercise description is written to the header of the exercise file.

In the ‘Ground Truth’ section of the ‘General’ tab, a ground truth file must be entered. The ground truth file can be entered by typing in a filename (including the path) at the ‘Filename’ prompt, or by selecting the ‘Browse’ button. The ‘Browse’ button launches a file dialog. The ground truth file must be in WILD format.

The ‘Positioning System’ section of the ‘General’ tab provides the ability to configure the potential positioning systems used in TMS. If ‘Arc Second’ is selected, the Master searches in the workstation’s archive directory for a “.REF” file with the same name as the ground truth file. If the “.REF” file is not found, a dialog is launched prompting the evaluator to input the Arc Second Universal Transverse Mercator (UTM) reference coordinates. A “.REF” file (with the same name as the ground truth file) is created in the workstation’s archive directory containing the reference coordinates. These values are used during the exercise to translate the relative Arc Second position data to absolute UTM positions. The default positioning system, ‘Other’, does not perform any translation processing.

The 'Entities' tab shown in Figure 5-17 lists the available field entities through which exercise data can be received. Available entities correspond to communications interfaces configured and set-up by TMS DataComms. An exercise may have multiple entities selected. The primary entity is the entity that is used in the coverage analysis and sensor data display of the Master, and displayed on the CTMS workstation. By default, if there is only 1 selected entity, the primary entity is the selected entity. However, if there is more than 1 selected entity, the evaluator must select the primary entity by double-clicking on the desired entity in the 'Selected Entities' list.

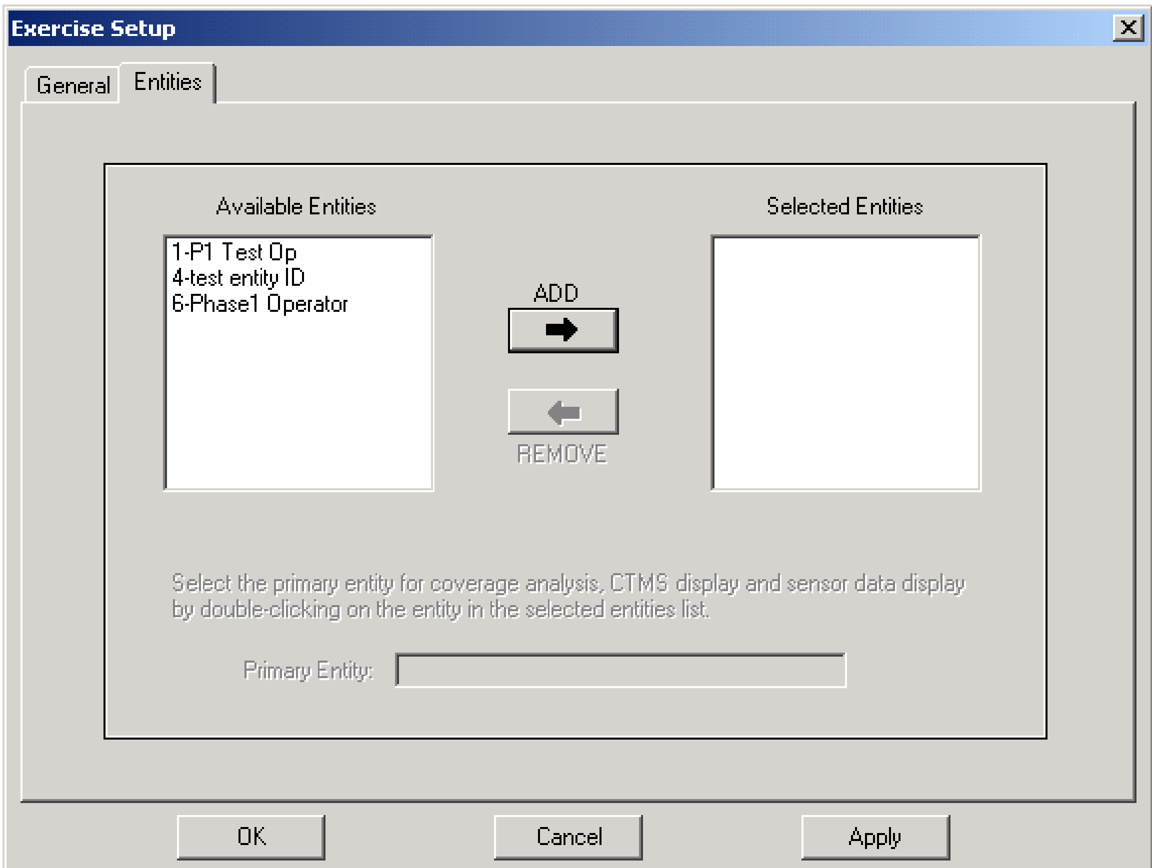


Figure 5-17. Entities tab

After all required parameters have been entered and the 'OK' button has been clicked, the Master changes its display, menus, toolbar and status bar as shown in Figure 5-18. The first pane on the status bar displays the operation type. The second pane displays the ground truth filename and the third pane is the exercise name. The icons on the grid display depict the objects in the ground truth file.

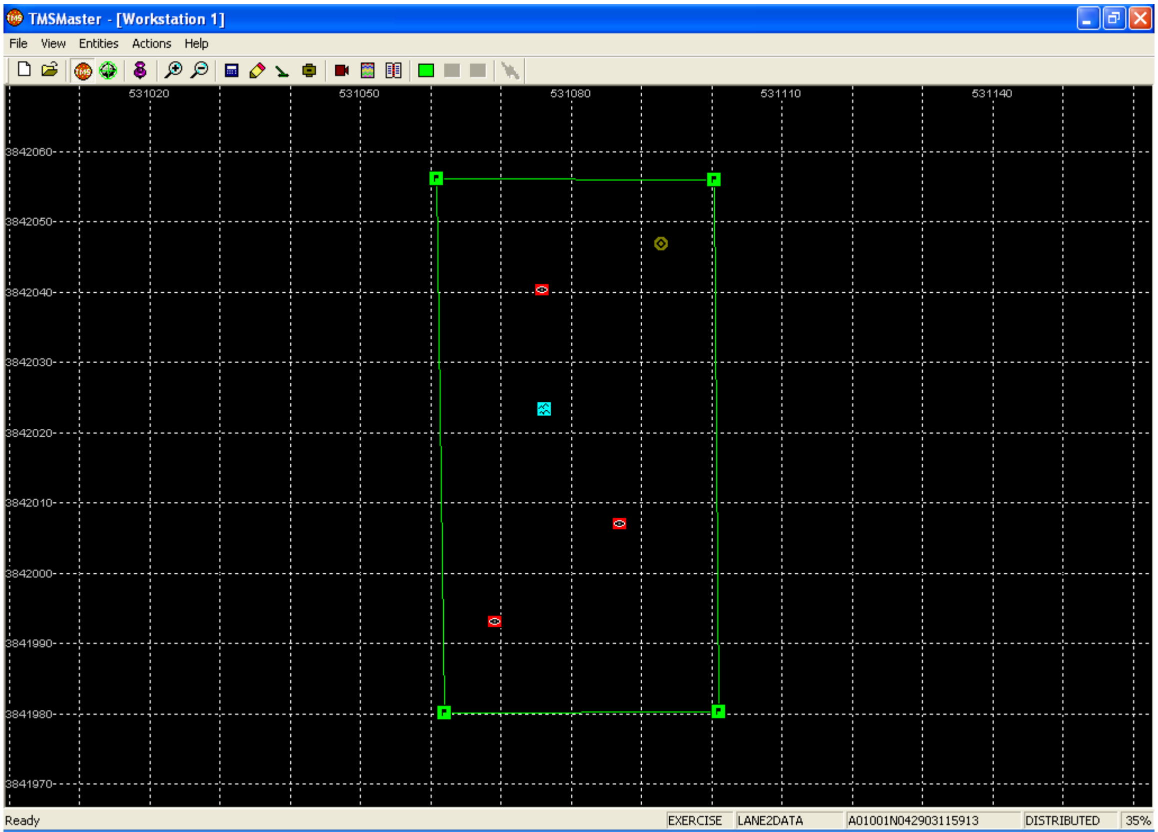


Figure 5-18. Exercise operation

If CTMS is chosen as a display application, an exercise cannot begin until the ground truth file has been loaded in CTMS on the CTMS workstation. On the status bar of the Master and the CTMSHost application, a flashing message alerts the evaluator to load the ground truth file. Refer to Section 5.3.4.2.1 for instructions on loading a ground truth file in CTMS. After the ground truth file is loaded in CTMS, the 'Start' button and the 'Start' item on the 'Actions' menu are enabled.

Before an exercise can begin, it must also be determined that the selected field entities are configured and ready. After the exercise is configured, if the selected entities are not ready, DataComms sends a message to the Master. When the entities become ready, the 'Start' button turns green and the 'Start' item on the 'Actions' menu becomes enabled.

When the 'Start' button turns green, the system enters calibration mode; real-time position data is plotted for the platform and sensor. The calibration mode is used to prove that the positioning system is calibrated with respect to the selected ground truth. The operator can arbitrarily place a position sensor at any point relative to the lane and the evaluator's display should correctly indicate the relative position of the position sensor and the ground truth object. In calibration mode, no analysis is performed.

Exercise Functions

The following sections describe the application controls and options provided during an exercise operation.

New Exercise

To configure a new exercise, select the 'New Exercise' item on the 'File' menu or click the toolbar button shown in Figure 5-19. This selection displays the tabular 'Exercise Setup' dialog shown in Figure 5-3.

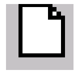


Figure 5-19. New Exercise toolbar button

Open Ground Truth

Before an exercise begins, the ground truth file can be reselected. To select a new ground truth file, select the 'Open Ground Truth' item on the 'File' menu or click the toolbar button shown in Figure 5-20. The 'Open Ground Truth' item launches a file dialog.

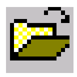


Figure 5-20. Open Ground Truth toolbar button

Application Display

Before an exercise begins, the selected application display(s) can be modified. The TMS display and the CTMS display toolbar buttons are shown in Figure 5-21. When an application display is selected, its button appears depressed.

Figure 5-21. TMS and CTMS toolbar buttons

Archive

The 'Archive' toolbar button shown in Figure 5-22 is a toggle button. The button appears depressed when archiving is turned on. To turn on archiving, invoke the exercise name dialog shown in Figure 5-23, by selecting the 'Archive' toolbar button. Use the default exercise name or modify it using the pull-down lists under each field header and click 'OK'.

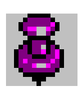


Figure 5-22. Archive toolbar button

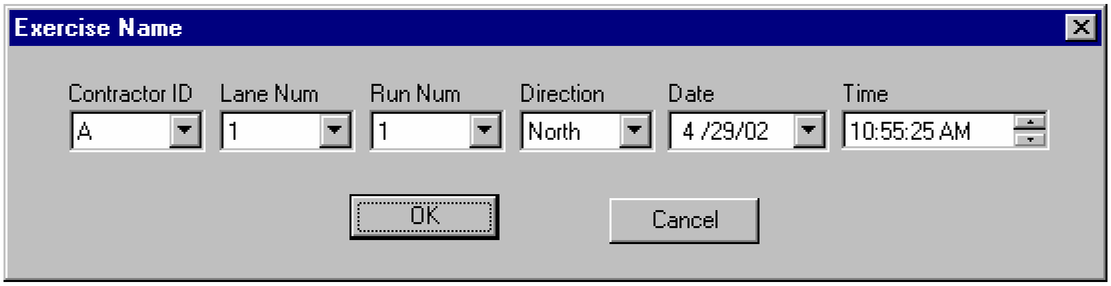


Figure 5-23. Exercise Name dialog

View

The dimensions represented by the grid display can be increased and decreased using the zoom out and zoom in operations, respectively. Zooming operations maintain the current center point of the grid display. The zoom operations can be invoked in two ways. The toolbar contains two toolbar buttons, shown in Figure 5-24; one for zoom out and one for zoom in. Clicking one of these buttons changes the grid display by one zoom increment. The 'View' menu also contains 'Zoom In' and 'Zoom Out' submenus. Each of these submenus contains options for zooming by one or multiple increments.

Figure 5-24. Zoom Out/Zoom In toolbar buttons

Coverage Display

The 'Coverage Display' toolbar button, shown in Figure 5-25, and the 'Coverage Display' item on the 'View' menu launches a modeless dialog of checkboxes that toggle the display of areas covered too fast, too slow and areas covered okay. Each coverage item is displayed on the grid display using different colors and different fill patterns.

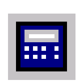


Figure 5-25. Coverage Display toolbar button

Display Options

The 'Display Options' toolbar button, shown in Figure 5-26, and the 'Display Options' item on the 'View' menu launches a modeless dialog of checkboxes that toggle the display of grid lines, lane boundaries, landmarks and alarms. By default, each of the objects is displayed.

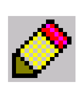


Figure 5-26. Display Options toolbar button

Handheld Parameters

To set the parameters specific to a handheld system, select the ‘Handheld Parms’ item on the ‘View’ menu or select the toolbar button shown in Figure 5-27. The detector’s radius, minimum speed and maximum speed values can be modified. The speed parameters are used in depicting areas covered by the detector within the Coverage Display option.

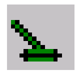


Figure 5-27. Handheld Parameters toolbar button

Ground Vehicle Parameters

Specific ground vehicle parameters will be added when operational requirements are sufficiently defined.

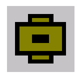


Figure 5-28. Ground Vehicle Parameters toolbar button

Video

To begin processing video from the primary entity during a live exercise, select the ‘Video’ item on the ‘View’ menu or select the toolbar button shown in Figure 5-29. This action creates a video session and sends a command to the instrumentation unit of the primary entity to send video. The video session will be waiting until the instrumentation unit processes the command and begins sending the video. The video session window is displayed in Figure 5-X. If a system alert indicating that the Video On command was not sent successfully appears, reselect the Video item on the View menu or the toolbar button to send the command again. An active video session can exist across multiple consecutive exercises with the same primary entity. If the video is to be recorded, launch TechSmith SnagIt. When the exercise is started, the SnagIt video capture processing will commence. To terminate video, close the video session window. When the exercise is stopped or the video is terminated during the exercise, the SnagIt video capture will also terminate. Note: when prompted for a name for the video file produced by the SnagIt capture process, pressing the Ctrl-V key combination will paste the current exercise name into the file name text field on the Save As file dialog.

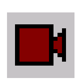


Figure 5-29. Video toolbar button

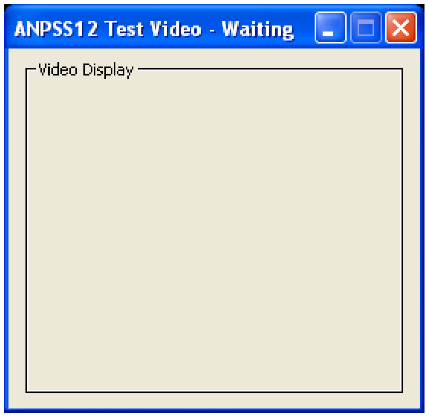


Figure 5-30. Video session window

Detector Data

To display the incoming metal detector data, select the ‘Incoming Metal Detector Data’ item on the ‘View’ menu or select the toolbar button shown in Figure 5-31. When this selection is made, the modeless dialog shown in Figure 5-32 is launched displaying the detector channel data in strip charts. The maximum number and scaling of the displayed channels are specific to the type of detector used in the exercise. To modify a strip chart’s parameters, double-click on the strip chart. The modifiable parameters are line width, line color, grid color, background color, minimum Y-axis and maximum Y-axis. Any displayed strip chart can be disabled independently of all others. Disabling a strip chart freezes the chart with the currently displayed data and does not update the display with subsequent data. A strip chart is disabled by placing the cursor on the strip chart and typing ‘d’ and is enabled by typing ‘e’. The display of all channels can be paused by selecting the ‘Pause’ button on the dialog. A strip chart can be removed from the display by de-selecting the corresponding check box at the top of the dialog. The display status and scale values for each channel of each supported type of detector are retained for subsequent exercises and execution sessions.

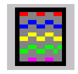


Figure 5-31. Metal Detector Data toolbar button

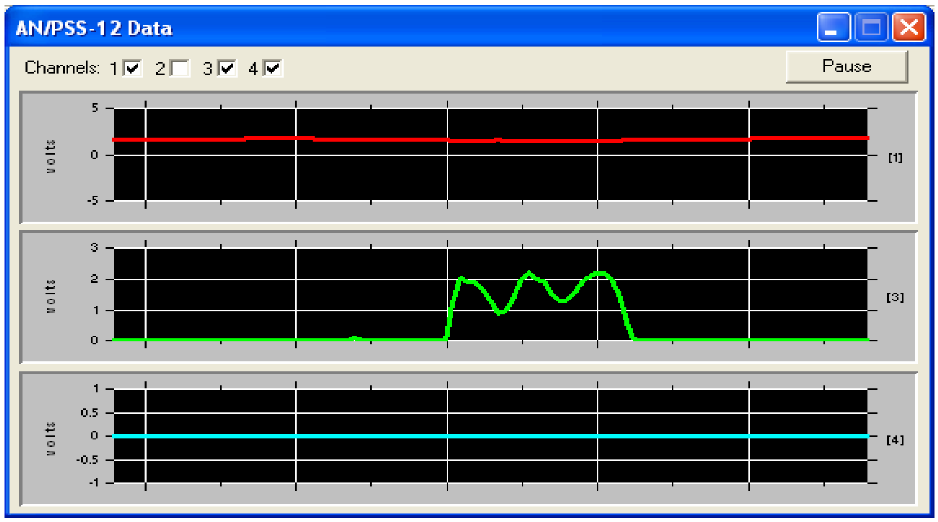


Figure 5-32. Metal Detector Data Strip Chart dialog

System Events Log

To display the system events log, select the 'TMS Master System Log' item on the 'View' menu or select the toolbar button shown in Figure 5-33. The system events log is a modeless dialog containing the system event and error messages encountered by the Master.

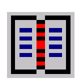


Figure 5-33. System Events Log toolbar button

Start

To start an exercise, select the 'Start' item on the 'Actions' menu or select the toolbar button shown in Figure 5-34. When an exercise is started, the 'Start' action is disabled and the 'Pause' and 'Stop' actions are enabled.

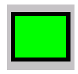


Figure 5-34. Start toolbar button (green)

Pause

After an exercise is started, the 'Pause' toolbar button, shown in Figure 5-35, and the 'Pause' item on the 'Actions' menu are enabled. When an exercise is paused, the 'Stop' action is disabled. In paused mode, the position of the platform and sensor continue to be displayed, but in a different color. No evaluation processing occurs during paused mode. To resume a paused exercise, reselect 'Pause'.

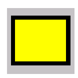


Figure 5-35. Pause toolbar button (yellow)

Stop

The 'Stop' toolbar button shown in Figure 5-36 and the 'Stop' item on the 'Actions' menu terminates an exercise. A stopped exercise cannot be resumed; hence, a confirmation box is displayed for the evaluator to confirm/cancel the 'Stop' action. Included in the confirmation box are the following options: power down instrumentation, delete exercise file, delete exercise. After the exercise is stopped, the selected options are performed. The confirmation box is not displayed when stopping a playback exercise.

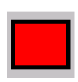


Figure 5-36. Stop toolbar button (red)

Restart

The 'Restart' toolbar button shown in Figure 5-37 and the 'Restart' item on the 'Actions' menu are used to configure an exercise using the setup parameters of the previous exercise. If the previous exercise was archived, the exercise name dialog shown in Figure 5-23 is displayed when 'Restart' is selected.

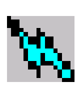


Figure 5-37. Restart toolbar button

Track Primary Entity

To maintain the display of the primary entity within the current grid display, select the 'Track Primary Entity' item on the 'View' menu.

Entity List

To display the available and selected entities in an exercise, select the 'View Entity List' item on the 'Entities' menu. This selection launches a dialog similar to Figure 5-17. Before an exercise begins, the selected and primary entity can be modified. After an exercise begins, the selected entities can be reviewed, but not modified.

Set CTMS Data Rate

When CTMS display mode is selected, the position data passed to CTMS Host for processing by CTMS can be decimated by a factor set using the Set CTMS Data Rate item of the File menu. Selecting this item displays the CTMS Position Data Rate Reduction dialog shown in Figure 5-38. This dialog allows the user to specify data rate reduction (decimation) factors that are applied separately to the platform (feet) and detector head position data. The rate at which the corresponding data is sent to CTMS Host is the rate the data is received from the FIU reduced by the specified factors. For example, if the position data is received at a rate of 10 Hz, a factor of 10 will reduce the data transfer rate to 1 Hz. Setting the rate factor control to the "No Data" position will stop the transfer of that data. Selecting the "Default" button will restore both of the factors to the original recommended values. The factor values specified using this feature are used for subsequent exercises and execution sessions.

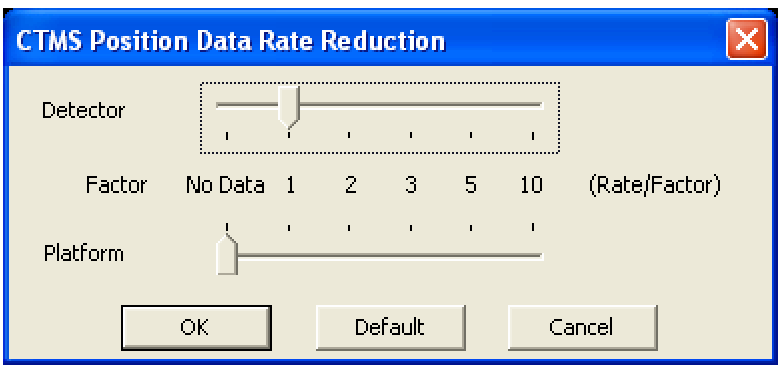


Figure 5-38. CTMS Position Data Rate Reduction dialog

Detector Head Velocity

Once position data from the exercise primary entity is available, a display in strip chart format of the detector head velocity can be accessed using the Primary Detector Velocity item of the View menu. This display, shown in Figure 5-39, plots the calculated velocity of the detector head versus time. The strip chart background is divided into three bands based on the detector head minimum and maximum speed values referenced in Section 5.3.2.2.1.1.8. These bands correspond to the assessment of head velocity depicted with the Coverage Display option: too slow, OK, and too fast. The currently entered values for minimum and maximum speed are indicated at the top of the display. The vertical axis scaling for this display can be adjusted using the technique described in Section 5.3.2.2.1.1.11.

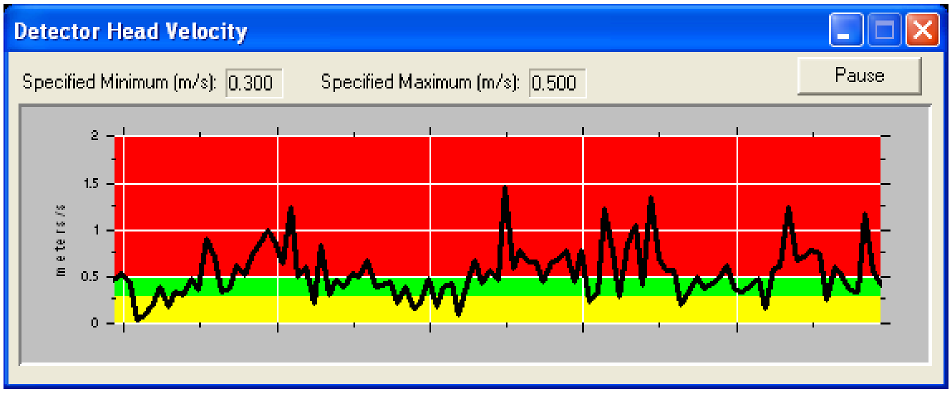


Figure 5-39. Detector Head Velocity dialog

Playback

To initiate Playback, select the 'Playback' item on the 'Operations' menu. This selection displays the file dialog shown in Figure 5-40. By default, the dialog lists exercise files (with a ".ARH" extension) in the workstation's archive directory. To view the header information of an exercise file, highlight the filename by placing the cursor over the name and left clicking. The header information contains the exercise name, exercise description, ground truth name, location of ground truth file, number of entities, duration of exercise and for each entity: ID, type and number of components. If the highlighted file is not in the correct format, an error message will be displayed. To select a file for playback, select 'Open'.

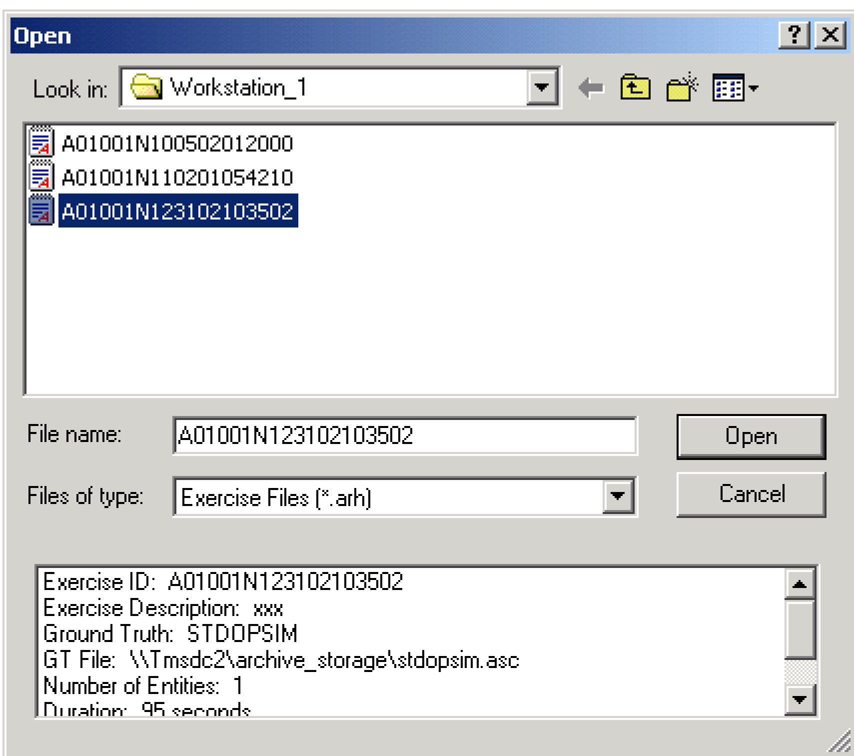


Figure 5-40. Exercise File Selection dialog

After the file is selected, the evaluator is prompted to select which application(s), TMS and/or CTMS, will graphically display the exercise's position and ground truth data. Both TMS and CTMS are the defaults, but a single application can be chosen. If both applications are selected, the 'Start', 'Pause', 'Stop', and fast-forward actions can be manipulated from either application to control the exercise. If TMS is not selected, TMS displays the exercise's ground truth data, but does not display position updates.

As shown in Figure 5-41, the Master changes its display, menus, toolbar and status bar after the file is opened. The status bar panes definitions in Playback are identical to their Exercise definitions. The first pane on the status bar displays the operation. The second pane displays the ground truth filename and the third pane is the exercise name. The icons on the grid display depict the objects in the ground truth file.

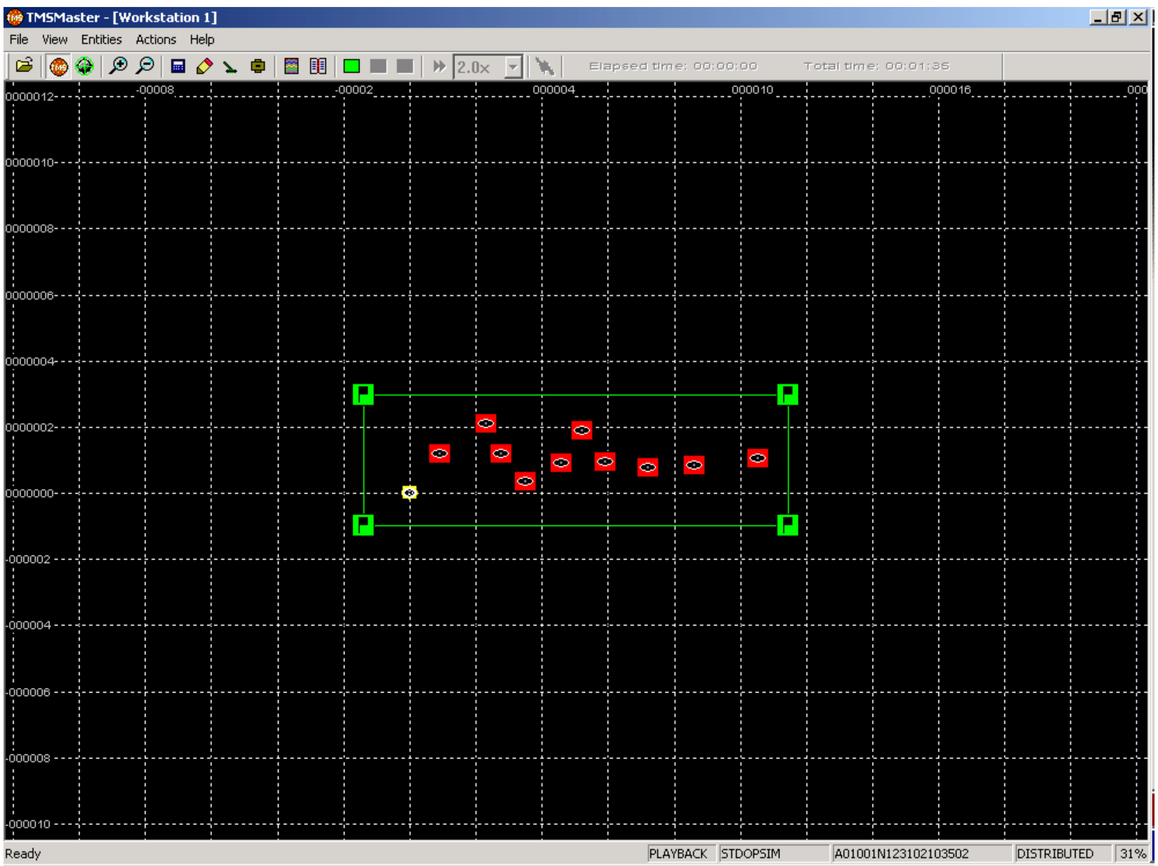


Figure 5–41. Playback operation

If CTMS is chosen as a display application, a playback exercise cannot begin until the ground truth file has been loaded in CTMS on the CTMS workstation. On the status bars of the Master and the CTMSHost applications, a flashing message alerts the evaluator to load the ground truth file. Refer to Section 5.3.4.2.1 for instructions on loading a ground truth file in CTMS. After the ground truth file is loaded in CTMS, the 'Start' button and the 'Start' item on the 'Actions' menu are enabled.

Playback Functions

The following sections describe the application controls and options provided during a playback operation.

Open Exercise File

To configure another playback exercise, select the ‘Open Exercise File’ item on the ‘File’ menu or click the toolbar button shown in Figure 5-20. This will display the file dialog shown in Figure 5-40. Select a file and click ‘Open’.

Application Display

Refer to Section 5.3.2.2.1.1.3.

View

Refer to Section 5.3.2.2.1.1.5.

Coverage Display

Refer to Section 5.3.2.2.1.1.6.

Display Options

Refer to Section 5.3.2.2.1.1.7.

Handheld Parameters

Refer to Section 5.3.2.2.1.1.8.

Ground Vehicle Parameters

Refer to Section 5.3.2.2.1.1.9.

Video

The ‘Video’ item of the ‘View’ menu allows the user to select a video file (.AVI format) recorded during a live exercise to play during the playback of the archived exercise data. The recorded video display is controlled along with the position and instrumentation data by the playback controls. The video display window can be closed at any time, but a video file can be selected only prior to starting the exercise data playback.

Detector Data

Refer to Section 5.3.2.2.1.1.11.

System Events Log

Refer to Section 5.3.2.2.1.1.12.

Start

Refer to Section 5.3.2.2.1.1.13.

Pause

Refer to Section 5.3.2.2.1.1.14.

Stop

Refer to Section 5.3.2.2.1.1.15.

Restart

The ‘Restart’ toolbar button shown in Figure 5-36 and the ‘Restart’ item on the ‘Actions’ menu are used to configure a playback exercise using the same exercise file as the previous playback exercise.

Fast Forward

After a playback exercise is started, the display rate can be changed using the fast forward control, shown in Figure 5-42. Using the combo box, highlight the desired value then left click the double arrow toolbar button. This button will remain in the “down” condition while in fast forward mode. The display rate of the exercise file is divided by the selected value. While in fast forward mode, the rate can be changed by selecting another value in the combo box. To return to the original display rate of the exercise file, click the double arrow toolbar button again.

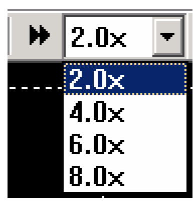


Figure 5-42. Fast Forward control

Track Primary Entity

Refer to Section 5.3.2.2.1.1.17.

Entity List

To view the entity(s) in a playback exercise, select the ‘View Entity List’ item on the ‘Entities’ menu.

Set CTMS Data Rate

Refer to Section 5.3.2.2.1.1.19.

HLA

To initiate an HLA exercise in TMS, select the ‘HLA’ item on the ‘Operations’ menu. This selection invokes the ‘HLA Exercise Setup’ dialog shown in Figure 5-43. The setup dialog consists of 2 tabular dialogs, General and Reference Point.

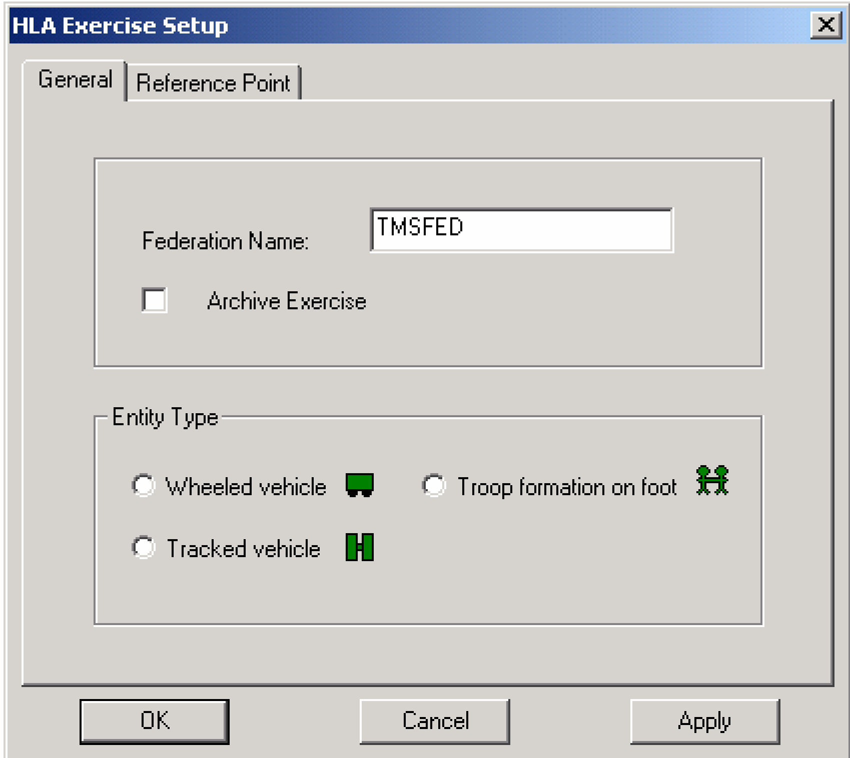


Figure 5-43. HLA Exercise Setup dialog

On the 'General' tab, enter a 'Federation Name' or use the default, TMSFED. The federation name identifies the FED file. The FED file is an ASCII file containing the Federation Object Model (FOM). The FOM used by TMS is RPRFOM 1.0. As a part of the TMS installation, the FED file, TMSFED.fed, is copied to the DataComms executable directory. If the default federation name is not used, a FED file must be created and placed in the DataComms executable directory. The FED file naming convention is FederationName.fed.

To archive an HLA exercise, check the box 'Archive Exercise'. Currently, only the federation name and the ground truth filename are written to the exercise file in the workstation's archive directory. The exercise filename is the name of the exercise with the extension .HLA. An HLA exercise name is the federation name plus a date and timestamp.

On the 'General' tab, an exercise entity type must be selected. In an HLA exercise, TMS can interact with the following entity types: troops, wheeled vehicles or tracked vehicles. A troop may consist of many soldiers or a single soldier.

An HLA exercise requires an initial position, a reference point, with which to initialize the orientation of the grid display and the ground truth file. The reference point is derived from the object data in the ground truth file. On the 'Reference Point' tab shown in Figure 5-44, enter the ground truth filename in the 'Ground Truth Name' field or select 'Browse' to invoke a file dialog. The ground truth data must be in WILD format. The ground truth data only specifies UTM easting and northing components, hence, the UTM zone number and hemisphere must be provided on the 'Reference Point' tab.

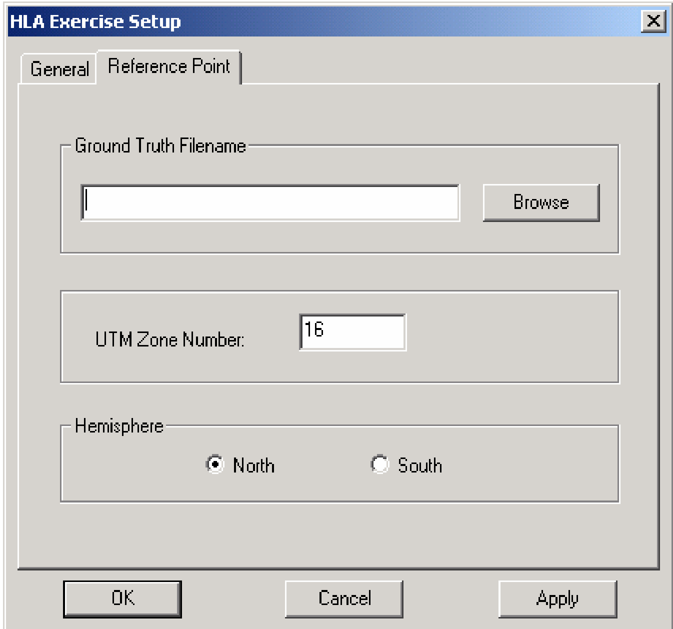


Figure 5-44. Reference Point tab

As shown in Figure 5-45, the Master changes its display, menus, toolbar and status bar after all the required parameters have been entered and the 'OK' button is selected. The first pane on the status bar displays the operation. The second pane displays the ground truth filename and the third pane is the exercise name. The icons on the grid display depict the objects in the ground truth file.

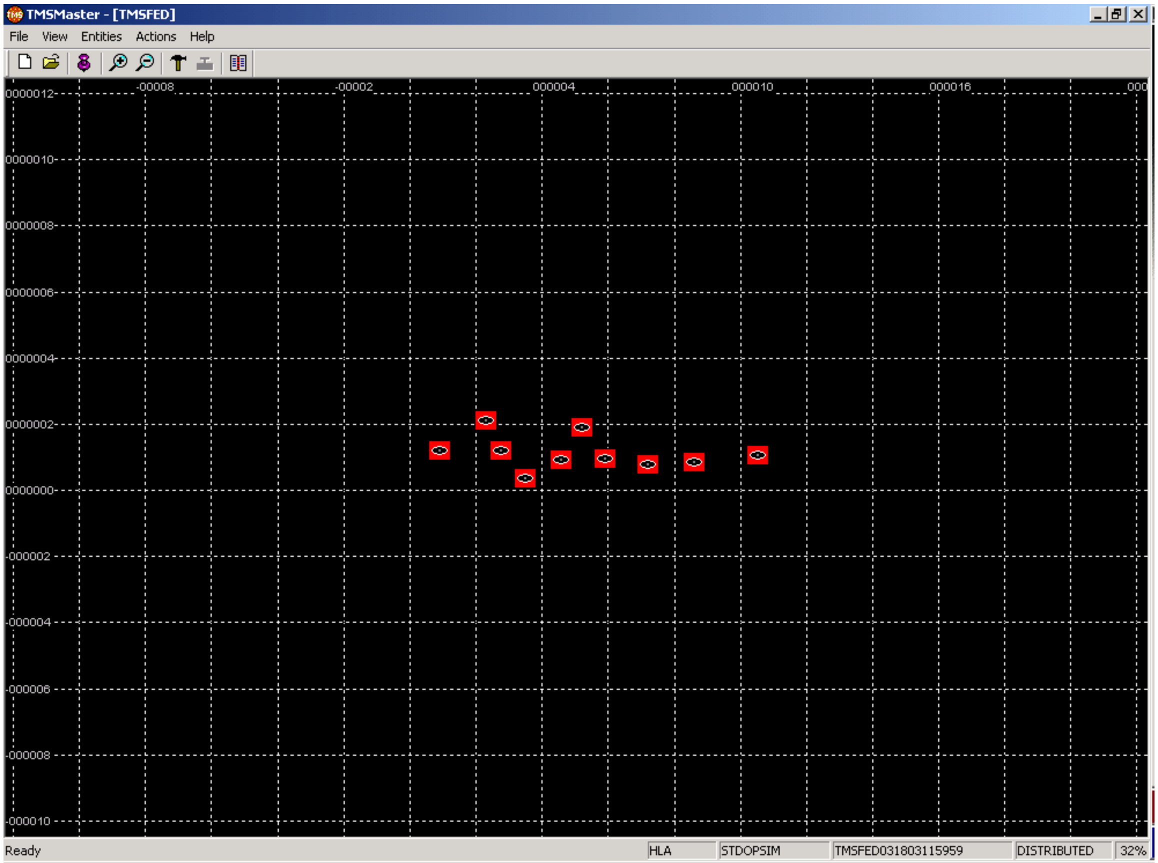


Figure 5-45. HLA operation

If the DataComms/DSP computer has 2 network interfaces, the RTI must be configured before executing (creating/joining) an HLA exercise. TMS uses RTI1.3NGv4. To configure the RTI, edit the ‘RTI.rid’ file. As a part of the TMS installation, there should be an ‘RTI.rid’ file in the DataComms executable directory. In the RID file, modify the line: ;;(RTIExecutiveEndpoint hostname:port). The semicolons serve as comment tokens and must be removed. The hostname is the IP address or hostname of the federate that will execute the ‘rtiexec’ and port is a valid port number. The federate executing the ‘rtiexec’ should invoke the ‘rtiexec’ as follows: rtiexec –endpoint hostname:port. The values of hostname and port are identical to the values entered in the RID file.

HLA Functions

The following sections describe the application controls and options provided during an HLA exercise operation.

New Exercise

To configure a new HLA exercise, select the ‘New Exercise’ item on the ‘File’ menu or click the toolbar button shown in Figure 5-19. This selection will display the HLA Exercise Setup dialog shown in Figure 5-43.

Open Ground Truth

Before an HLA exercise begins, the ground truth file can be reselected. To select a new ground truth file, select the ‘Open Ground Truth’ item on the ‘File’ menu or click the toolbar button shown in Figure 5-20. This selection will launch the dialog shown in Figure 5-44. Provide a ground truth name, zone number and hemisphere and click ‘OK’.

Archive

The ‘Archive’ toolbar button shown in Figure 5-22 is a toggle button. If archiving is selected, the button appears depressed. To turn on archiving, click the ‘Archive’ toolbar button.

View

Refer to Section 5.3.2.2.1.1.5.

Create and Join

To start an HLA exercise, select the ‘Create and Join’ item on the ‘Actions’ menu or select the toolbar button shown in Figure 5-46. When “Create and Join’ is selected, the evaluator is asked to verify that the ‘rtiexec’ is running. If the ‘rtiexec’ is not running, DataComms will crash when TMS tries to create the federation. When TMS joins a federation, the ground truth data is published to the other federates.

Figure 5-46. Create and Join toolbar button

Resign and Destroy

The ‘Resign and Destroy’ toolbar button shown in Figure 5-47 and the ‘Resign and Destroy’ item on the ‘Actions’ menu is enabled after an HLA exercise begins. To end the participation of TMS in an HLA exercise, select the ‘Resign and Destroy’ item.

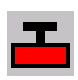


Figure 5-47. Resign and Destroy toolbar button

System Events Log

Refer to Section 5.3.2.2.1.1.12.

Track Primary Entity

Refer to Section 5.3.2.2.1.1.17.

Entity List

To display the selected entity in an HLA exercise, select the ‘View Entity List’ item on the ‘Entities’ menu. Before an HLA exercise begins, the selected entity can be modified. After an HLA exercise begins, the entities can be viewed, but not modified.

Survey

The Survey operation, in conjunction with commercially available field survey equipment, provides an automated method of developing and graphically modifying ground truth files. Ground truth files may be created using survey point data transmitted wirelessly from one or more surveyors in the field or from data entered manually. To initiate a survey session, select the ‘Survey’ item on the ‘Operations’ menu. This presents a submenu consisting of 2 items: ‘New Survey…’ and ‘Open Survey Data’. Select the ‘New Survey Data…’ item to start a new survey or to resume using the data from the immediately previous survey session. Selecting the ‘Open Survey Data’ item presents another submenu consisting of 2 items: ‘Ground Truth File…’ and ‘Saved Survey Data…’. Select the ‘Ground Truth File…’ item to open an existing ground truth file in the WILD format generated from a previous survey session or by other methods implementing the WILD format. Select the ‘Saved Survey Data…’ item to open the data generated from any previous survey session. Initiating a survey session will display the Survey operation main window shown in Figure 5-48. This window includes a grid display for graphically depicting the surveyed area and objects; a variable content display that optionally displays lists of object data, position message data, and reference point data; and a running list of system events.

The Survey operation requires an initial position with which to initialize the orientation of the grid display and other system components. This position data is entered at the start of a new survey session in the Survey Data dialog shown in Figure 5-49. The data required consists of a UTM grid number, a grid easting, a grid northing, an altitude, and the selection of the northern or southern hemisphere. After this data is entered into the system, the equivalent latitude and longitude (in degrees) of the reference point will also be provided in the survey data display. The reference point position data can be modified at any time during a survey session. An initial object identification number as well as initial lane identification data consisting of a lane number and a lane description is also required. Additional lane identification data can also be added at any time during a survey session.

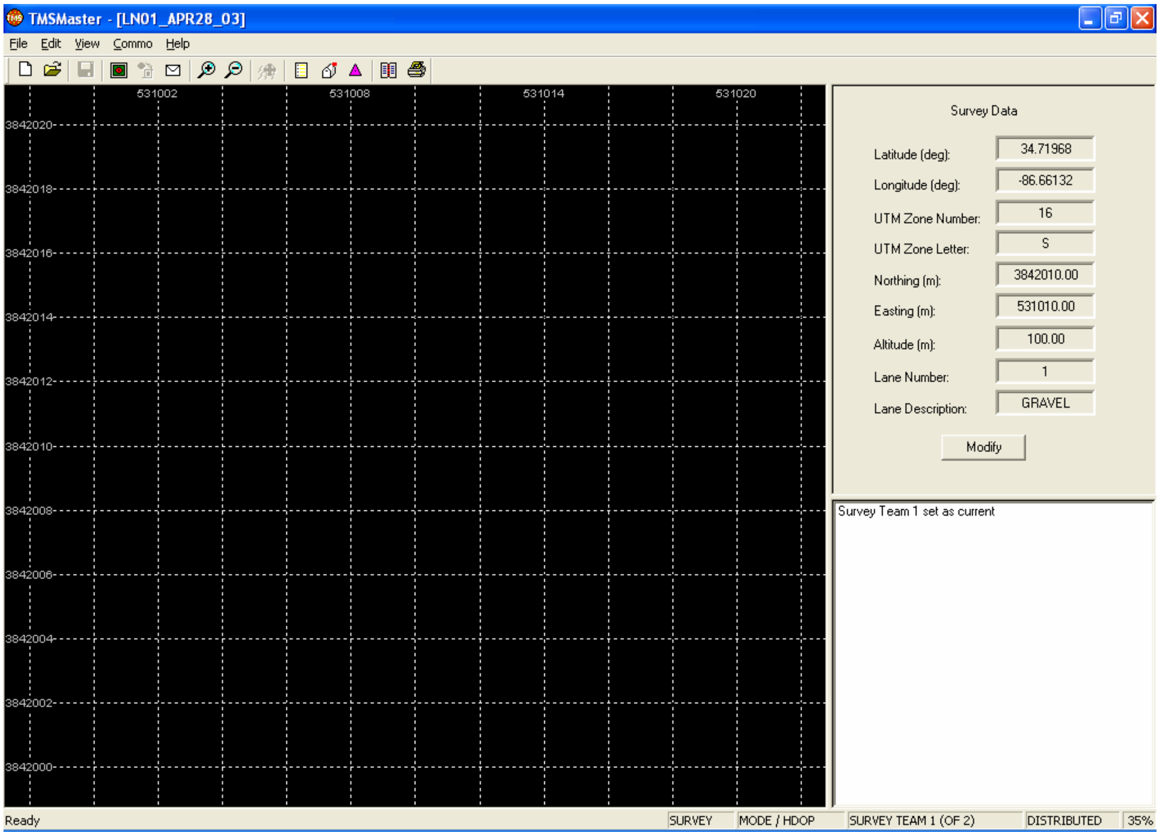


Figure 5-48. Survey operation initial main window

The Survey Data dialog also contains a "Log survey data" check box. Selecting this check box will log all of the raw data received from field surveyors in a file for later processing and review. This log file is not required for any Survey application function.

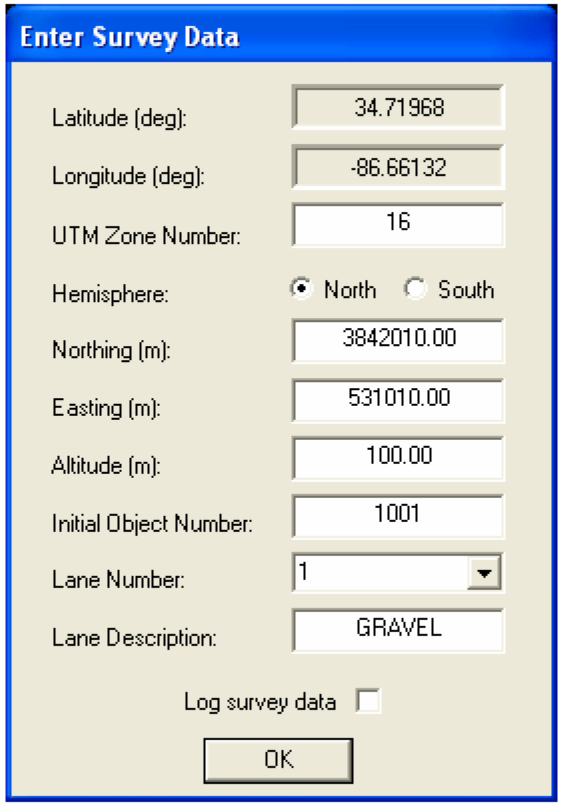


Figure 5-49. Enter Survey Data dialog

The Survey operation receives and processes position data generated at and transferred from field surveyors. This data is transferred in the form of messages sent over wireless communications channels. A corresponding communications interface of the appropriate type must be configured within TMS DataComms prior to initiating survey operations with a field surveyor. A descriptive label entered as part of the interface configuration information is used within the Survey operation to identify the field surveyor. In order to receive position messages from field surveyors, one or more configured survey communications interfaces must be selected by the user. Surveyors are selected using the ‘Select Surveyor’ item of the ‘Commo’ menu. Selecting this item will display the Select Surveyors dialog shown in Figure 5-50. This dialog presents a list of available survey communications interfaces (“surveyors”) as established by TMS DataComms as well as a list of surveyors already allocated to the current survey session. Surveyors are moved on and off each list using the ‘Add’ and ‘Remove’ buttons, as appropriate. Surveyors may be selected and de-selected for a survey session at any time, provided that the corresponding communications interface is available through TMS DataComms.

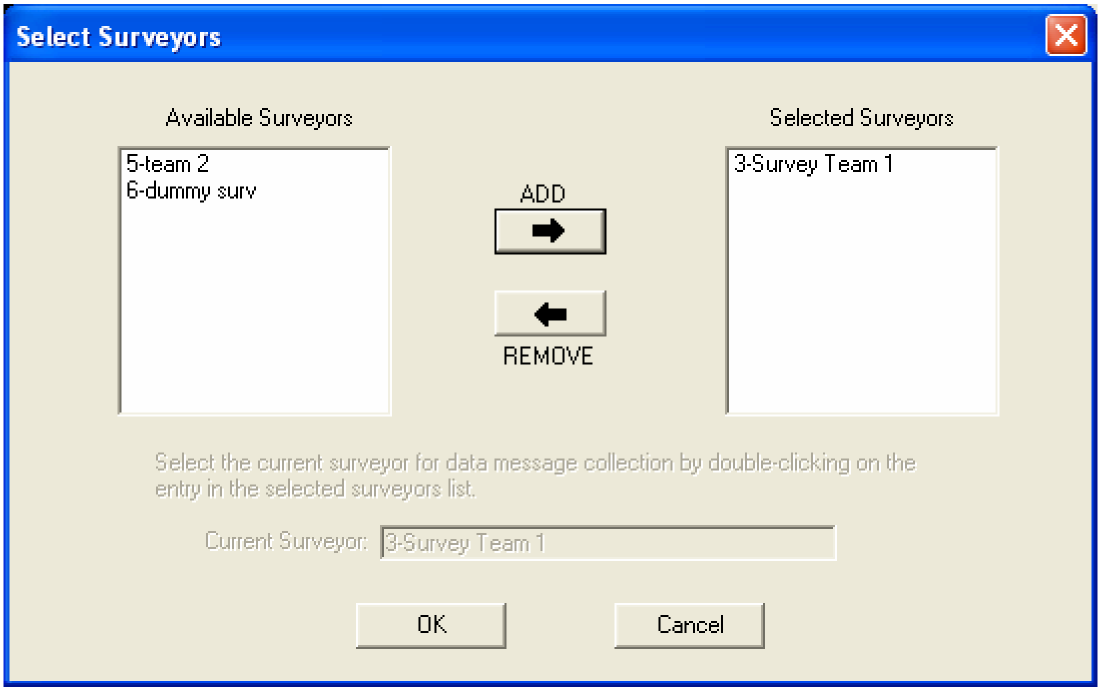


Figure 5-50. Select Surveyors dialog

When multiple surveyors are selected for a survey session, one must be designated as "current." The current surveyor is that from which the user will request and process position data messages. The surveyor designated as current is indicated by a unique icon and is also indicated in a pane of the status bar at the bottom of the main window. Figure 5-51 shows the icons for the current and active surveyors The current surveyor may be set from among all selected surveyors at any time using the 'Current Surveyor' item of the 'Commo' menu, which presents the Select a Surveyor dialog shown in Figure 5-52, or by double-clicking on the icon of the desired surveyor.

Figure 5-51. Current and Active Surveyor icons

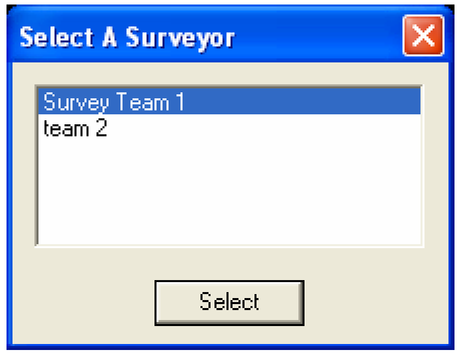
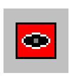
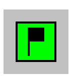
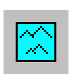


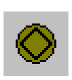
Figure 5-52. Select a Surveyor dialog

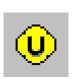
The type of objects that may be created within the Survey operation, and their corresponding icons, consist of the following:

 Mines

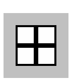
 Lane Boundaries

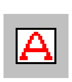
 Landmarks

 Other

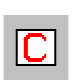


Unknowns

 Monuments



Alarms indicating mines



Alarms indicating clutter

The mine types and landmark identifiers available for assignment are extracted from the TMS/CTMS database to ensure consistency with other TMS functions. (Note: objects identified as monuments and alarms are not included in ground truth files. Only objects identified as alarms are included in alarm files.)

Survey Views

The application main window for the Survey operation includes multiple views. The grid view and the system event list are always visible. However, the survey data view, the object list and the position message list share a window and are swapped based on actions of the user. Figure 5-53 shows an example of the main window during a survey operation. The window in this example is displaying the grid view, the position message list, and the system event list. In addition, while in the Survey operation, the panes of the main window's status bar provide the following information: the current operation is SURVEY; the latest GPS mode and HDOP values received from the current surveyor ("MODE/HDOP" indicates no communications;) the ID of the current surveyor and the number of selected surveyors; the TMS configuration (DISTRIBUTED, STANDALONE, etc.;) and the usage percentage of the archive volume.

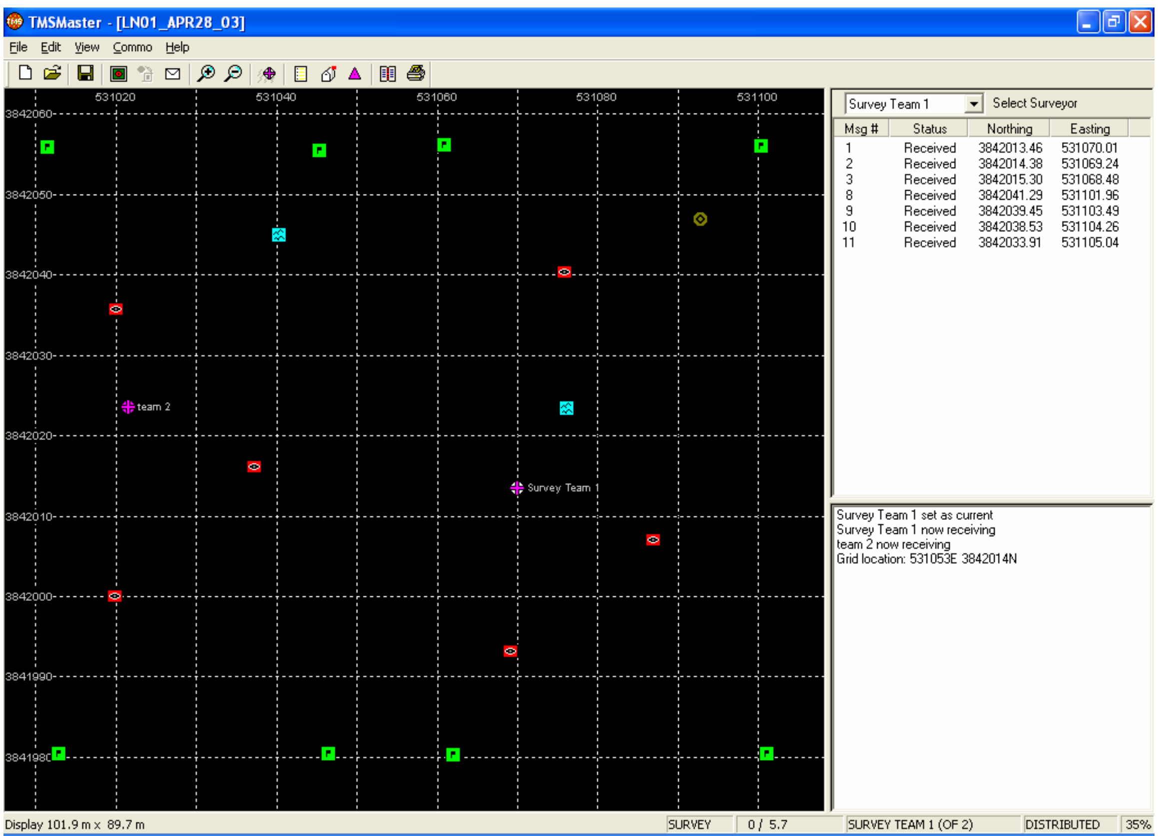


Figure 5-53. Example survey main window

Grid View

The grid view provides a graphical representation of the relative positions of the surveyed area and identified objects. The area of the survey is depicted as a section of a UTM grid, with easting values corresponding to the vertical lines and northing values corresponding to the horizontal lines. The grid is oriented with north at the top and is initially centered at the reference point. The current dimensions of the area depicted in the grid view are displayed in the information pane (left-most section) of the status bar at the bottom of the application window.

When an object is entered into the system, an icon is displayed in the grid view at a location corresponding to the object's position. An icon is also displayed to represent the current position of active surveyors as determined from messages received from the field equipment. Clicking the left mouse button once with the pointer over an empty section of the view will enter the corresponding position in the system view. A number of operations affect the area depicted by the grid view. The following sections describe these operations.

Grid View Zooming

The area depicted by the grid view can be increased and decreased using the zoom out and zoom in operations, respectively. Zooming operations maintain the current center point of the view. The zoom operations can be invoked in two ways. The toolbar contains two zoom buttons, shown in Figure 5-54; one for zoom in and one for zoom out. Clicking one of these buttons changes the area depicted by the grid view by one zoom increment. The 'View' menu also contains 'Zoom In' and 'Zoom Out' submenus. Each of these submenus contains options for zooming by one or multiple increments. After zooming, the current dimensions of the area depicted in the grid view are updated in the information pane of the status bar at the bottom of the application window.

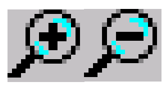


Figure 5-54. Zoom In/Zoom Out toolbar buttons

Grid View Panning

Holding down the right mouse button and moving the mouse pans over the area depicted by the grid view. When in panning mode, the mouse pointer changes to a panning pointer. When the right mouse button is released, panning mode is terminated and the pointer changes back to the standard pointer. Panning will change the center point of the view.

Grid View Centering

The location of the center of the grid view can be set corresponding to several positions. The 'View' menu contains a 'Center Grid On' submenu. The items of this submenu will center the grid view on one of the following: the reference point; the current position of the surveyor; the currently selected object icon; or the icon of an object selected from a list of all objects entered in the system. In addition, the 'Center Grid On' submenu contains an option to track the current surveyor's position. After selecting this option, the current surveyor's position is maintained at the grid center as the current surveyor moves. Centering the grid on either the current surveyor's position or tracking the surveyor's position can also be invoked using the 'Track Surveyor' toolbar button, shown in Figure 5-55. This toolbar button is "sticky": clicking the button once puts the grid view in track surveyor mode; clicking it again takes the view out of track surveyor mode.

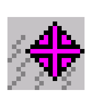


Figure 5-55. Track Surveyor toolbar button

System Event List

The system event list provides a running log of survey operations. Survey operations consist of receiving position messages, creating new objects, deleting objects, modifying objects, etc. For an example of the system view, see Figure 5-53.

Survey Data View

The survey data view contains the reference point position data and the lane identification data. To activate the survey data view, select the 'Survey Data' item of the 'View' menu or click the toolbar button shown in Figure 5-56. For an example of the survey data view, see Figure 5-53. In this view, the reference point position data includes a UTM grid letter, which is a component of a fully qualified UTM position, as opposed to simply a hemisphere indicator. The 'Modify' button at the bottom of the view is used to change any of the survey data. Clicking this button will open the Survey Data dialog, shown in Figure 5-57, in which any of the data values can be edited. The lane number list contains lane numbers that have been entered previously. To specify a new lane number, type the number into the list box. The lane description corresponds to the displayed lane number. This dialog also contains a 'Message' button. When position data messages are being received from the current surveyor, clicking this button will set the reference point to the position reported by the surveyor. This button is disabled when position data messages are not being received from the current surveyor.

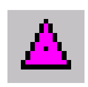


Figure 5-56. Survey Data View toolbar button

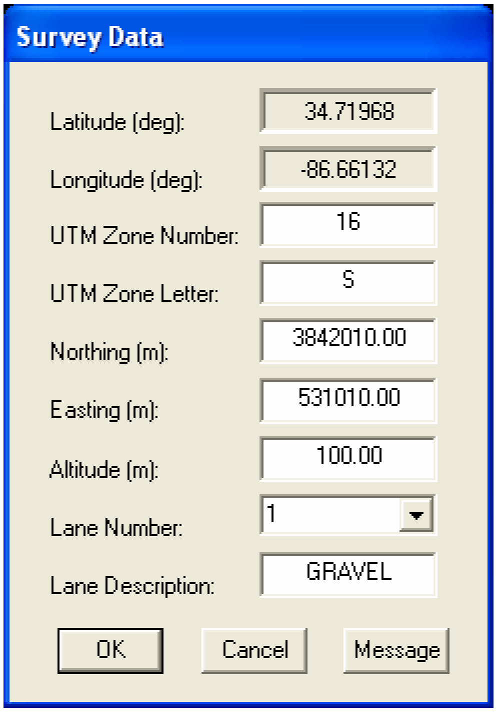


Figure 5-57. Survey Data modification dialog

Object List

The object list is a cumulative list of objects in the current survey session. The object list displays the object's number, ID and description. Double-clicking on a list item opens a dialog presenting all of the information on the corresponding object. The object list can be sorted by object number or by ID. To sort the object list, click the object number or ID column heading. The column heading that is selected is used as the primary sort key. To activate the object list, select the 'Object List' item of the 'View' menu or click the toolbar button shown in Figure 5-58. For an example of the object list, see Figure 5-59.

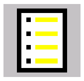


Figure 5-58. Object List toolbar button

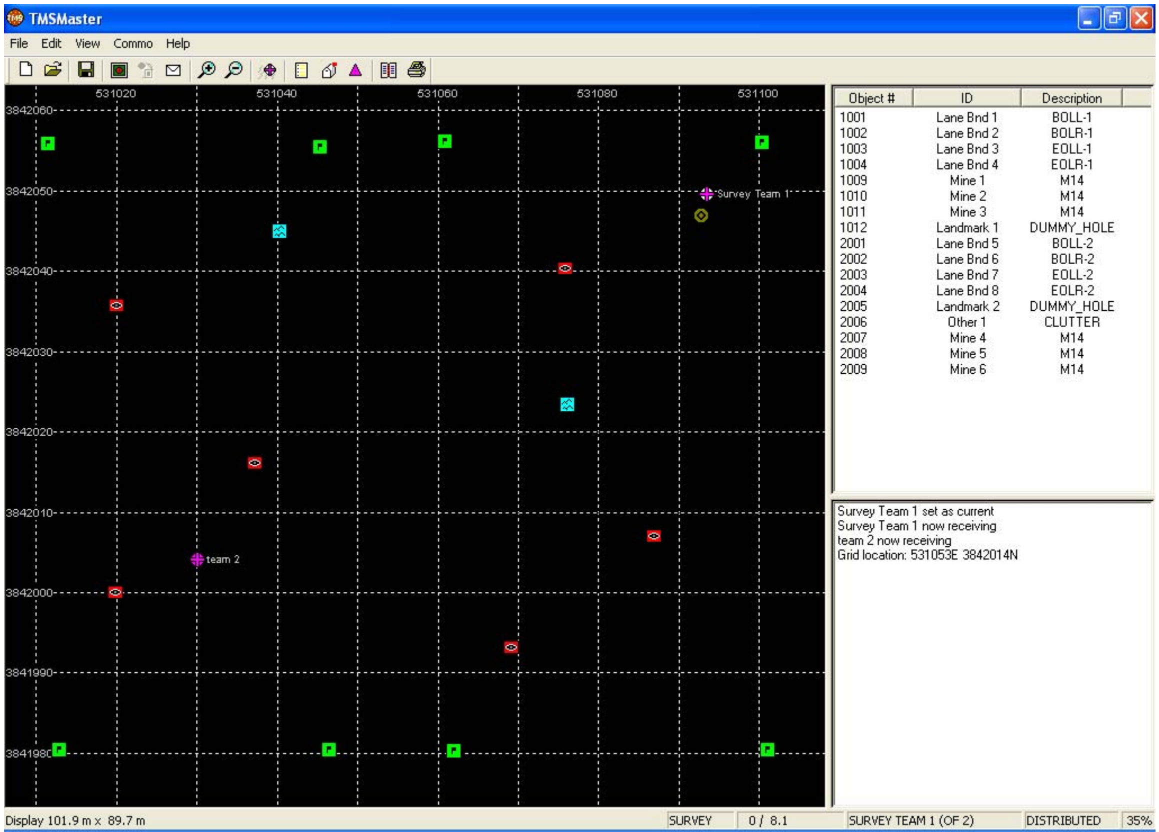


Figure 5-59. Object List example

Position Message List

The position message list is a cumulative list of position messages received during the survey session. The list view includes a pop-up list of surveyors that allows the user to limit the messages displayed to only those from the selected surveyor. The position message list displays the position message's number, status, and northing and easting values. The possible message status values are: Received, Read, Assigned (the first point assigned to an object), Assigned+ (one of several points assigned to an object). To activate the position message list, select the 'Received Message List' item of the 'View' menu or click the toolbar button shown in Figure 5-60. For an example of the position message list, see Figure 5-53.

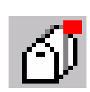


Figure 5-60. Position Message List toolbar button

Survey Functions

The following sections describe the application controls and options provided during a survey operation.

Processing Position Messages

Position messages are obtained at the request of the user from the active surveyor designated as current. When the requested position message is received, the user may perform a sequence of operations on the data contained in the message.

Requesting Position Messages

To request a position message, select the ‘Get New Message’ item of the ‘Edit’ menu or click the toolbar button shown in Figure 5-61. If a position message is available, the position message is retrieved and added to the position message list. The messages in the list will be automatically limited to those from the current surveyor. Also, a time-stamped message of this operation is written to the system event list. If a position message is not available, “No message available” is written to the system event list. If no surveyors are selected or no communications are available with the selected surveyors, the ‘Get New Message’ menu item and toolbar button are disabled.

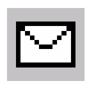


Figure 5-61. Get New Message toolbar button

Viewing a Position Message

To view a position message, activate the position message list, following the instructions in Section 5.3.2.2.4.1.5, then left click on the corresponding item in the message list. The displayed position data may be used in creating a new object, added to an existing object, or used to modify an existing object. Figure 5-62 shows the Position Message dialog.

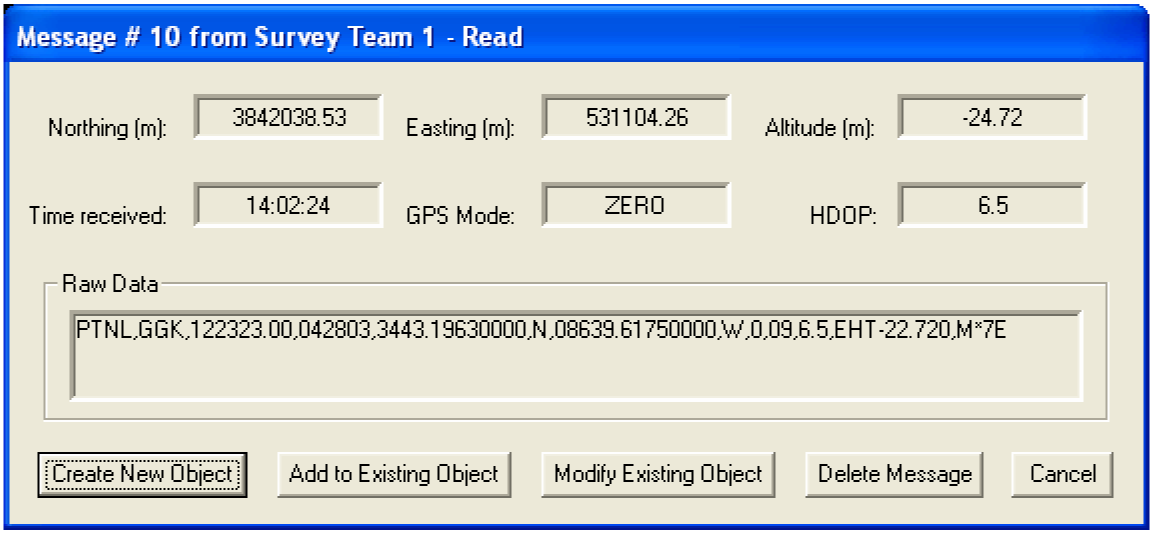


Figure 5-62. Position Message dialog

Deleting a Position Message

To delete a position message, view the position message, following the instructions in Section 5.3.2.2.4.2.1.2, then click the 'Delete Message' button.

Creating an Object

An object may be created using any of the methods described in the following sections.

From a Position Message

To create an object from a position message, view the position message, following the instructions in Section 5.3.2.2.4.2.1.2, and then click the 'Create New Object' button. In the resulting Create Object with Position Message dialog, shown in Figure 5-63, select the desired object type. Once the object type is selected, only the associated object type information controls for that object type are enabled and the position message data is displayed in the Position Data section. Using this method of creating an object, the Position Data cannot be modified at that time. All enabled text fields except 'Comments' require data. The user may opt to use several position messages to generate a weighted average position for the object. To do so, click the 'Avg' button next to the corresponding position point. This will open the Object Position Data for Point dialog shown in Figure 5-64. The first item in the list in this dialog will be the original position message associated with the object position point. To collect additional messages for this point, click the 'Record' button. This will add received position messages to the list. Up to 20 messages may be recorded for a single point. To stop collecting position messages click the 'Stop' button (which replaces the 'Record' button while recording.) To calculate a weighted average position from all of the collected messages, click the 'Apply' button. To remove a message, select the message in the list and click the 'Clear' button. When a weighted average position is calculated for a point, the 'Avg' checkbox associated with the point data in the Object dialog is checked. To create the object using the data displayed in the Object dialog, click 'OK'; otherwise, click 'Cancel'. If insufficient data is given, the user is alerted and prompted to supply the required data. Also, if the object is outside of the current grid display, a message box will alert the user and provide options to continue or cancel the operation. (Note: Monument objects cannot be created from position messages.)

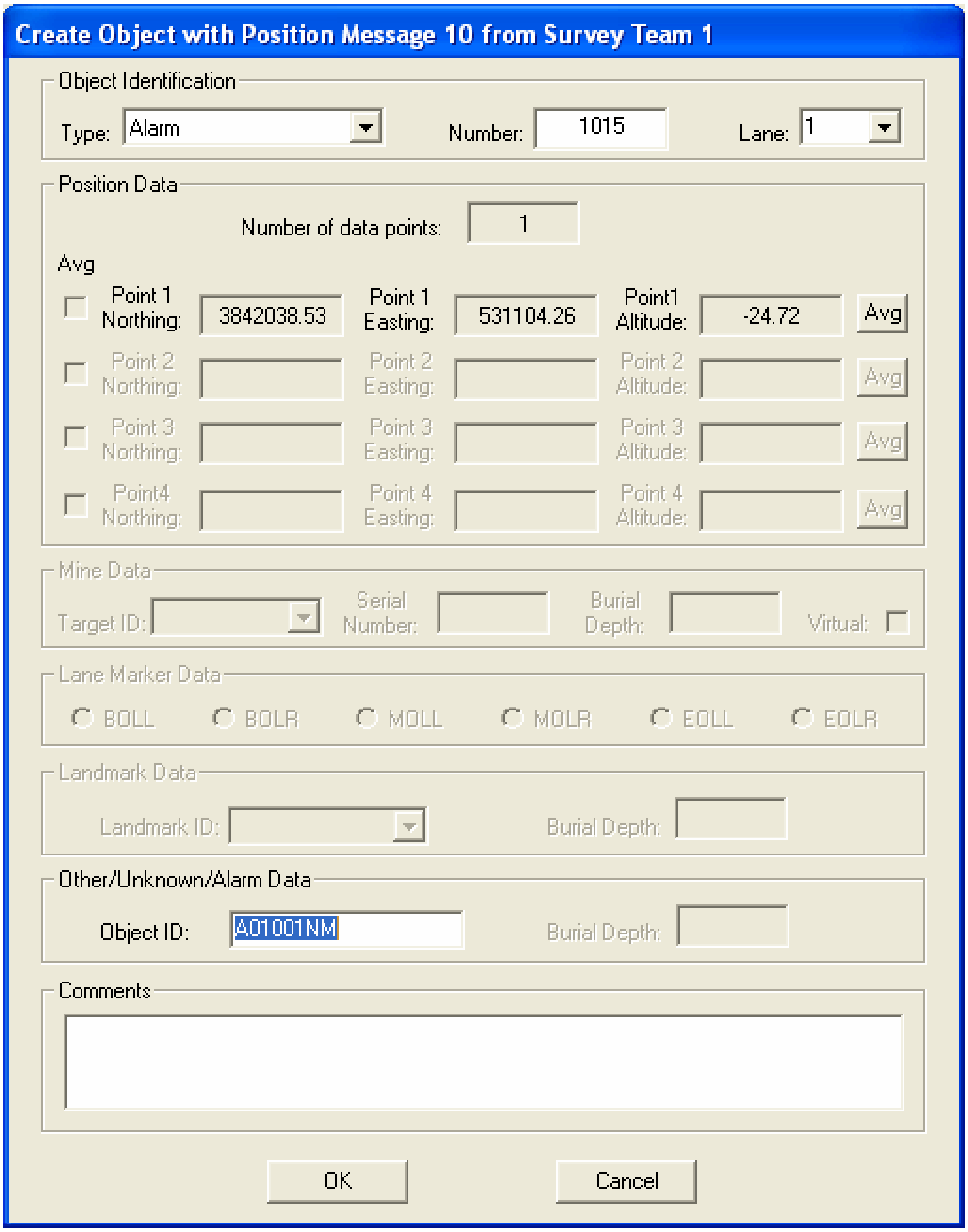


Figure 5-63. Create Object from Position Message dialog

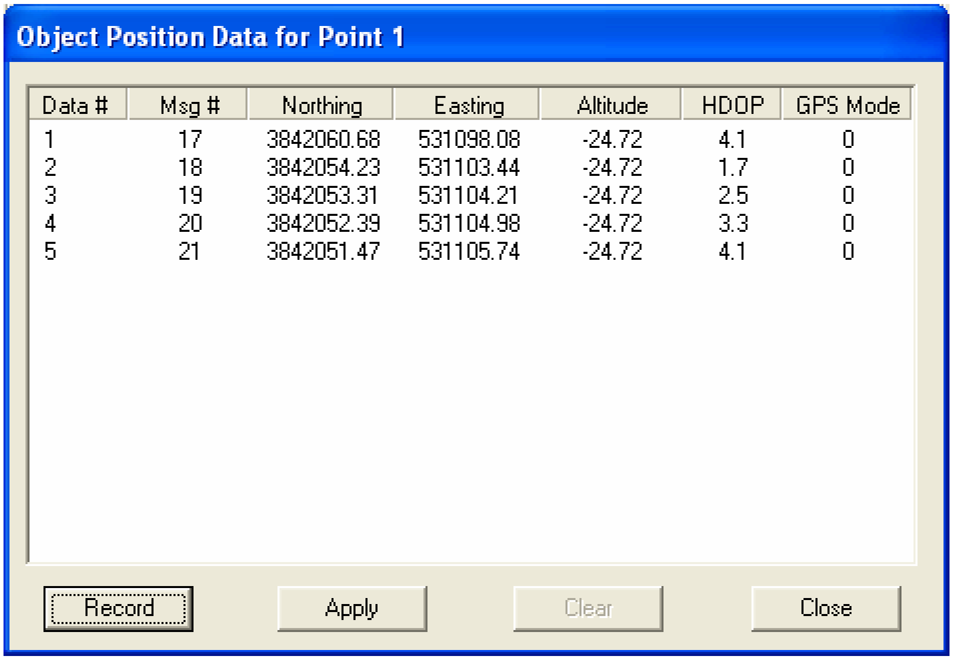


Figure 5-64. Object Position Data for Point dialog

Manual Position Data Entry

A second method of creating an object is to select the 'Create New Object' item of the 'Edit' menu or by clicking the toolbar button shown in Figure 5-65. In the Object data dialog shown in Figure 5-66, select the desired object type. Once the object type is selected, the associated object type information controls are enabled. Using this method of creating an object, the Position Data is entered manually by the user. All enabled text fields except 'Comments' require data. To create the object, click 'Create'; otherwise, click 'Cancel'. If insufficient data is given, the user is alerted and prompted to supply the required data. Also, if the object is outside of the current grid display, a message box will alert the user and provide options to continue or cancel the operation.

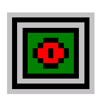


Figure 5-65. Create New Object toolbar button

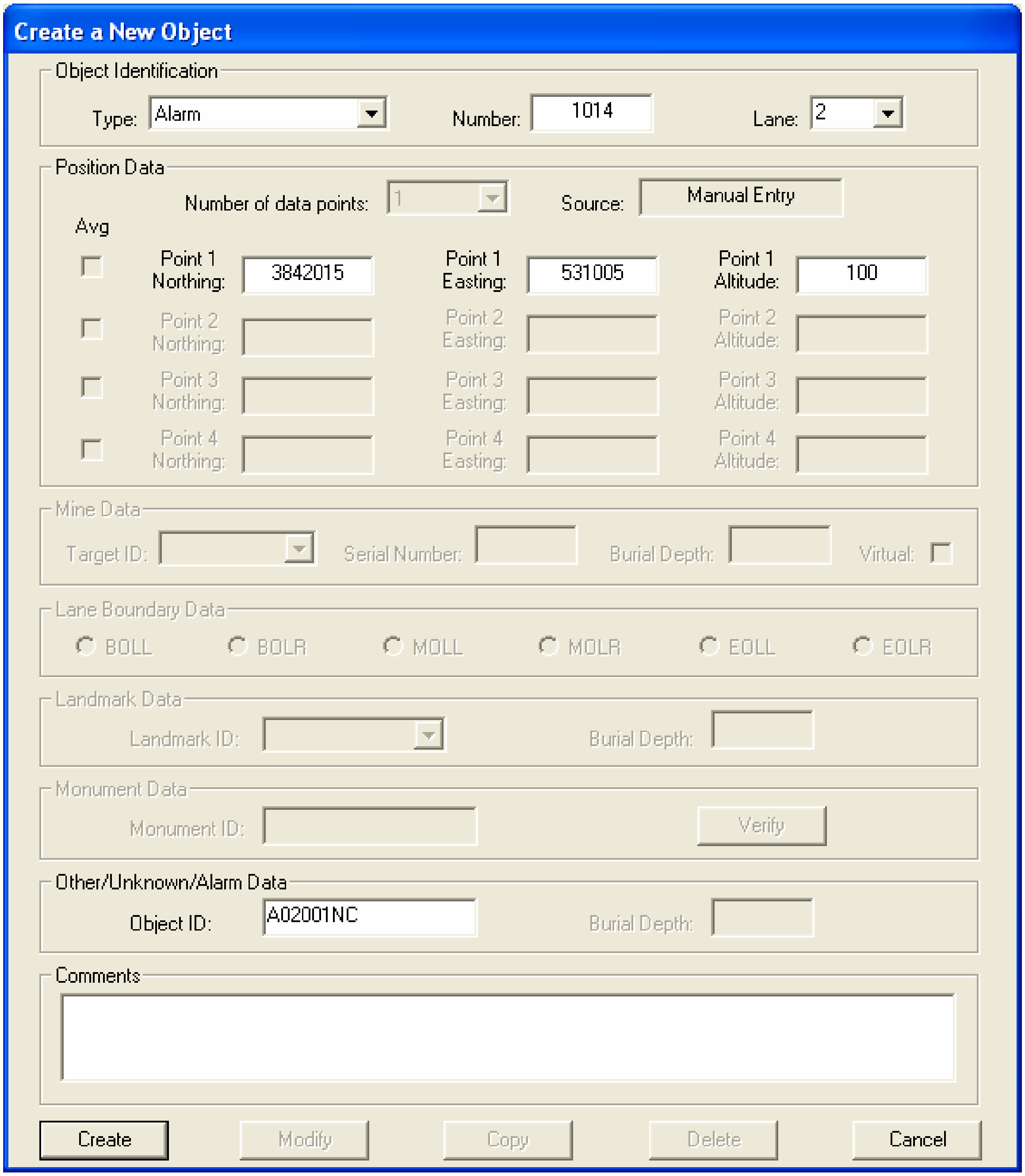


Figure 5-66. Object dialog

Double-clicking the Grid view

A third method of creating an object is to double-click an empty location on the grid view. Place the pointer at the position on the grid view where the object is to be located and double-click. Upon double clicking, the Object dialog shown in Figure 5-66, is displayed. The northing and easting positions corresponding to the location of the pointer are displayed in the Point 1 Northing and Easting edit boxes and the other associated object type information controls are enabled. The Point 1 Altitude is set to the default value specified for the reference point. All enabled text fields except ‘Comments’ require data. Using this method of creating an object, the position data values can be modified by the user. To create the object, click ‘Create’; otherwise, click ‘Cancel’. If insufficient data is given, the user is alerted and prompted to supply the required data. (Note: the accuracy of the position data resulting from graphical operations may not be sufficient for ground truth data. You may want to use these types of operations for “gross” placement, and then manually edit the data in the object dialog to specify values to greater accuracy.)

Viewing Object Information

The information for an existing object may be viewed and modified by selecting the object in several ways.

Using the Object List

To view an object using the object list, activate the object list, following the instructions in Section 5.3.2.2.4.1.4, and then double-click on the corresponding list item.

Double-clicking the Object Icon

To view an object displayed on the grid view, double-click the object icon using the left mouse button.

Adding a Point from a Position Message to an Existing Object

To add a position point to an existing object using a position message, view the position message, following the instructions in Section 5.3.2.2.4.2.1.2, and then click the ‘Add to Existing Object’ button. Upon making this selection, the dialog shown in Figure 5-67, will display a list of all the objects that can have more than 1 position point in the survey session created from position messages from the current surveyor. To select an object in the dialog, highlight the object’s row and click ‘OK’ or double-click the object’s row. The maximum number of position data points for an object is four. If the selected object already contains the maximum number of points, the user must choose another object or cancel the operation. When a valid object is selected, the Object dialog, shown in Figure 5-64, is displayed showing the position message’s northing and easting values added to the Position Data as the next available point of the existing object. To confirm the addition of the position data to the existing object, click ‘OK’; otherwise, click ‘Cancel’.

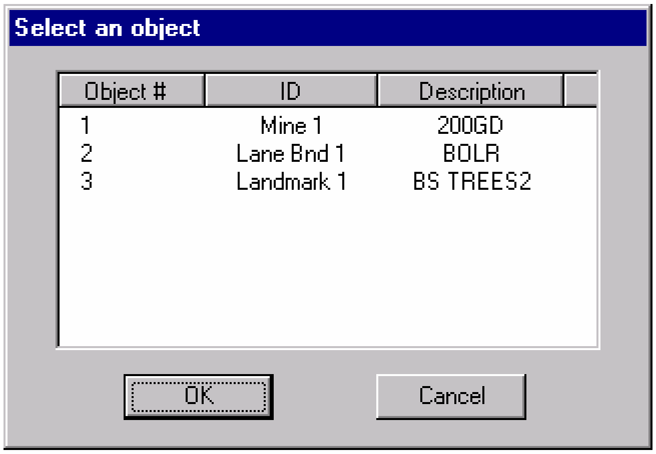


Figure 5-67. Select an Object dialog

Modifying an Existing Object

Using a Position Message

To modify an existing object using a position message, view the position message, following the instructions in Section 5.3.2.2.4.2.1.2, and then click the 'Modify Existing Object' button. Upon making this selection, the dialog shown in Figure 5-67 will display a list of all the objects in the survey session created from position messages from the current surveyor. To select an object in the dialog, highlight the object's row and click 'OK' or double-click the object's row. The next task is to select the data point to modify using the dialog shown in Figure 5-68. To select the data point, highlight the data point's row and click OK, or double-click the data point's row. The Object dialog then opens, displaying the existing object with the position message values substituted into the selected data point. To confirm the modification of the existing object with the position message, click 'OK'; otherwise, click 'Cancel'.

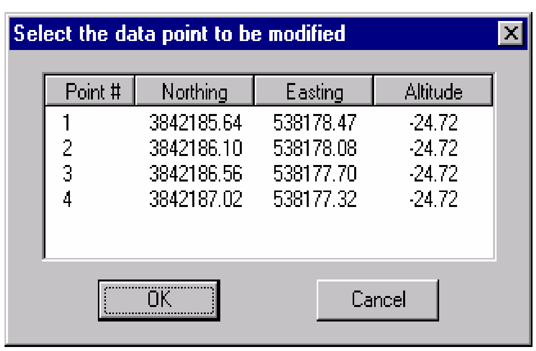


Figure 5-68. Data Point Selection dialog

Using the Modify button

To modify an existing object using the 'Modify' button, view the object information using either of the methods described in Section 5.3.2.2.4.2.3. Modify the desired value(s) displayed in the Object dialog. To apply the modifications, click ‘Modify’, otherwise, click ‘Cancel’.

Moving the Object Icon

The position of an existing object can be changed by clicking on the object icon with left mouse button, holding the button down, and moving the pointer to the desired new location. (Note: the accuracy of the position data resulting from graphical operations may not be sufficient for ground truth data. You may want to use these types of operations for “gross” placement, and then manually edit the data in the object dialog to specify values to greater accuracy.)

Copying an Object

To copy an object, view the object information using either of the methods described in Section 5.3.2.2.4.2.3, then click the ‘Copy’ button. Modifications can be made to any of the object information displayed in the Object dialog except for the object type. To save the new object, click ‘Create’, otherwise, click ‘Cancel’.

Deleting an Object

An existing object may be deleted in two ways.

Using the Menu or Toolbar Button

To delete an object using the menu or toolbar button, select the object icon on the grid view then select the ‘Delete Object’ item of the ‘Edit’ menu or click the toolbar button shown in Figure 5-69.

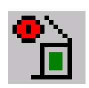


Figure 5-69. Delete Object toolbar button

Using the Delete Button

To delete an object using the ‘Delete’ button, display the object information in the Object dialog using either of the methods described in Section 5.3.2.2.4.2.3, and then click the ‘Delete’ button.

Clearing Alarms from a Lane

All alarms within a specified lane may be cleared simultaneously using the ‘Clear Alarms from Lane…’ item of the ‘Edit’ menu. This function does not delete the alarm data from the survey session, but does clear the alarms from the display. Also, cleared alarms will not be included in subsequent alarm files created for the corresponding lane. This feature allows the scoring of several exercises on a lane within a single survey session without deleting previously received alarms on that lane.

Verifying Position Data with a Monument

A Monument is a special type of object that allows the verification of data received from a field surveyor against a well known, accurately measured, recorded point. A Monument can be created only by manually entering recorded position data. Once the Monument exists, the user can verify the data in position messages sent from that point by a field surveyor against the recorded position. Clicking the ‘Verify’ button in the Monument data section of the Object data dialog opens the Verify Monument Position dialog shown in Figure 5-70.

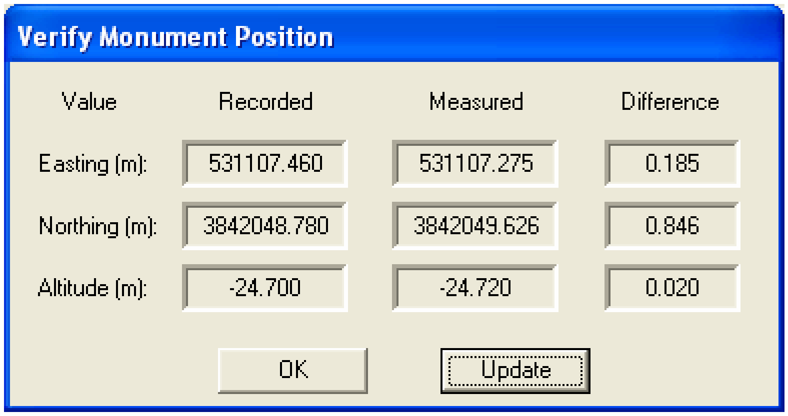


Figure 5-70. Verify Monument Position dialog

This dialog displays the position data recorded for the Monument, the position data from a position message from the current surveyor at the time the dialog was opened, and the difference between the two. Clicking the ‘Update’ button of this dialog will continuously update the measured and difference values using position messages from the current surveyor.

Communication Status

To view a summary of the overall communication status, select the ‘View Commo Status’ item of the ‘Commo’ menu. Selecting this item opens the Communications Status dialog, shown in Figure 5-71. The information includes the number of selected surveyors, the name of the raw data log file, and, for a selected surveyor, the current status and number of communications updates received. These values are not modifiable from this dialog. In addition, the corresponding icon on the grid display indicates the communications status of an individual field surveyor. The icons in Figure 5-51 are displayed when the current and active surveyors, respectively, are receiving updates. If the updates for either cease, the icons in Figure 5-72 are displayed.

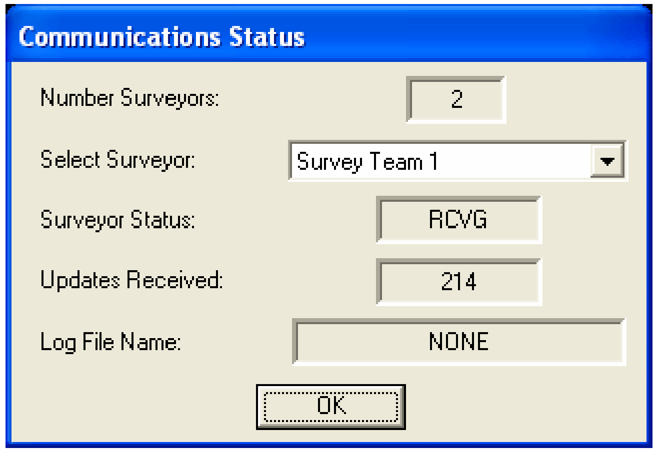


Figure 5-71. Communications Status dialog

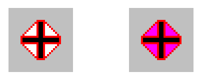


Figure 5-72. Current and Active Surveyor icons indicating No Communications

Setting Options

The ‘File’ menu contains an ‘Options’ submenu that allows the user to set two features that are persistent across successive survey operations. Each item is set on when the corresponding ‘Options’ submenu item includes a check mark. The first option indicates whether or not the serial numbers assigned to mines should be included in ground truth files created by TMS Survey. The second option indicates whether or not the user can modify an object’s position by dragging its icon within the grid display.

Survey Data GPS Mode Checks

The data contained in position messages received from field surveyors include a GPS mode or quality value. The ‘Set GPS Mode Checks’ item of the ‘Commo’ menu opens the dialog shown in Figure 5-73. This dialog allows the user to turn on and off two automatic actions based on the value of this item in associated position messages.

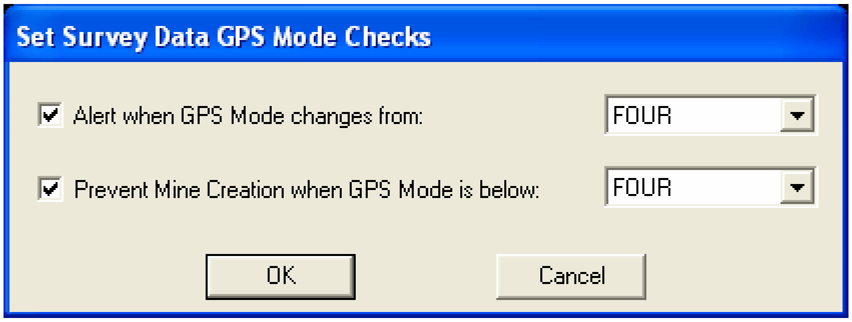


Figure 5-73. Set Survey Data GPS Mode Checks

The first action is to alert the user when the GPS Mode value changes to or goes below the specified value. The second action is to prevent the creation of mine objects using position messages where the GPS Mode value is below the specified value. (Note: these options are saved between survey sessions.)

Printing a Survey Grid

To print the current grid view, select the 'Print' item of the 'File' menu or click the toolbar button shown in Figure 5-74.

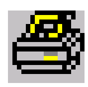


Figure 5-74. Print toolbar button

Printing a Ground Truth File

The contents of a ground truth file can be printed by selecting the 'Print Ground Truth File' item of the 'File' menu.

Saving Survey Data

The Survey operation creates several distinct sets of data: the survey session data; ground truth files in the WILD format; and alarm files. The following sections describe when and how these data sets are saved.

Creating Ground Truth Files

Selecting the 'Create Ground Truth File…' item of the 'File' menu or the 'Create GT File' toolbar button, shown in Figure 5-75, opens the Select File Data Contents dialog, shown in Figure 5-76. This dialog allows the user to limit the data written to the file to items in one of several categories: objects created from position data from one of any surveyors that are currently active; objects created from position data from any source, including surveyors that are or were active, data entered manually, or from an existing ground truth file; data pertaining to a single lane; or all current data. Responding OK to this dialog creates a ground truth file using objects entered in the system at that time that meet the limiting criteria. Also, upon application shutdown, a dialog will be presented providing the option of creating a ground truth file from object data existing at that time. (Note: the default file name extension for WILD format ground truth files used by CTMS is “.ASC”; this file extension will be applied by default unless another extension is provided as part of the file name.)

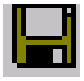


Figure 5-75. Create GT File toolbar button

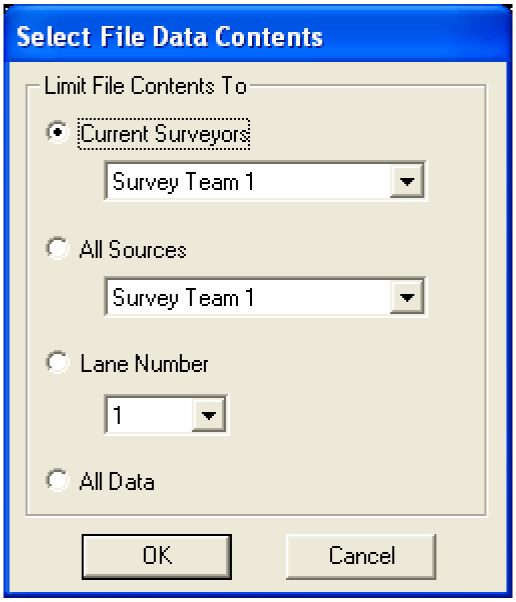


Figure 5-76. Select File Data Contents dialog

Creating Alarm Files

Selecting the ‘Create Alarm File…’ item of the ‘File’ menu opens the Alarm Tag Data dialog, shown in Figure 5-77.

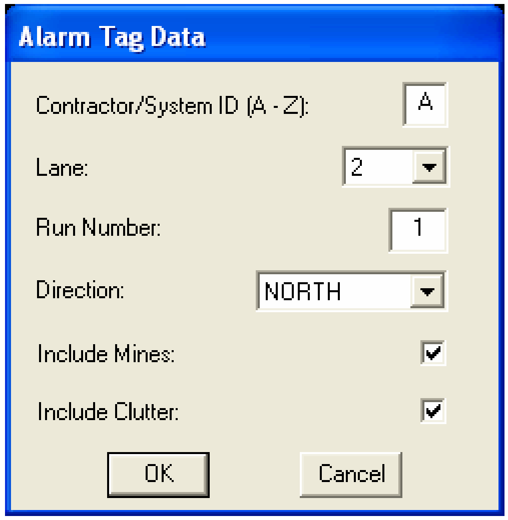


Figure 5-77. Alarm Tag Data dialog

This dialog allows the user to specify descriptive information that will be used in creating the default file name, specifying the lane number in which alarms are located, and limiting the alarms to mine alarms, clutter alarms, or both. Responding ‘OK’ to this dialog will then create the alarm file based on the specified information. The ‘Create Alarm File…’ menu item is enabled only when alarms exist in the current survey data. (Note: the default file name extension for alarm files used by CTMS is “.ASC”; this file extension will be applied by default unless another extension is provided as part of the file name.)

Saving Survey Session Data

Selecting the ‘Save Survey Data As…’ menu item allows the current survey session data to be saved to a new file. Also, upon application shutdown, a dialog will be presented providing the option of saving the current survey session data for the next session. Selecting this option will make the current survey data available the next time the survey application is started. (Note: the default file name extension for survey session data files is “.MDB”; this file extension will be applied by default unless another extension is provided as part of the file name.)

Opening Survey Data

Ground truth files and saved survey session data files may be used to initialize a survey session. The following sections describe opening ground truth files and survey session data files.

Opening Ground Truth Files

An existing ground truth file can be opened using the ‘Ground Truth File’ item of the ‘Open’ submenu of the ‘File’ menu or the ‘Open GT File’ toolbar button, shown in Figure 5-78. Selecting either of these items presents a file selection dialog. Using this dialog, an existing ground truth file in the WILD format can be selected. Once a file is selected, a survey session data set is created from the lane and object data contained in the file. A reference point is derived from the object data in the file; however, as the object data only specifies UTM easting and northing components, UTM grid data will have to be provided. (Note: the objects created from the data in the file will be identified as having originated from a ground truth file.)

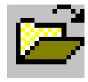


Figure 5-78. Open GT File toolbar button

Opening Survey Session Data

The data from a previous survey session can be opened using the 'Saved Survey Data' item of the 'Open' submenu of the 'File' menu. Selecting this item presents a file selection dialog. Using this dialog, a previously saved survey session data set can be opened.

Creating a New Survey Session

A new survey session can be initiated using the 'New' item of the 'File' menu or the 'New Survey' toolbar button shown in Figure 5-79. After selecting this item, the dialog for entering reference point and lane identification data is presented.

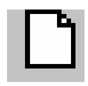


Figure 5-79. New Survey toolbar button

Exiting the Survey application

To exit the survey application, use the 'Exit' item of the 'File' menu. If one or more objects has been created or modifications have been made that have not been written to a ground truth file, a dialog will be presented providing the option of saving the objects to a ground truth file. If the user chooses to save the objects, the Select File Data Contents dialog will open to allow the user to limit the data in the file, and a file creation dialog will allow the user to select a file name and a folder in which the file will be created. Also, upon exiting the survey application, the user is given the option of saving the current survey session data for the next session. If the user selects to save this data for the next session, the next time the user starts a survey operation he will be prompted to use the existing data. If the user does not save the data for the next session, he will be given the option of saving it to an archive folder. Survey session data saved to an archive folder may be reopened within the survey application using the 'Saved Survey Data' item of the 'Open' submenu of the 'File' menu.

Mine Interactive Simulation Program (MISP)

This section provides instructions in the use and understanding of the evaluator interface portion of MISP. The MISP process uses operator-in-the-field location information (x,y,z) and internal modeling information from the TMS Virtual Mine Model (VMM) database to obtain various predictions and evaluation metrics with respect to the events associated with operator/mine encounters. MISP presents this information in various dialog boxes and windows.

An evaluator uses this information, in the form of visual cues, to direct and evaluate all trainee actions within a real or simulated minefield environment.

MISP Relationships within TMS

TMS Master initiates MISP process after the evaluator elects either to run an exercise or to playback the data from a previous exercise. MISP initializes once the evaluator has selected the ground truth data or the exercise data file for playback. MISP obtains operator position and detector response data directly from the RGM. The processing of the operator data by MISP is controlled by the evaluator interaction with the TMS Master process. MISP processing will cease once the evaluator selects the Stop control of TMS Master, or, in the case of an exercise playback, when the exercise data stream reaches end-of-file. MISP is active within TMS only during a live, playback or HLA exercise operation.

Description of MISP Data Flow/Processing

Figure 5-80 below depicts the top-level data flow and processing associated with the MISP process. Each Operator Workstation is dedicated to a distinct exercise. An exercise is currently defined by a particular operator (human or vehicular) and by an associated ground truth file. The MISP process simply obtains and processes all static and real-time data contained in the RGM. For TMS Phase 2 this data comprises: (1) Operator real-time component (foot or track and detector) positions (x,y,z); (2) Operator real-time alarm events; (3) Modeling parameters for mine detonation algorithms; (4) Modeling parameters for the blast effects (lethal radius) algorithm; (5) Modeling parameters for attenuated pressure at the mine pressure plate as a function of burial depth and subsurface properties; and (6) Baseline operator statistical data (also referred to as average user statistics) used for comparisons and evaluations. During the configuration of an exercise, file data residing in both the VMM database file and the ground truth file is retrieved and placed in the RGM shared memory area (a data structure). At runtime, an external system obtains operator appendage/detector positions and operator alarms and sends these data items to the DataComms/DSP component over a digital link or connection. DataComms/DSP processes and reduces this data and places it into RGM; MISP then accesses and processes this in real-time to determine detonations, blast effects, operator performance evaluations, and detector feedback responses to virtual mines (if any).

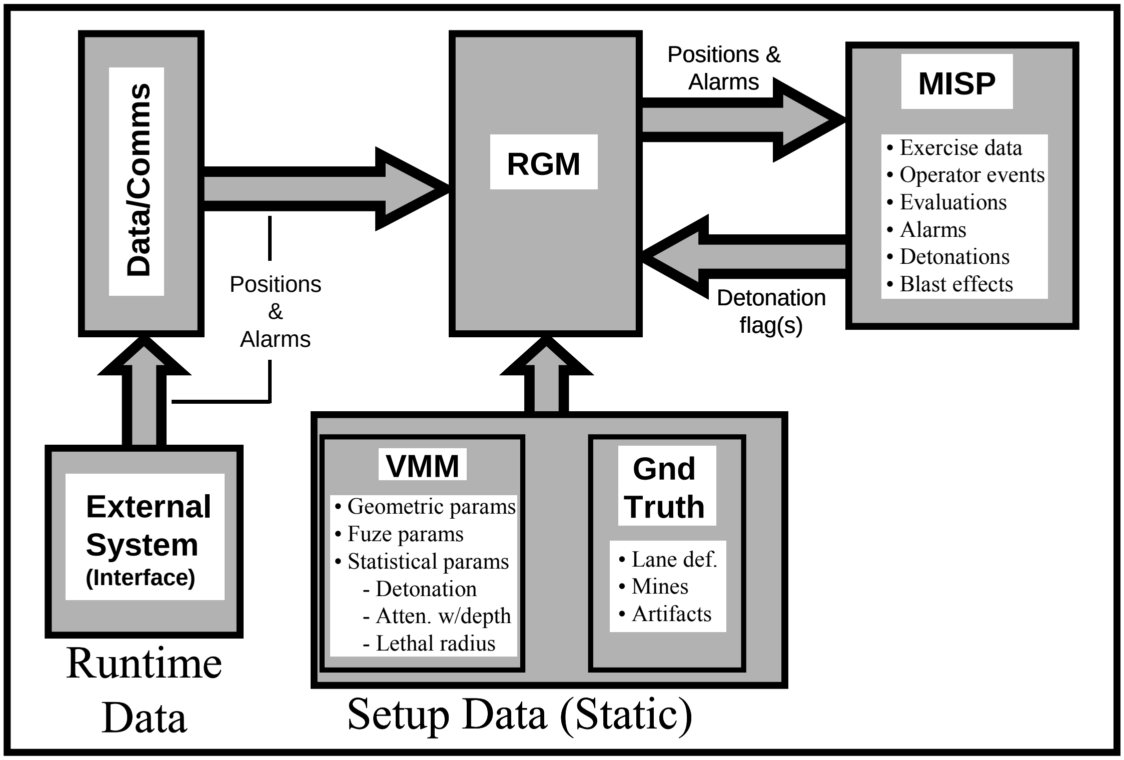


Figure 5-80. MISP data flow/processing.

The Default MISP window

Figure 5-81 below depicts the Default MISP window, which is displayed by the TMS software when an evaluator clicks the MISP taskbar button. This button becomes visible when the TMS Master launches (spawns) the MISP process. This window is relatively small in size. It can be repositioned but not resized; this is a design feature intended to reduce potential obscuration of displayed TMS display information. Clicking the close (**X**) button located in the right-hand portion of the title bar minimizes the window but does not terminate or pause the MISP process. Clicking the TMS icon, located in the left-hand portion of the title bar, provides access to the process' system menu, which provides alternate methods with which the evaluator can move or close the default window, and which provides access to the "About" dialog for MISP.

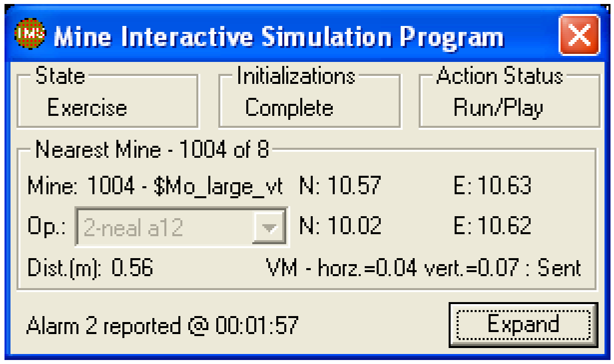


Figure 5-81. The Default MISP window.

Description of MISP Window Functional Items

Items within the default MISP window are intended mainly to provide operational feedback to evaluators of MISP status-related information. These include:

<u>State text box</u>

This box contains the current state of the overall TMS system (as controlled by TMS Master). Valid states are: Pre-Exercise, Exercise, and Post-Exercise.

<u>Initializations text box</u>

This box indicates whether TMS/MISP initializations are Complete or Pending.

<u>Action Status text box</u>

This box contains the current TMS Action Status as invoked by the evaluator using Master. Valid text indicators are: Run/Play, Pause, Stop. Also, the color MISP button on the Windows taskbar simultaneously depicts this same Action Status using the following color scheme (green-Run/Play, yellow-Pause, red-Stop).

<u>Nearest Mine - M of N group box</u>

This box contains several items: (1) the nearest mine and its coordinates (Northing, Easting); (2) Operator k coordinates, where for TMS Phase 2 the number k is by definition k=1 and functionality of this list box is disabled (dimmed); (3) the computed distance from the nearest mine to the nearest appendage (foot or track) of the selected field operator; (4) when the exercise ground truth data includes virtual mines, an indicator of the horizontal and vertical distance between the detector head and the virtual mine when the head is in close proximity to a virtual mine, as well as whether or not detector response data is being sent to the FIU.

Most recent event (number & time)

This item (along the lower window border) indicates the most recent event and its sequence number along with a time tag. Defined events include Detonation alerts, Operator Alarms, and mine Encounters.

Detonation indications

When the MISP detonation algorithm determines that a mine detonation event has occurred, it posts several simultaneous notices of this event. Two of these notices involve the default MISP window title bar and the MISP taskbar button. These two items are triggered to flash (blink) for a couple of seconds or so after a detonation decision and remain colored (orange) thereafter. At the same time, an acoustic signal sounds (similar to the sound of a revolver blast). Refer to Sections 5.3.3.3.1 and 5.3.3.3.3 for the other detonation notices.

The Expand button

Selecting this button opens the expanded MISP window. This new window is arranged as a Property Sheet that contains three pages accessed using the following three tabs: Exercise Data tab, Evaluation tab, and Detonations tab. Refer to the following Section 5.3.3.3 for specific details.

The Expanded MISP window

Figure 5-82 below depicts the expanded MISP window, which is displayed by the TMS software when an evaluator clicks the Expand button in the default MISP window (see Section 5.3.3.2.2 above). Upon initial display of this window, the page accessed by the Exercise Data tab is selected by default. This window can be repositioned but not resized. Clicking the close (**X**) button, located in the right-hand portion of the title bar of this window, causes the window to disappear but does not terminate or pause the MISP process; in this case, the window in-focus is once again the smaller default MISP window.

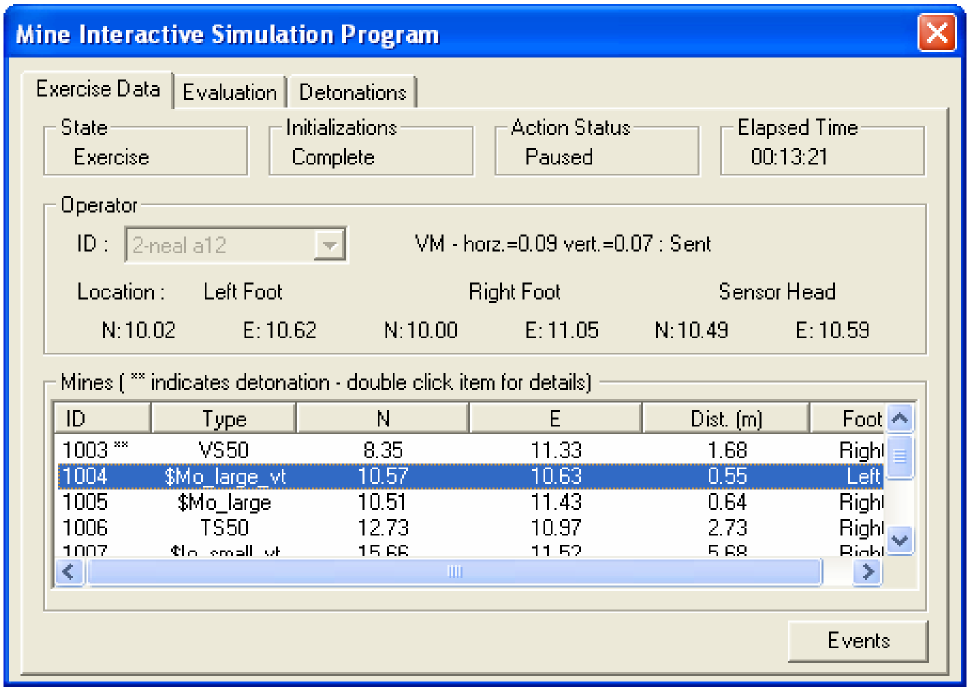


Figure 5-82. Expanded MISP window / Exercise Data page.

The Exercise Data page

Refer again to Figure 5-82 above. This page contains many items of information related to the progress of the exercise.

<u>State</u>

Indicates the current state of the overall TMS system (as controlled by Master). Valid states are: Pre-Exercise, Exercise, and Post-Exercise.

<u>Initializations</u>

Indicates whether TMS/MISP initializations are Complete or Pending.

<u>Action Status</u>

This box lists the current TMS Action Status as invoked by the evaluator using the TMS Master. Valid text indicators are: Run/Play, Pause, Stop. Also, the MISP taskbar button simultaneously depicts this same Action Status using the following color scheme (green-Run/Play, yellow-Pause, red-Stop).

<u>Elapsed Time</u>

Uses the internal system clock to record the elapsed time from the beginning of the exercise (once the evaluator selects the Start control of the TMS Master.)

<u>Operator group box</u>

This box contains operator ID selection (disabled) plus operator and sensor locations.

ID

Operator k selection; for TMS Phase 2 the number k is by definition k=1 and functionality of this list box is disabled (dimmed).

Location

Northing and easting coordinates (in meters) for the field operator's left/right appendages, and the detector head location. Also, when the exercise ground truth data includes virtual mines, an indicator of the horizontal and vertical distance between the detector head and the virtual mine when the head is in close proximity to a virtual mine, as well as whether or not detector response data is being sent to the FIU.

The Mines (** indicates detonation) list box

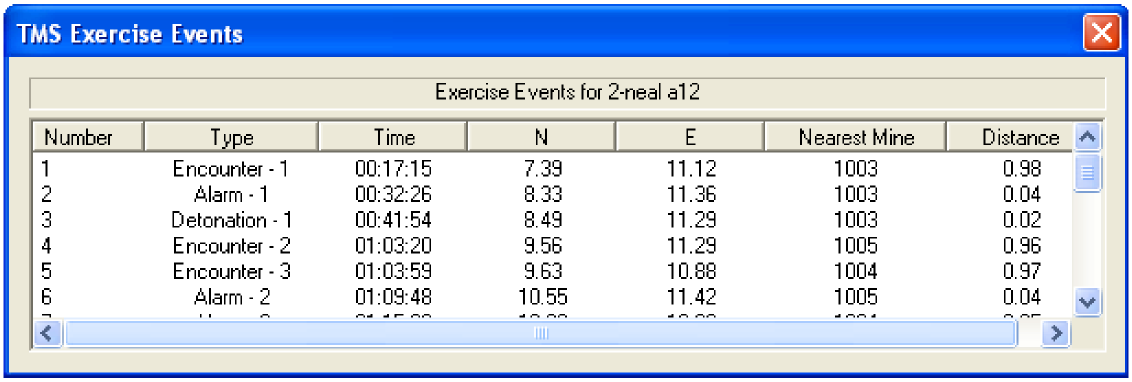
The Exercise Data page contains the Mines (** indicates detonation) list box. Table 5-1 below provides a brief description of each of the columns in the list. During the course of an exercise, MISP highlights the row representing the undetonated mine that is currently nearest the operator.

Table 5-1. Mines (indicates detonation).**

Column Name	Description
ID	Unique ID tag per mine; a double asterisk (**) will be appended to the tag if the mine detonates.
Type	Typically the name of the mine.
N	Mine northing coordinate value in ground truth (in meters).
E	Mine easting coordinate value in ground truth (in meters).
Dist. (m)	Distance in meters from the mine to the operator (min. of left/right foot distances).
Foot	Right or left, whichever appendage is closest to the mine.

The Events button

Figure 5-83 below depicts the TMS Exercise Events window, which is displayed by the TMS software when the evaluator clicks the Events button in the Exercise Data page of the expanded MISP window. This window can be repositioned but not resized. Clicking the close (**X**) button, located in the right-hand portion of the title bar of this window, causes the window to disappear but does not terminate or pause the MISP process; in this case, the window which comes in-focus is once again the expanded MISP window/Exercise Data page. The Events button will be disabled until MISP detects an event during the exercise/playback.


TMS Exercise Events

Exercise Events for 2-neal a12

Number	Type	Time	N	E	Nearest Mine	Distance
1	Encounter - 1	00:17:15	7.39	11.12	1003	0.98
2	Alarm - 1	00:32:26	8.33	11.36	1003	0.04
3	Detonation - 1	00:41:54	8.49	11.29	1003	0.02
4	Encounter - 2	01:03:20	9.56	11.29	1005	0.96
5	Encounter - 3	01:03:59	9.63	10.88	1004	0.97
6	Alarm - 2	01:09:48	10.55	11.42	1005	0.04

Figure 5-83. TMS Exercise Events window.

<u>Description of the Exercise Events list box</u>

The TMS Exercise Events window contains the Exercise Events list box. Table 5-2 below provides a brief description of each of the columns in the list.

Table 5-2. Exercise Events List Contents.

Column Name	Description
Number	Unique ID tag per exercise event
Type	Information about the event as follows: • Encounter - i^{th} • Alarm - j^{th} • Detonation - k^{th} where i, j, k are running counters for each of the above event types
Time	Computer clock time when event occurred
N	Operator northing coordinate value (nearest appendage, in meters)
E	Operator easting coordinate value (nearest appendage, in meters)
Nearest Mine	Numeric ID tag for nearest mine
Distance	For this event, the distance in meters to the nearest mine (min. of left/right appendage distances)

The Detonation Results window

Refer to the Mines list box in the expanded MISP window/Exercise Data page (Figure 5-82). Figure 5-84 below depicts the Detonation Results window, which is displayed by the TMS software when an evaluator double-clicks a row that indicates a detonated mine (as denoted by a double asterisk, "**").

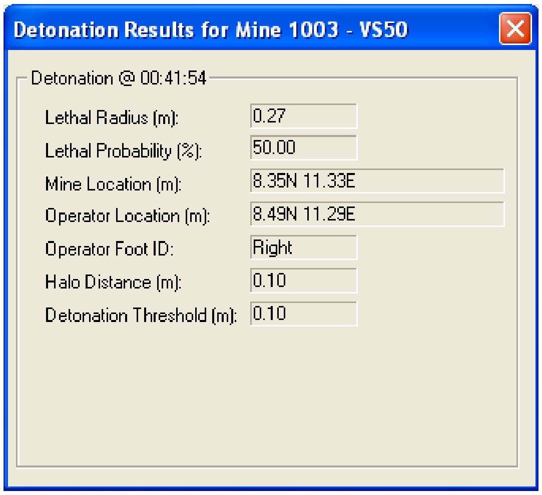


Figure 5-84. Detonation Results Window.

This Detonation Results window can be repositioned but not resized. Clicking the close (**X**) button, located in the right-hand portion of the title bar of this window, causes the window to disappear but does not terminate or pause the MISP process; in this case, the window which is in-focus is once again the expanded MISP window/Exercise Data page. Table 5-3 below provides a brief description of the data displayed in this window.

Table 5-3 Detonation Results Data.

Data Item Name	Description
Detonation @ xx:yy:zz	Time of detonation
Lethal Radius (m)	The lethal radius value (in meters) calculated by MISP at detonation, based on the characteristic data for the mine type.
Lethal Probability (%)	The lethal probability value (%) used to calculate the lethal radius.
Mine Location (m)	The northing and easting components of the location of the mine (in meters).
Operator Location (m)	The northing and easting components of the position of the left or right appendage of the operator at the time of detonation (in meters).
Operator Foot ID	Left or Right, whichever appendage is closest to the detonated mine.
Halo Distance (m)	The detonation halo distance (radius from the mine pressure plate in meters) calculated at detonation; a value of 0.0 or greater is listed for the foot causing the detonation, a value of –1.0 is listed for the foot not causing the detonation.
Detonation Threshold (m)	The detonation threshold distance (radius from the mine pressure plate) within which a detonation will occur.

The Evaluation Page

Figure 5-85 below depicts the Evaluation page that is displayed by the TMS software when the evaluator clicks the corresponding tab. The information MISP displays assists an evaluator in evaluating and directing the field operator training session.

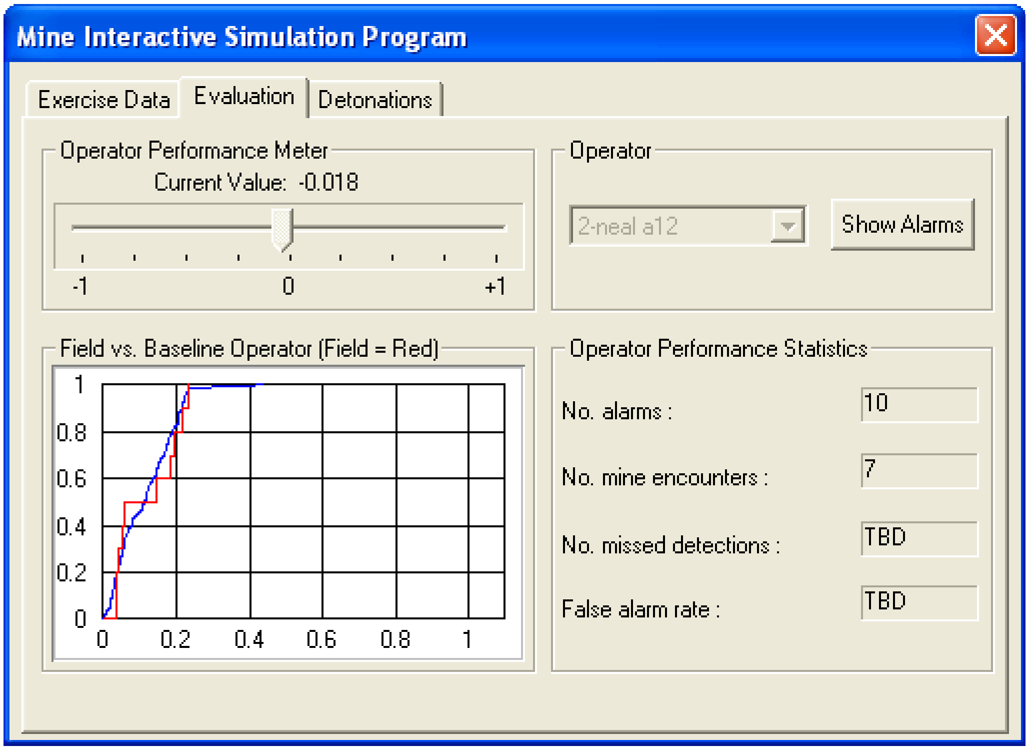


Figure 5-85. Evaluation page

<u>The Operator Performance Statistics group box</u>

There are four items in this box. Two of these items, the number of missed detections and the false alarm rate, are TBD/disabled and, so, do not display any useful information for TMS Phase 2. The first of the enabled items, the number of alarms, simply keeps a running sum of all alarms for the chosen operator. Currently, TMS/MISP supports just one operator. The other enabled item, the number of mine encounters, keeps a running sum of all mines encountered. Currently, an encounter is defined using nearest distance measures and proximity thresholds. The nearest distance is measured from each appendage to each mine centroid, with selection of the smaller of these two measurements.

<u>The Field vs. Baseline Operator CDF plots</u>

The VMM Access database stores discrete data representing points of the baseline operator's Cumulative Distribution Function (CDF) curve (also referred to as Average User Statistics). This is an experimentally derived set of points representing statistics against which the field operator's (trainee's) experimental statistics are compared. Let $\mathbf{F_X}(x)$ denote a CDF defined with respect to the random variable x. Recall that $0 \leq \mathbf{F_X}(x) \leq 1$ and that $\mathbf{F_X}(x_0)$ is, by definition, the probability that $x \leq x_0$ for all extracted random variables, x. Currently for Phase 2, the underlying random variable is the alarm miss distance, which is defined as the distance from the particular alarm position to the centroid of the nearest mine. During TMS Setup mode, MISP displays this baseline curve in the Evaluation page by connecting every two successive points in the plot with straight lines. During the course of an exercise, the field operator (trainee) generates alarms in sequence and their miss distances form a discrete (stair-step) CDF curve. For every alarm update this CDF curve changes. After every such update, MISP plots the most recent discrete (stair-step) CDF curve. Plotting it in this stair-step fashion emphasizes the discreteness of the data, especially during the early stages of an exercise. As an example, the plot in Figure 5-83 above depicts the field operator (trainee) CDF after ten alarms.

The Operator Performance Meter (slider control)

In order to report trainee performance deviations, either positive or negative, relative to some baseline, a computable metric must be used. For Phase 2, the manner of evaluation is as follows. Denote the set of baseline operator miss distances as $X=\{x_i; i=1,2,\ldots,N_1\}$ and denote the set of trainee miss distances as $Y=\{y_j; j=1,2,\ldots,N_2\}$. Using these sets, we obtain first order estimates of their respective cumulative distribution functions (CDFs) using sorted (ascending) sequences, i. e., $X_{sorted} = \{x_{\langle i \rangle}\}$, $i=1,2,\ldots,N_1$ and $Y_{sorted}=\{y_{\langle i \rangle}\}$, $i=1,2,\ldots,N_2$. Thus, the curve which passes through the ordered set of points $F_X = \{ (x_{\langle n \rangle}, 1/n); n=1,2,\ldots,N_1 \}$ represents an estimated CDF derived from the set X while the curve which passes through the ordered set of points $F_Y = \{ (y_{\langle n \rangle}, 1/n); n=1,2,\ldots,N_2 \}$ represents an estimated CDF derived from the set Y. As discussed in the previous section, TMS/MISP displays both of these curves, F_X and F_Y, in real time within the expanded MISP window/Evaluation tab. A simple metric, used to measure the difference between F_X and F_Y, is the integrated difference (normalized via a sigmoidal map). It is:

$$m_{diff} = s(z_I), \text{ where } z_I = (I_{Operator} - I_{Baseline})$$

$s(\cdot)$ is monotonically increasing, $s(-\infty) = -1$, and $s(+\infty) = +1$. Currently, the sigmoidal map $s(\cdot)$ is $s(z) = \arctan(k \cdot z)$. The factor k is an expansion or compression parameter intended to improve the intuitive feel of the final performance value. Presently, k=1.

For continuous curves,

$$I_{Baseline} = \int_{r=0}^{R_{\max}} F_X(r)dr$$

$$I_{Operator} = \int_{r=0}^{R_{\max}} F_Y(r)dr$$

for which R_{max} = Max(r_1, r_2) with r_1=smallest r such that $F_X(r)$=1 and r_2=smallest r such that $F_Y(r)$=1. For our case of discretely defined curves,

$$I_{Baseline} \cong A_1 + \sum_{n=1}^{N_1-1} \frac{n}{N_1} \cdot \left(x_{\langle n+1 \rangle} - x_{\langle n \rangle} \right) \;\; with \;\; A_1 = \begin{cases} \left(y_{\langle N_2 \rangle} - x_{\langle N_1 \rangle} \right), & x_{\langle N_1 \rangle} < y_{\langle N_2 \rangle} \\ 0, & x_{\langle N_1 \rangle} \geq y_{\langle N_2 \rangle} \end{cases}$$

$$I_{Operator} \cong A_2 + \sum_{n=1}^{N_2-1} \frac{n}{N_2} \cdot \left(y_{\langle n+1 \rangle} - y_{\langle n \rangle} \right) \;\; with \;\; A_2 = \begin{cases} \left(x_{\langle N_1 \rangle} - y_{\langle N_2 \rangle} \right), & y_{\langle N_2 \rangle} < x_{\langle N_1 \rangle} \\ 0, & y_{\langle N_2 \rangle} \geq x_{\langle N_1 \rangle} \end{cases}$$

Due to the sigmoidal normalization, the computed value for m_{diff} is always between -1 and +1. TMS/MISP displays the outcome of this computation using the position of a slider control in the Operator Performance Meter Group box on the Evaluation page.

The Operator group box

Items in this box deal with the field operator alarm data used in the plotted display.

The Operator N list box

For TMS Phase 2, the number N is by definition N=1 and so the functionality of this list box is currently disabled (dimmed). If enabled at some point, selection of Operator N will display data in the entire window exclusively for the N^{th} field operator.

The Show Alarms button

This button, when clicked, presents a display of all field operator alarms up to the present time. Figure 5-86 below depicts the Alarms window per such a request. Clicking the close (**X**) button, located in the right-hand portion of the title bar of this window, causes the window to disappear but does not terminate or pause the MISP process; in this case, the window in-focus is once again the expanded MISP window/Evaluation page.

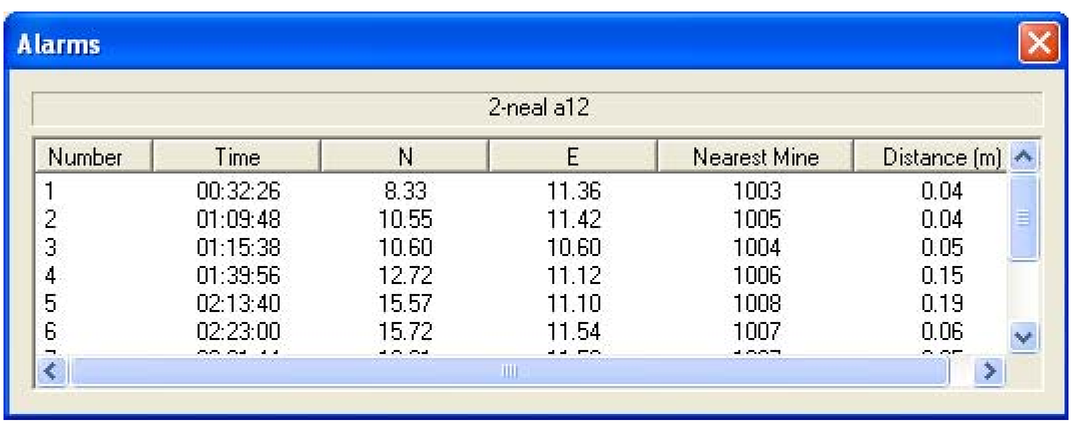


Figure 5-86. Alarms data window.

The Alarms list box

The Alarms window contains the Alarms list box. Table 5-4 below provides a brief description of each of the columns in the list.

Table 5-4. Alarms List Contents.

Column Name	Description
Number	Unique ID tag per alarm.
Time	Computer clock time when alarm notification was placed.
N	Alarm location northing coordinate value (in meters).
E	Alarm location easting coordinate value (in meters).
Nearest Mine	Numeric ID tag for nearest mine.
Distance (m)	Distance from alarm to nearest mine (in meters).

The Detonations Page

Figure 5-87 below depicts the Detonations page that is displayed by the TMS/MISP software when an evaluator clicks the corresponding tab in the expanded MISP window. The information MISP displays relates to detonated mines and predicted blast effects, in particular the lethal radius estimate.

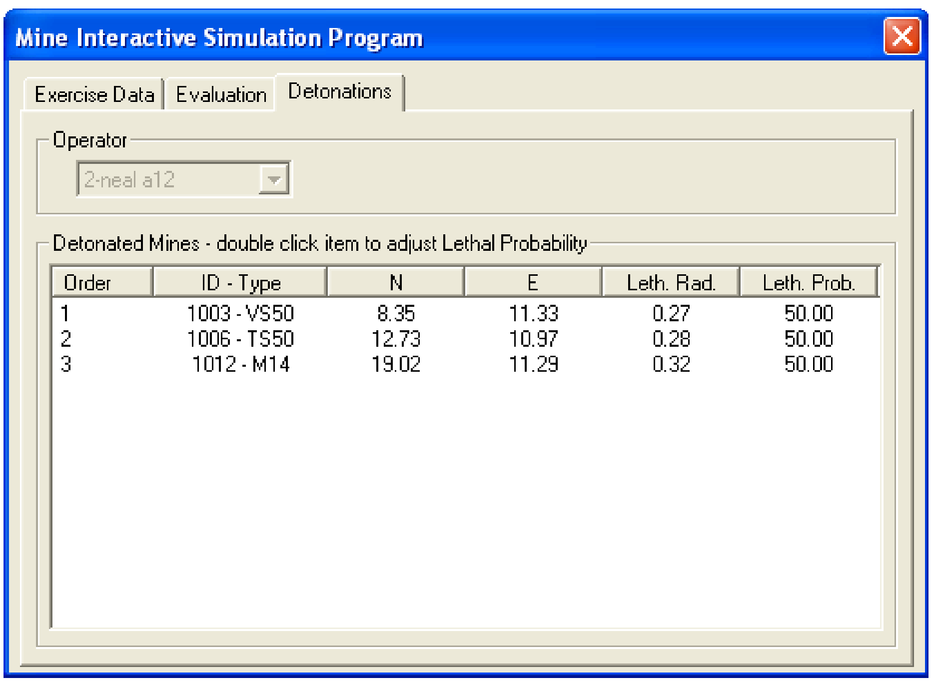


Figure 5-87. Detonations Page in the Expanded MISP Window.

The Operator group box and Operator N list box

For TMS Phase 2, the number N is by definition N=1 and so the functionality of this list box is currently disabled (dimmed). If enabled at some point, selection of Operator N will display detonation data on this page exclusively for the Nth field operator.

Description of Detonated Mines group/list box

Table 5-5 below provides a brief description of each of the columns in the list. When an evaluator double-clicks a particular row in the list, the Adjust Lethal Probability window appears (see next section).

Table 5-5 Detonated Mines List Contents.

Column Name	Description
Order	Sequential numbering tag per detonation per operator.
ID - Type	Mine ID and Type (name); for example, "2-M14" denotes ID=2 and Type=M14
N	Mine location northing coordinate value (in meters).
E	Mine location easting coordinate value (in meters).
Leth. Rad.	Computed lethal radius value (in meters).
Leth. Prob.	Requested lethal probability (%), defaulted from VMM during setup or reentered at runtime (by double clicking a row in the list).

The Adjust Lethal Probability window

Figure 5-88 below depicts the Adjust Lethal Probability window. To open this window the evaluator must initially be in the expanded MISP window/Detonations page and double click the row in the Detonated Mines list box that corresponds to a mine of interest. Clicking the close (**X**) button, located in the right-hand portion of the title bar of this window, causes the window to disappear but does not terminate or pause the MISP process; in this case, the window in-focus is once again the expanded MISP window/Detonations page.

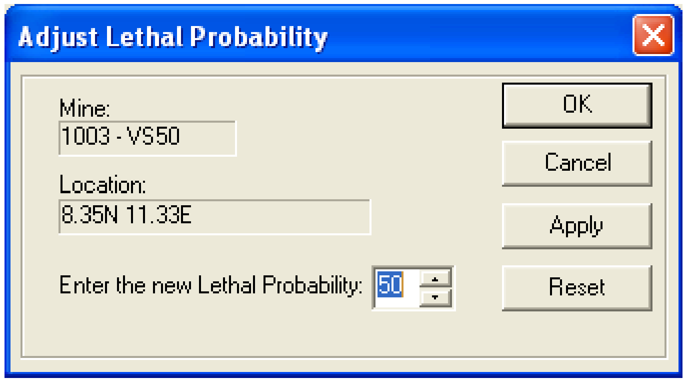


Figure 5-88. The Adjust Lethal Probability window.

The Mine and Location text boxes
The display-only information in these boxes is associated with the chosen mine (its ID, type, and location).

Enter the New Lethal Probability
The evaluator enters a new value for the lethal probability in integral percentage units (1 - 100) directly or via the spin button control.

The Apply button
Clicking this button forces a new computation of the MISP Phase 2 blast effects algorithm using the requested lethal probability value as described above and the modeling parameters contained in the VMM database. The output of this algorithm is the lethal radius. This output may be observed in the entry for the selected mine in the Detonated Mines list box on the Detonations page of the expanded MISP window. It may require some repositioning of the Adjust Lethal Probability window in order to observe these numbers. Note also that the evaluator need not reenter a new lethal probability value before clicking the Apply button; a new lethal radius value will be calculated each time using the probabilistic parameters in effect.

The Reset button
This button resets the lethal probability to the default value listed in the VMM and resets the lethal radius to the value initially computed upon mine detonation.

The OK button
This button performs the same function as the Apply button, but closes the window after performing the lethal radius calculation.

The Cancel button
This button closes the window without performing the lethal radius calculation.

CTMSHost

The CTMSHost application provides the interface between the TMS Master and the Countermine Test Management System (CTMS). In TMS Phase II, CTMS executes on a separate computer from other TMS evaluation and simulation components. The Master and CTMSHost interact through the exchange of messages over a dedicated Ethernet connection.

Local to the CTMS workstation, CTMSHost initializes RGM compliant with the TMS Phase 1 application programming interface (API) for data and event communications between itself and CTMS, invokes the CTMS Reports Manager for post-exercise analysis, and provides the mechanism for configuring CTMS for Exercise and Playback operations.

Startup

At startup, the CTMSHost and CTMS windows appear as shown in Figure 5-89. Figure 5-90shows the CTMSHost underlying startup menus. The Exit menu terminates both CTMSHost and CTMS and sends a notification message to the Master. The ‘Analysis’ item of the ‘Operations’ menu allows the evaluator to invoke the CTMS Reports Manager for post-operation analysis of exercise results.

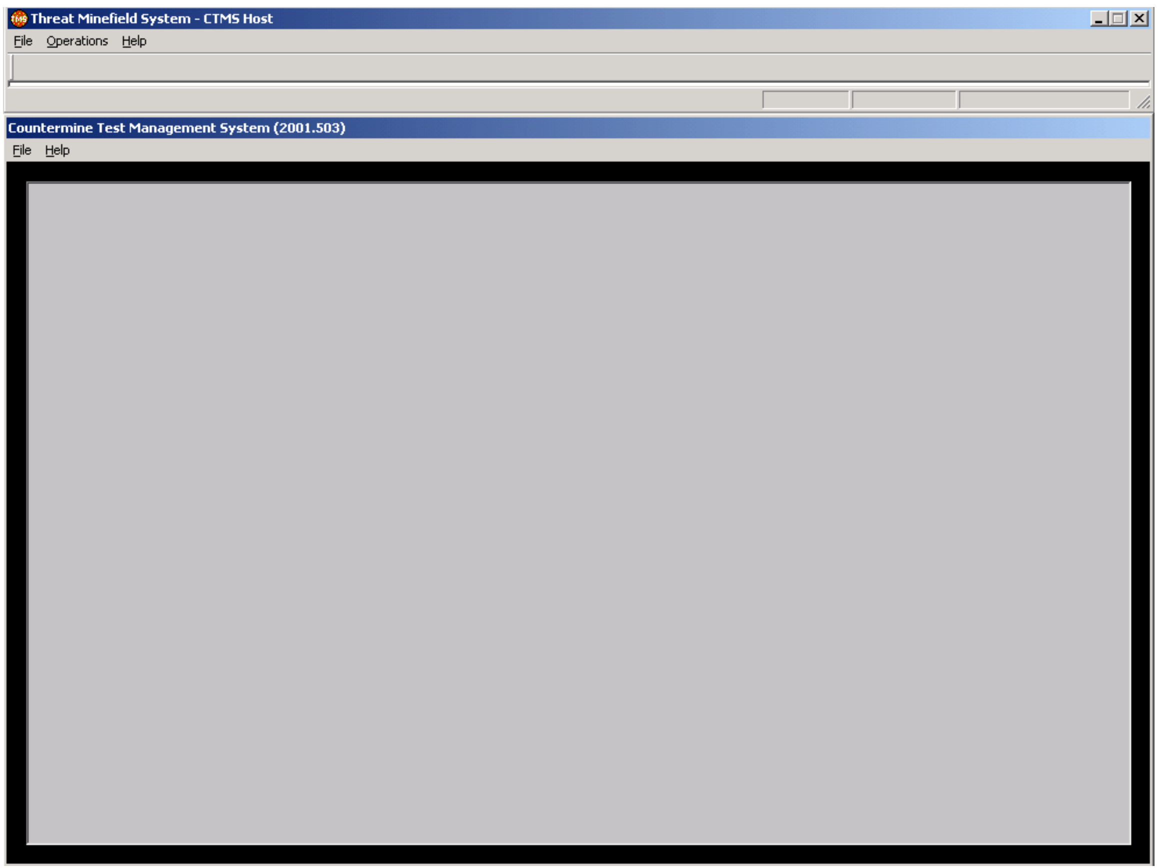
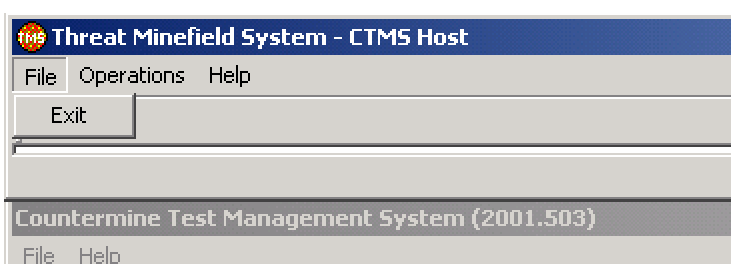


Figure 5-89 CTMSHost and CTMS main windows



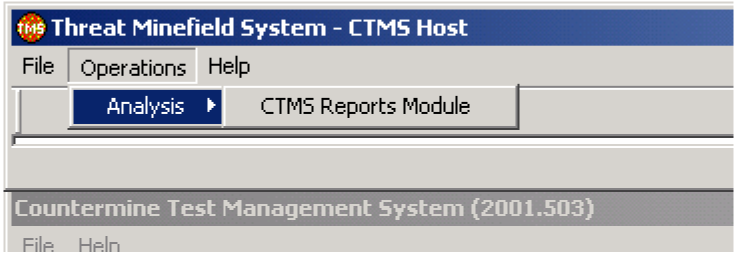


Figure 5-90. Startup menus

Operations

Exercise

To execute an Exercise operation on the CTMS workstation simultaneously with TMS Master, the exercise must first be initiated on the Master by following the procedures in Section 5.3.2.2.1. To load the ground truth file in CTMS, select the 'New Test Importing' item of the CTMS 'File' menu. In the 'Target, Lane and Landmark Files' dialog, select the appropriate ground truth file and click 'Open'. In the next dialog, 'Characteristics for New Test Data', enter an ID for the exercise and click 'OK'. The dialog's additional fields are not required. After the ground truth file is loaded, the status bar message turns to 'Ready' and the 'Start' button and the 'Start' item on the 'Actions' menu are enabled. (Note: to ensure that alarms received during an exercise are saved to the CTMS database for inclusion in post-operations analysis, the 'Save Automatically' item of the CTMS 'File' menu should not be selected - selection is indicated by a check mark by the item in the menu.)

Figure 5-91 shows the CTMS workstation applications configured for an exercise. The first pane on the CTMSHost main window status bar displays the operation type. The second pane displays the ground truth filename and the third pane is the exercise name. The icons on the grid display depict the objects in the ground truth file.

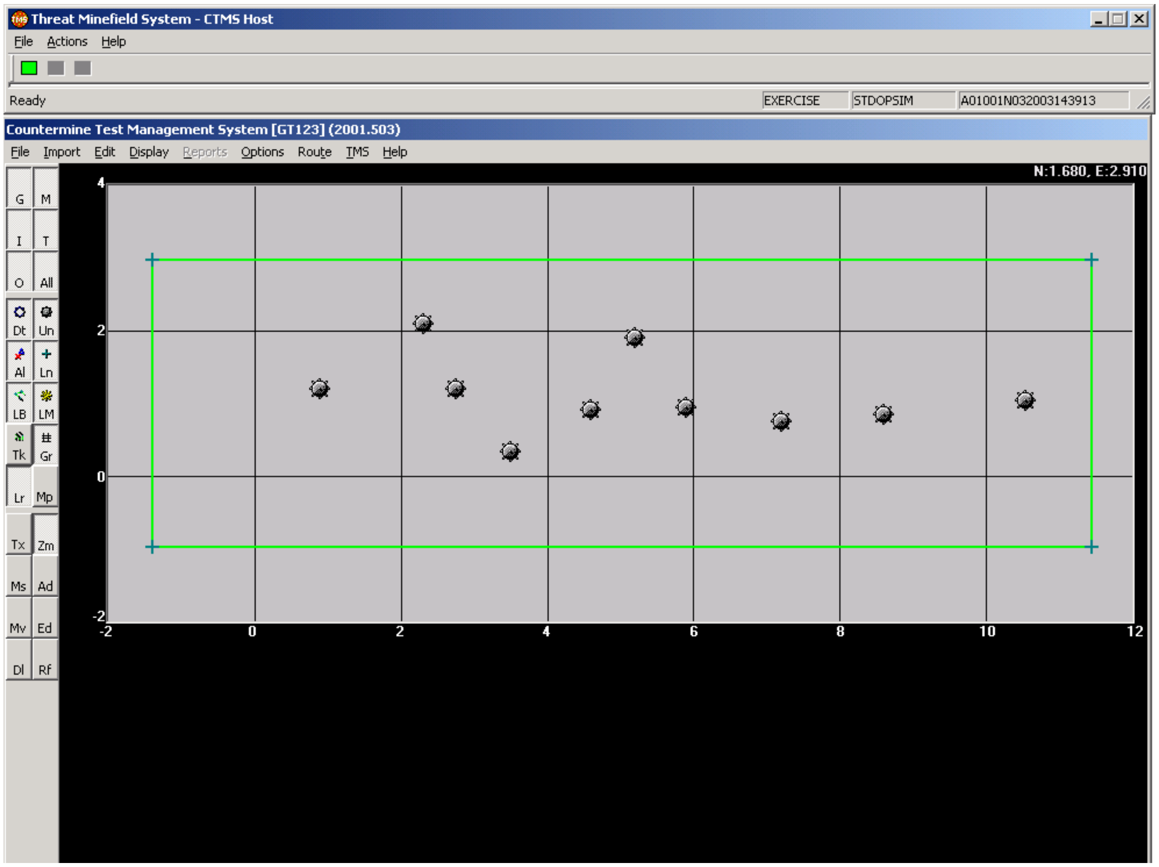


Figure 5-91. Exercise operation

Exercise Functions

The following sections describe the application controls and options provided during an exercise operation.

Start

Refer to Section 5.3.2.2.1.1.13. Note: The exercise can be started in the TMS Master or CTMSHost.

Pause

Refer to Section 5.3.2.2.1.1.14. Note: The exercise can be paused in the TMS Master or CTMSHost.

Stop

Refer to Section 5.3.2.2.1.1.15. Note: The exercise can be stopped in the TMS Master or CTMSHost.

Stop Exercise in CTMS

CTMS may experience a delay in reading and displaying exercise data, hence after an exercise is stopped, a dialog is launched prompting the evaluator to stop the exercise in CTMS or continue. To eliminate the 'Stop Exercise in CTMS' dialog, check the 'Apply to subsequent exercises' option and click 'OK'. Checking the 'Stop Exercise in CTMS' item of the 'Options' submenu of the 'File' menu also eliminates the dialog.

Saving Alarms in CTMS

For alarms reported during an exercise to be saved in the CTMS database for inclusion in analysis provided by the CTMS Reports Manager, they must be saved manually in CTMS. To save the alarms, select the 'Save Now' item of the 'File' menu in CTMS.

After an exercise is stopped, a dialog box is launched to remind the evaluator that alarms have to be saved manually in CTMS. To eliminate this dialog, check the 'Apply to subsequent exercises' option and click 'OK'. Checking the 'Display 'Save Alarms' message' item of the 'Options' submenu of the 'File' menu also eliminates the dialog.

Playback

To execute a playback exercise from CTMSHost, the exercise must first be initiated on the Master by following the procedures in Section 5.3.2.2.2. CTMS does differentiate between a live exercise and playback exercise.

Figure 5-92 shows the CTMS workstation applications after a playback exercise is configured. The CTMSHost status bar pane contents are identical to those during an Exercise operation. The first pane on the status bar displays the operation. The second pane displays the ground truth filename and the third pane is the exercise name.

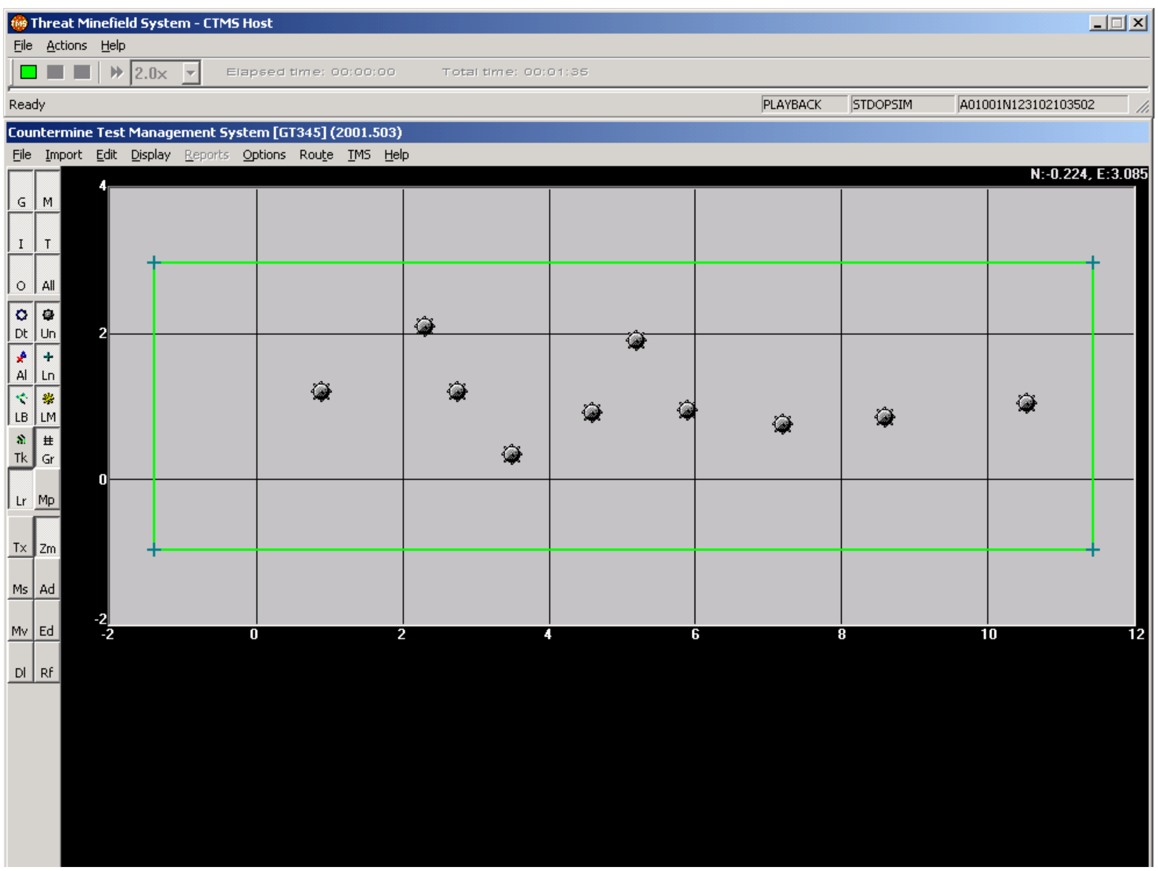


Figure 5-92. Playback operation

Playback Functions

The following sections describe the application controls and options provided during a playback operation.

Start

Refer to Section 5.3.2.2.1.1.13. Note: Playback can be started in the TMS Master or CTMSHost.

Pause

Refer to Section 5.3.2.2.1.1.14. Note: Playback can be paused in the TMS Master or CTMSHost.

Stop

Refer to Section 5.3.2.2.1.1.15. Note: Playback can be stopped in the TMS Master or CTMSHost.

Fast Forward

Refer to Section 5.3.2.2.2.1.15. Note: Fast forward can be manipulated in the TMS Master or CTMSHost.

Stop Exercise in CTMS

Refer to Section 5.3.4.2.1.1.4.

Saving Alarms in CTMS

Refer to Section 5.3.4.2.1.1.5.

Analysis

Using the 'File' menu, select 'Operations'→'Analysis'→'CTMS Reports Module', to initiate Analysis under CTMSHost. The CTMS Reports Manager invokes Microsoft Access, as shown in Figure 5-93.

Refer to the CTMS User's Guide for instructions on displaying and printing Report Module graphs and reports. The ID entered in the dialog, 'Characteristics for New Test Data', referred to in Section 5.3.4.2.1, is the ID that is entered in the 'Test Id' field of the Test Reports Manager.

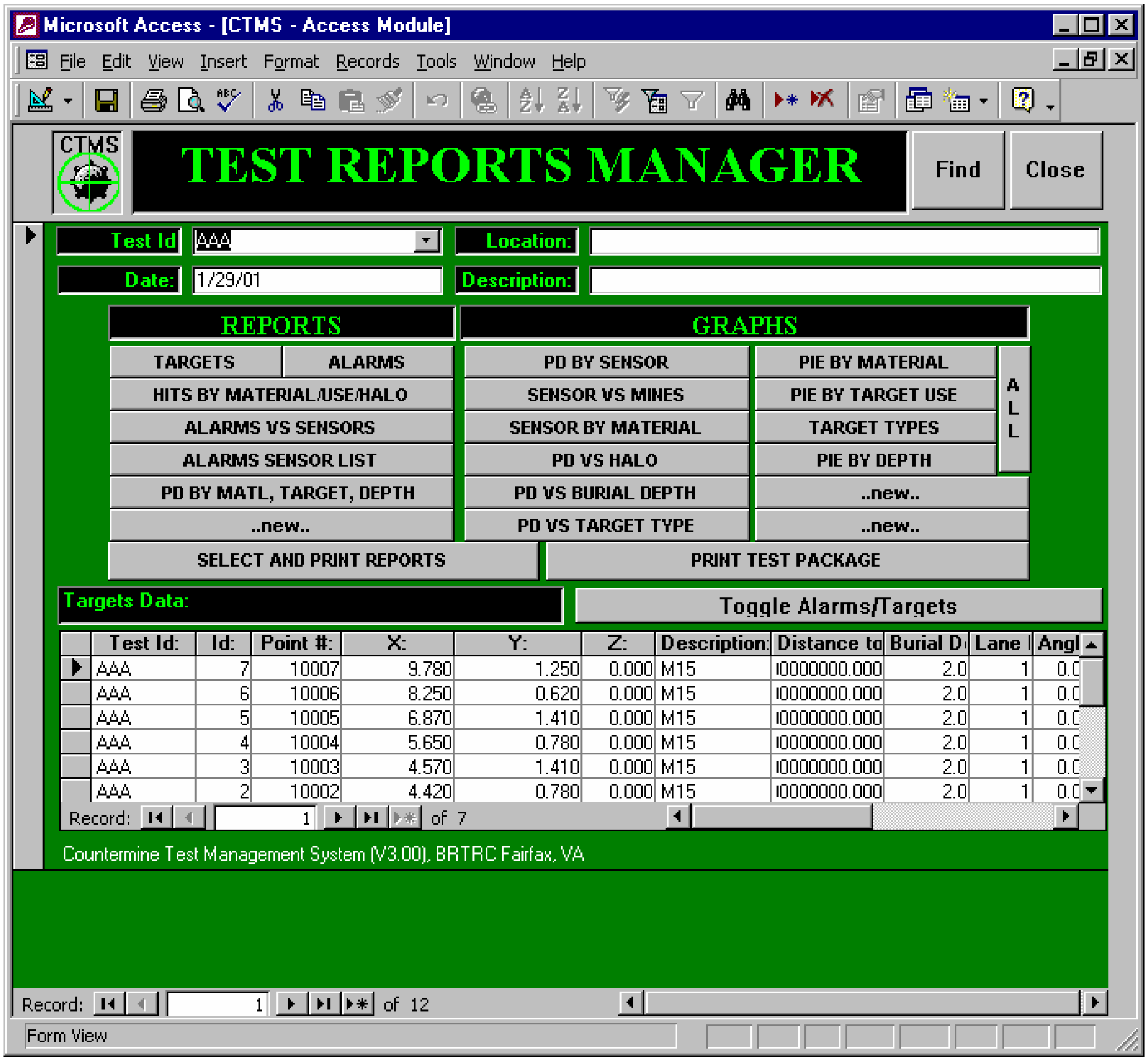


Figure 5-93. CTMS Reports Manager

Field Instrumentation

The TMS field instrumentation comprises hardware and software used to acquire and send data associated with mine detector operations to TMS DataComms/DSP and to receive commands and data from TMS DataComms/DSP. The field instrumentation is considered an embedded system and functions without any display device during normal operations. In the following sections, figures depicting screen shots are used to illustrate the processing within the field instrumentation and would not be visible or accessible to a mine detector operator during normal use.

Operator Client – Data Acquisition and Communications Application

The Operator Client application ("OpCli.exe") acquires mine detector and position data and sends it to DataComms/DSP. OpCli.exe retrieves XYZ position by using the GetPosition method exposed by the Arc Second, Inc. 3DiWorkbench application. Mine detector data is retrieved by either reading a data stream from the RS-232 port or from an Analog-to-Digital converter, depending upon the type of detector. Note: Currently TMS has been tested with 2 mine detectors: the F-3 and AN/PSS-12. The F-3 outputs data via an RS-232 port. The AN/PSS-12 outputs analog data. SRC modified the AN/PSS-12 such that the analog data is input into an Analog to Digital converter whose form factor is PCMCIA. OpCli.exe then reads the values from the A-to-D converter. As more mine detectors are integrated with TMS, other data acquisition methodologies may be implemented.

OpCli.exe Command-Line Parameters

OpCli.exe makes use of Windows initialization files (".INI" extension) that contain sections and key names (parameter settings) to configure an instance of OpCli.exe such that its runtime operation is characterized by the initialization file parameters. OpCli.exe uses two files: Operator.ini and TMS_Comm.ini. Operator.ini contains parameters that pertain to the operator software functionality only. TMS_Comm.ini contains parameters that apply to both DataComms/DSP and OpCli.exe. Both of these files reside in the Windows root directory (C:\Windows.) Given the command-line

```
C:\TMS_Home\TMS_Bin\OpCli.exe OPERATOR_6
```

OpCli.exe will use the key name parameter settings in the section OPERATOR_6, in both the Operator.ini and TMS_Comm.ini files (see Sections 5.3.5.1.2 and 5.3.5.1.3 for detailed descriptions of the ".INI" files) to define its runtime operability.

Operator.ini

Table 5-6 describes each of the key name entries in the Operator.ini file and shows all possible values for each key name.

Note: The contents of the .INI files are listed for the edification of the reader. The parameter values in these files are configured to provide optimal system performance. Modification of these files is NOT recommended.

Table 5-6. Operator.ini Key name Descriptions

Item	Values	Description
[OPERATOR_6]	NA	Section Name
CommPort	1 - 10	Com Port # used for remote communications purposes (Default: None)
CommBaudRate	300 1200 2400 4800 9600 19200 38400 57600 115200	Baud rate used for remote communications purposes (Default: None)
MineDetComPort	1 - 10	Com Port number when communicating with mine detector (Default: 5)
MineDetBaudRate	300 1200 2400 4800 9600 19200 38400 57600 115200	Baud rate used when communicating with the mine detector (Default: 9600)
MineDetType	ANPSS12 F1A4 F3	Mine detector type (this key name is ignored if the MineDetAutoDetect key name is set to 1) (Default: ANPSS12)
SensorUpdateRate	10 20 30 40 50 60 70 80 90 100	The sensor data acquisition update rate in hertz (Default: 20)
PositionUpdateRate	1 2 3 4 5 6	The position data acquisition update rate in hertz (Default: 10)

Item	Values	Description
	7 8 9 10	
PositionSysType	Time_Domain Arc Second	The positioning system type (Default: ArcSecond)
MineDetAutoDetect	0 - Off 1 - On	Flag determining whether or not to use the auto-configure feature to automatically detect what type of mine detector is connected to the instrumentation package (do not set this the auto detect key name to 1 when testing with the Arc Second position instrumentation using the same port as the F3; when the port is initialized to attempt to read F3 data, a fatal error occurs) (Default: 1)
SimSensorFeedbackInput	0 - Off 1 - On	Flag determining whether or not to manifest the Virtual Mine Modal feedback as a function of PC speaker (using the Beep API); or reading from the mine detector after the value has been injected into the mine detector (Default: 0)
AlarmKeyPressInterval	2 – 2 seconds 3 – 3 seconds 4 – 4 seconds 5 – 5 seconds	Flag determining how long to wait for a second key press after an initial alarm enunciator key has been pressed (Default: 3)

TMS_Comm.ini

Table 5-7 describes each of the key name entries in the TMS_Comm.ini file and shows all possible values for each key name.

Table 5-7. TMS_Comm.ini Key name Descriptions

Item	Values	Description
NetType	ETHERNET SERIAL P1_SERIAL SURVEY_INSTR_AS SURVEY_SERIAL	The network type (Default: ETHERNET)
Host ID	Valid IP Address	Host (DataComms/DSP) IP address (Default: NA)
TransportType	UDP TCP	Transport type (Default: UDP)

3DiWorkbench – Angle to XYZ Conversion

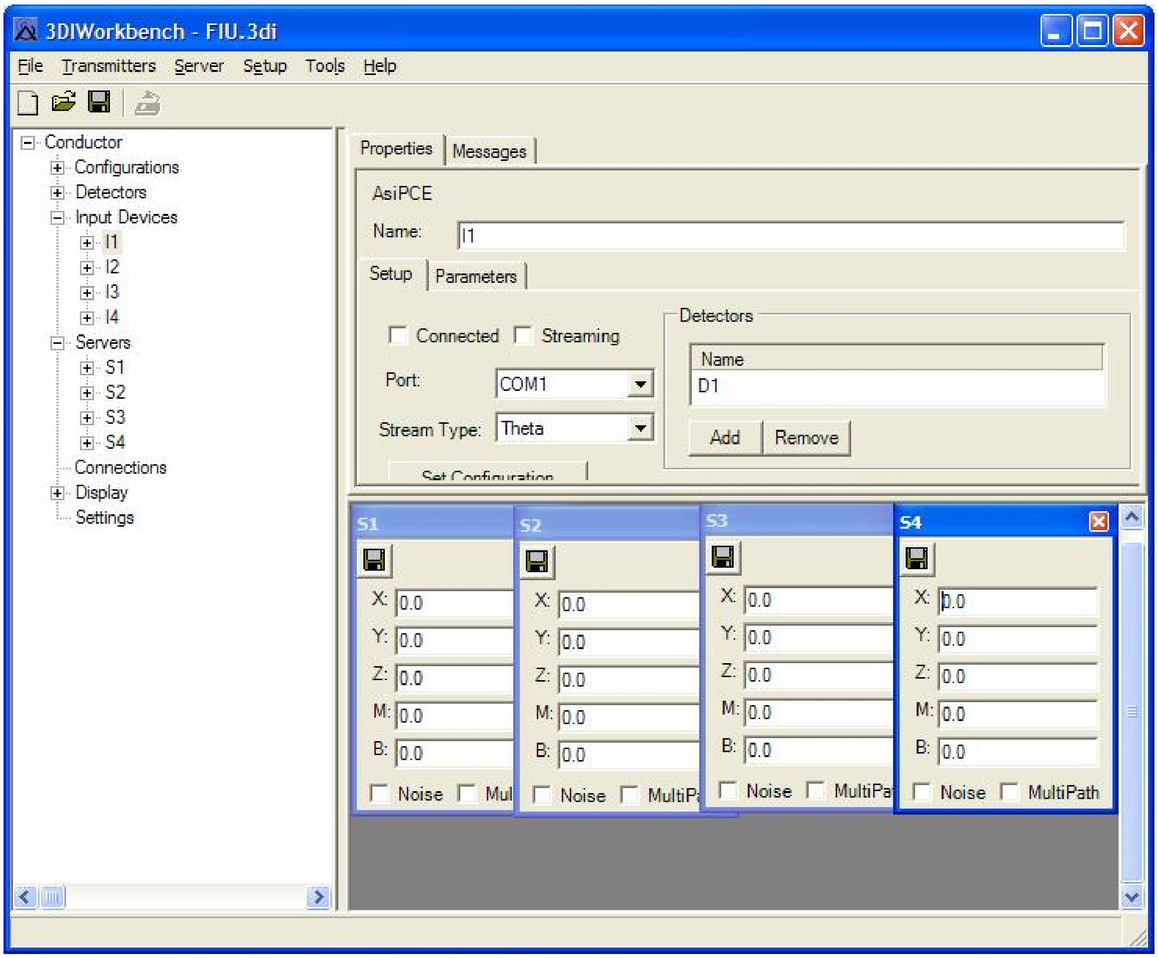


Figure 5-94. 3DiWorkbench

The Arc Second, Inc. 3DiWorkbench Windows Application acquires angles and converts them to XYZ coordinates. 3DiWorkbench is a position data server. That is, it exposes methods and properties that are used by Operator Client to extract XYZ position data from memory. Figure 5-94 shows the 3DiWorkbench application main window.

Operator Client and 3DiWorkbench Execution

To start sensor and position data acquisition on the FIU, 3DiWorkbench and Operator Client must be executed respectively. 3DiWorkbench is executed first to connect to the PCEs to begin collecting angle data and converting it to position data (X,Y,Z). Next, Operator Client is executed with the appropriate command line parameter. The procedure to begin data acquisition and transmission on the FIU is as follows:

Note: The following procedure assumes the following:

- A Wireless Ethernet connection to the FIU is available
- 3DiWorkbench calibration has been completed (see Appendix A)
- The optical detectors and the metal detector are properly connected to the FIU (the metal detector should be on)

1. Launch PCAnywhere on the appropriate workstation and connect to the FIU of interest (See Figure 5-95).

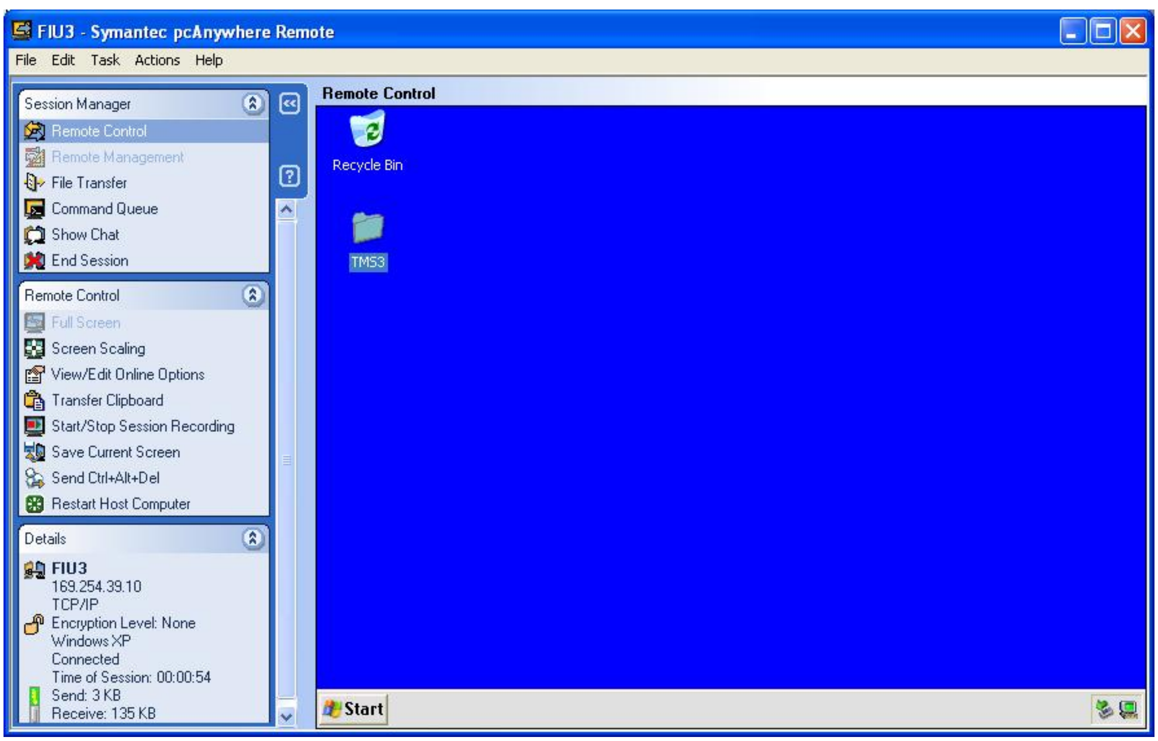


Figure 5-93. PCAnywhere window as displayed on the TMS Workstation

2. On the FIU, launch 3DiWorkbench (See figure 5-96).

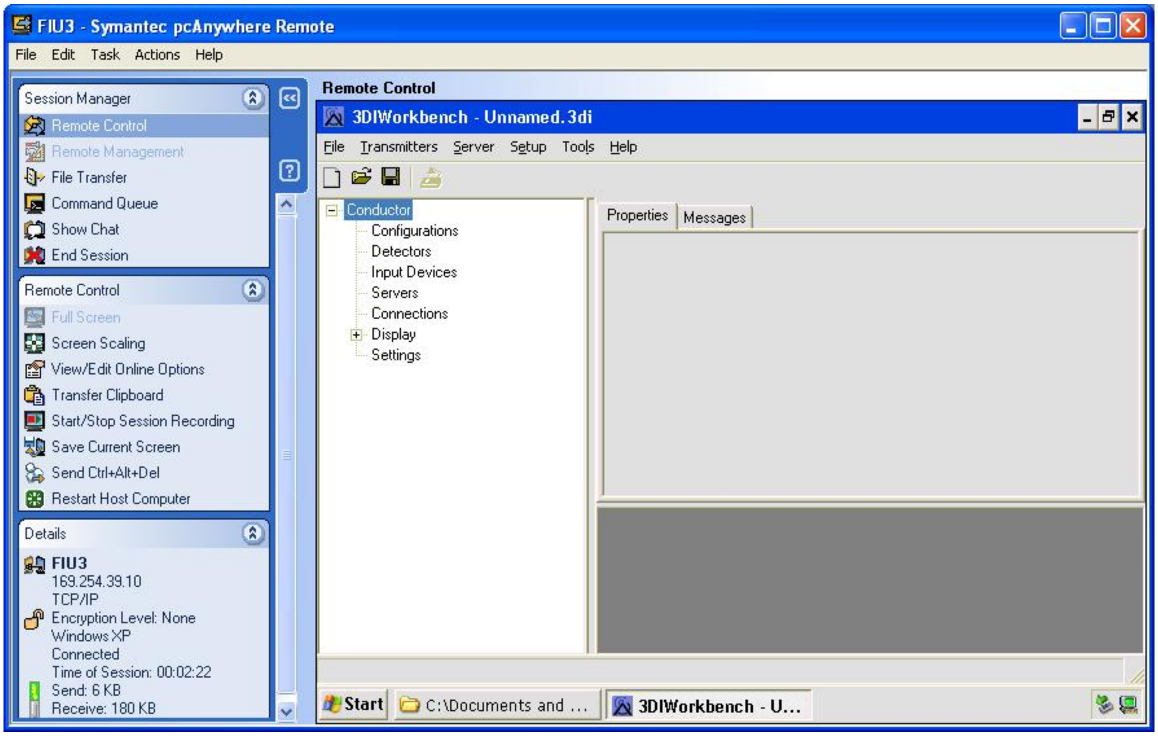


Figure 5-96. 3DiWorkbench Initial Display as displayed in PC anywhere

3. Within 3DiWorkbench, from the File menu, select Open. From the resulting file selection dialog, select the file \TMS_Home\TMS_Bin\FIU.3Di (See Figure 5-97).

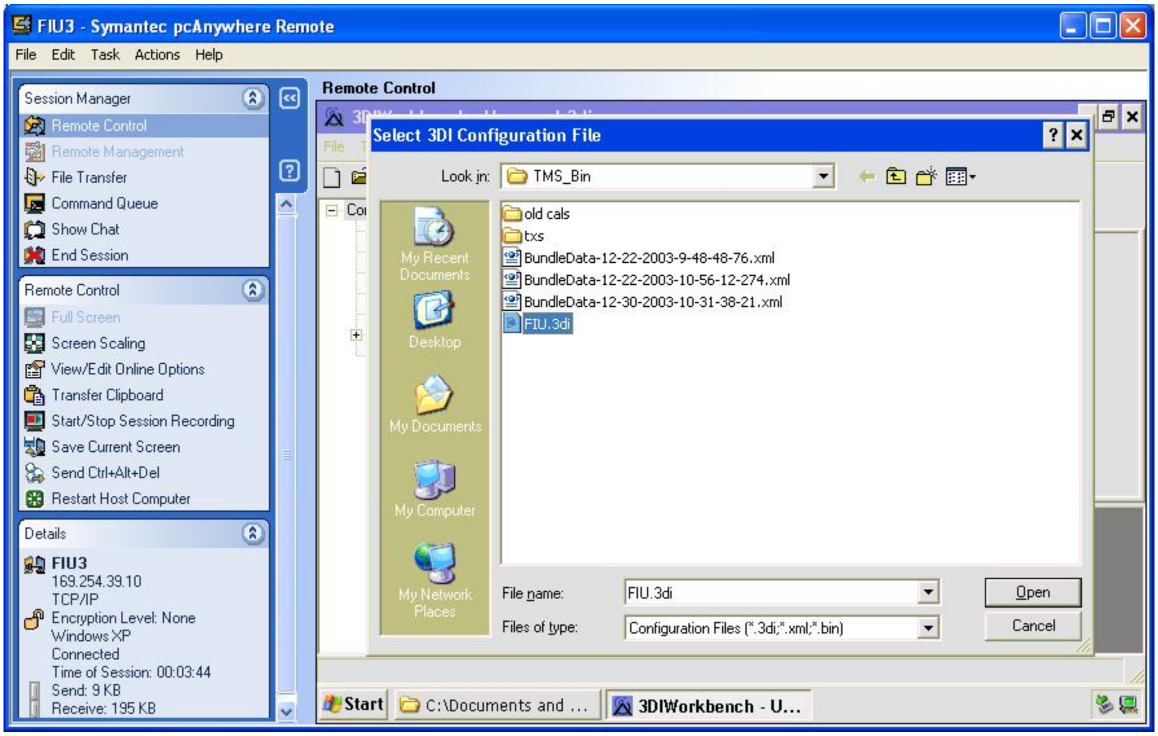


Figure 5-97. Opening the FIU.3DI File in 3DiWorkbench

4. From the 3Di Tree view (left pane) display, click on the Input Device branch. In the resulting Input Devices Property Section (right upper pane), under the Properties tab, click the Start All button. Non-zero position values should appear in the AsiServerSinglePoint dialogs entitled “0”, “1”, “2” and “3” (See Figure 5-98). Minimize the 3DiWorkbench window.

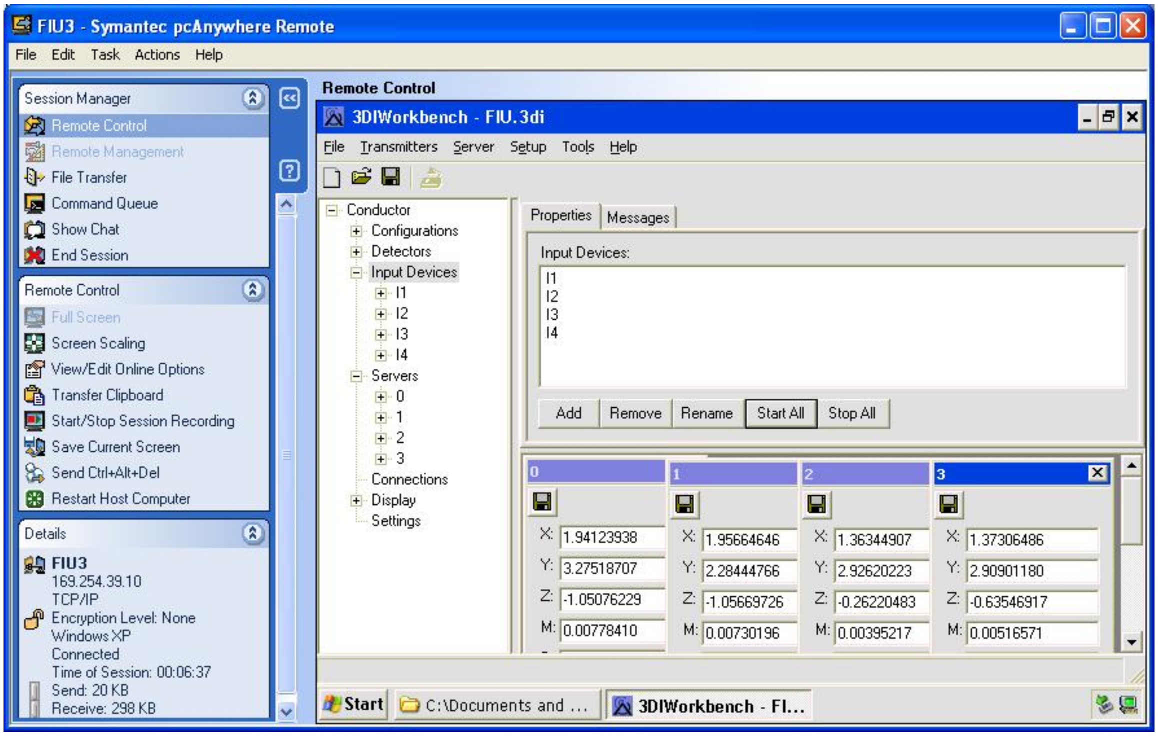


Figure 5-98. 3DiWorkbench Calculating Positions From Angles

5. On the FIU, launch Operator Client by opening a console window, navigating to the \TMS_Home\TMS_BIN directory and entering the following command line:

```
C:\TMS_Home\TMS_Bin\opcli.exe OPERATOR_3
```

   Note: The OPERATOR_3 parameter is used as an example. The actual parameter used will depend on the configuration of the FIU of interest (See section 5.3.5.1.1 for more information on using Operator Client command line parameters).

6. Close all open windows on the FIU except 3DiWorkbench (which should currently be minimized) and Operator Client. Bring Operator Client window to the foreground, maximize it and ensure that it is the active window. This is necessary to ensure that Operator Client is the foreground application to process input events corresponding to alarm notifications generated by the operator (See Figure 5-99).

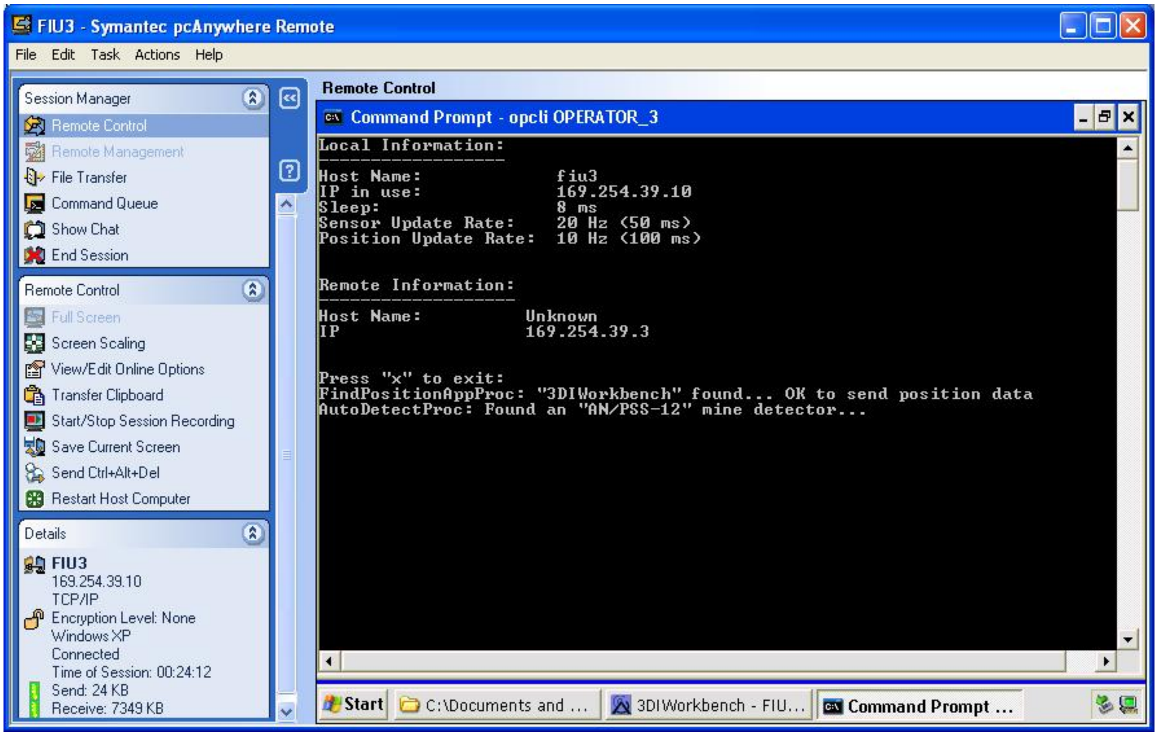


Figure 5-99. Operator Client console window as displayed in PC Anywhere

The FIU should now be transmitting sensor and position data to DC/DSP. The PCAnywhere session at the TMS Workstation should be terminated at this point.

FIU Shutdown

Since the FIU is a headless platform, the shutdown procedure requires the use of PCAnywhere. The procedure for shutting down the FIU is as follows:

1. Launch PCAnywhere on the TMS Workstation and connect to the FIU (See Figure 5-95).
2. Click on the Operator Client window and enter an “x”. Operator Client will kill the 3DiWorkbench process and then terminate itself.
3. Click the Windows XP Start button.
4. Click the Turn Off Computer item.
5. Click the Turn Off button (See Figure 5-100).

Figure 5-100. Windows XP Shutdown Window

After some hard disk activity, the red LED indicator located on the front panel of the FIU will go out. This is an indication that the FIU has been successfully shut down.

Related Processing

No additional processing not described herein is performed by TMS.

Data Backup

No TMS component has a requirement for an integrated or automated capability specifically relating to data backup. Any data file used or generated by any TMS component may be transferred to an appropriate available storage device by the user via the standard Windows file transfer mechanisms.

Recovery from Errors, Malfunctions, and Emergencies

No specific procedures for restart or recovery from errors or malfunctions during system processing are defined for TMS.

Messages

No TMS application presents to the user any coded messages in response to abnormal processing.

Quick Reference Guide

This paragraph has been tailored out.

Notes

Acronyms

Acronym	Meaning
BRTRC	Baum-Romstedt Technology Research Corporation
CD	Compact disc
CDF	Cumulative Distribution Function
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CM	Countermine
COR	Central Outdoor Router
CSCI	Computer Software Configuration Item
CTMS	Countermine Test Management System
DAQ	Data Acquisition
DATA COMMS/DSP	Data Communications/Digital Signal Processing
DIS/HLA	Distributed Interactive Simulation/High Level Architecture
DMSO	Defense Modeling and Simulation Organization
FIU	Field Instrumentation Unit
FOM	Federation Object Model
GPS	Global Positioning System
GSTAMIDS	Ground Standoff Mine Detection System
GUI	Graphical User Interface
HLA	High Level Architecture
HSTAMIDS	Handheld Standoff Mine Detection System
HWCI	Hardware Configuration Item
IP	Internet Protocol
JT&E	Joint Test and Evaluation
MISP	Mine Interaction Simulation Program
MS	Microsoft Corporation
NVESD	Night Vision and Electronic Sensors Directorate
OITL	Operator-In-The-Loop

Acronym	Meaning
PC	Personal Computer
PCE	Position Calculation Engine
PDR	Preliminary Design Review
PLT	Position, Location and Tracking
PM-CCS	Program Manager – Close Combat Systems
PM-ITTS	Project Manager – Instrumentation, Targets, and Threat Simulators
RGM	Runtime Global Memory
RS-232	Recommended Standard 232 (Serial Interface, IEEE)
RSM	Replicated Shared Memory
RTI	Runtime Infrastructure
SDD	Software Design Description
SRC	Scientific Research Corporation
SRS	Software Requirements Specification
STRICOM	Simulations, Training, and Instrumentation Command
SUM	System/Software Users Manual
TCP/IP	Transmission Control Protocol/Internet Protocol
TRADOC	Training and Doctrine Command
TBD	To Be Determined
TMS	Threat Minefield System
TDO	Technical Direction Order
TSMO	U.S. Army Threat Systems Management Office
UDP	User Datagram Protocol
USB	Universal Serial Bus
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VMM	Virtual Mine Model

Appendices

Appendix A Arc Second Laser-based Position Measurement System

A.1 Concept of Operation

The Arc Second, Inc. Constellation 3DI Measurement System operates by triangulating the position of a photo detector relative to two or more laser transmitters. Optimum system performance is obtained by positioning the transmitters to ensure good triangulation geometry to the desired measurement point. For the TMS system, four transmitters should be positioned so that at least two transmitters are visible to all the photo detectors at all times, regardless of operator orientation. The recommended optimal work-area is the square configuration as shown in Figure A-1. A rectangular or trapezoidal configuration will also work well.

A.2 Setting Up The Transmitters

The nominal working range is defined as the longest diagonal distance of the working zone. The nominal working range should be approximately the maximum range of the transmitters to the photo detectors. The Arc Second product is specified to work out to 35 meters. The nominal working range can exceed the maximum TX to RX range as inferred in Figure A-3. In practice, the typical maximum range is a function of several factors and has been observed in practice out to 50 meters. Try to position the transmitters so that the measurement area is completely enclosed by the nominal working zone.

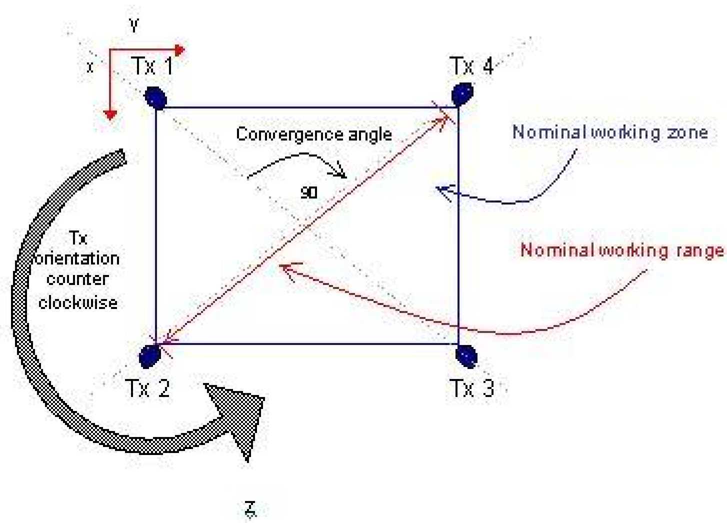


Figure A-1. Work Zone Geometry

To ensure good geometry, if possible, position the transmitters so there is an approximately 90° convergence angle at the center of the measurement area and ensure that all desired coverage areas lie within the work zone. The transmitters are numbered, and should be placed around the work zone in a counter clockwise numbered fashion, as shown in Figure A-1. This will provide proper orientation of the measurement coordinate system, following the right-hand rule, with the positive x- axis directed from Tx 1 to Tx 2 and the positive z-axis 90º vertical from the x-y plane. Because Tx 1 is auto-leveling, the x-y plane is always perpendicular to gravitational pull. Therefore, elevation differences in transmitters do not affect the "tilt" of the x-y plane or direction of the z-axis.

If the work zone is interior to the lines connecting the transmitter locations, or more basically, if the transmitters are set up beyond the perimeter of the desired measurement area, with the furthest distance between any two transmitters being the maximum range of the transmitters, it is most likely that at least two transmitters will be visible to the photo detectors on the operator at all times, regardless of the orientation of the operator. Measurement accuracy improves if there are more transmitters visible to the photo detectors. However, as long as two transmitters are visible, acceptable position measurement accuracy is achieved.

The transmitter handle orientation should be set toward the middle of the working zone as illustrated in Figure A-2.

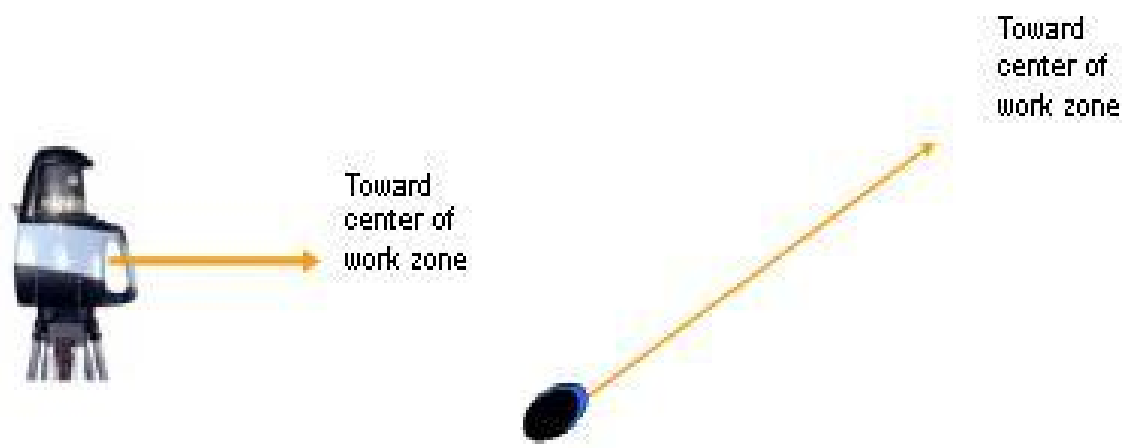


Figure A-2. Transmitter Handle Orientation

If the transmitters are set up in a four-sided configuration, with the transmitters oriented as described in Figure A-3, the areas that will be covered by at least two of the transmitters (i.e. where an unobstructed receiver will be within range of reception), will be similar to Figure A-3. Therefore, the actual total coverage area extends far beyond the prescribed work zone. However, if an operator of a handheld mine detector is beyond the work zone with his back to the work zone, it is likely there will be frequent position measurement dropouts. Suitability of the total coverage area beyond the work zone must be determined on a case-by-case basis.

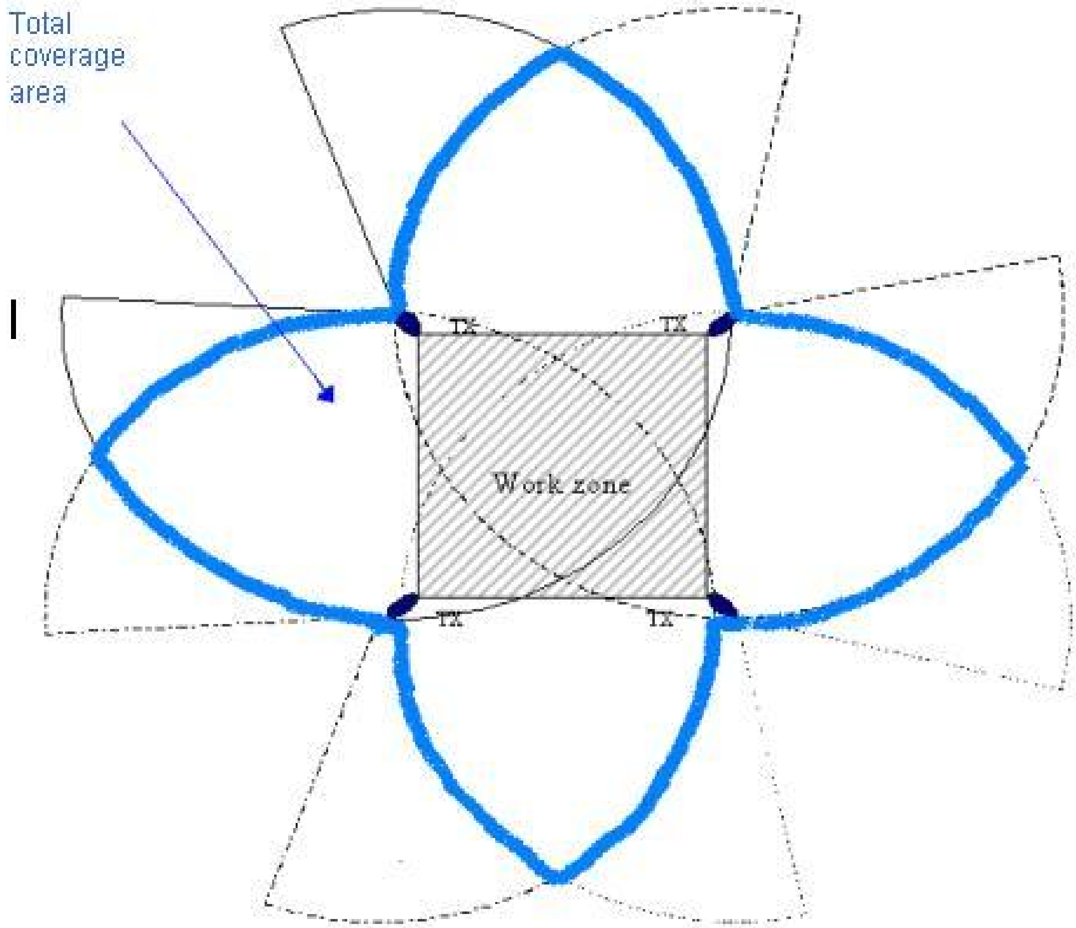


Figure A-3. Total Coverage Area Geometry

Laser fan beams that are emitted by the transmitters cover an elevation extent of +/- 45 degrees. Therefore, there is an area just under each transmitter that is not illuminated. Moreover, if a photo detector is too close to a transmitter, the photo detector is saturated. SRC recommends a minimum separation between a transmitter and photo detector of 20 feet. It does not harm the photo detector or electronics to be within the minimum suggested separation. The receiver electronics may not "recognize" the transmitter, however.

Each transmitter mounts to a tripod or other structure using a 5/8" by 11 threads per inch-threaded recess in its base. Secure attachment to a stable base is important to prevent transmitter movement during system operation. There is a small leveling window in the base of each transmitter in the interior of the handle. This can be used to level each transmitter. Transmitter #1 has a self-leveling mechanism, which will level the transmitter to the level of precision necessary for the system to operate properly. The remaining three transmitters need to be relatively level, but not necessarily perfectly level to operate properly. A transmitter location will be unknown if it is moved following calibration. Therefore a new calibration must be performed anytime that a transmitter is displaced from its original pre-calibration position. It is not recommended to move a transmitter while it is spinning.

Figure A-4. Laser Transmitter Mount

Table A-1. Constellation 3DI Transmitter Operation

Transmitter Item	Item Description
Ready LED	Flashes to show the transmitter's operational status (Item #1 in Figure A-5) Red – indicates the transmitter is on but not yet ready Green – indicates that the transmitter is ready for use (i.e. – spinning at the prescribed rate)
Power Button	Turns the transmitter on and off (Item #2 on Figure A-5)
Auto Leveling	Push items 3a & 3c (in Figure A-5) at the same time and hold them 3-5 seconds until an LED (3b) is blinking (this is neither necessary nor recommended for normal operation)
Battery Status LED	Flashes to show the approximate charge of the batteries (Item #4 on Figure A-5) Green – indicates that the batteries are ready Yellow – indicates that the batteries are low Red – indicates that batteries are too low to operate the transmitters
Service LED	Flashes red when the transmitter needs servicing (Item #5 on Figure A-5)

Transmitter batteries do not need to be removed for recharging. The recharger can be plugged into the battery tray while it is installed in the transmitter. However, transmitter operation is disabled during charging. The transmitter batteries should be almost or fully discharged before re-charging. The re-charge time is about 12 hours.

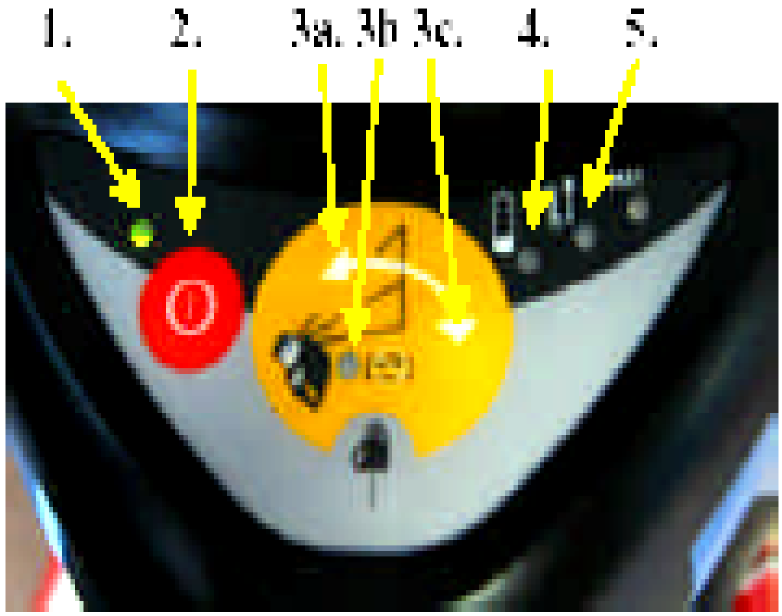


Figure A-5. Laser Transmitter Controls and Displays

A.3 Calibrating The System

A.3.1 Overview

The Constellation 3DI Measurement System must be calibrated before any measurements are taken. Calibration is the process of determining the exact location and orientation of each transmitter on the measurement site. This is accomplished by using calibration software and strategic measurement points to determine the position and orientation of each of the transmitters. The calibration process also establishes the default coordinate reference frame. After calibration, the reference frame remains intact unless the transmitters are moved. Only a single photo detector is used during the calibration process.

Once the transmitters are set up, turned on and verified through 3DiWorkbench to be visible by the connected photo detector, the system is ready for calibration. It is recommended that during the calibration process the 3DiWorkbench window displaying the status of the photo detector remain open for viewing. All transmitters must be visible to the photo detector used during calibration.

During each calibration operation, the user designates various points within the coverage area to be sampled (measured) by the Arc Second 3DiWorkbench calibration software. The calibration points should be distributed throughout the work zone volume. Usually a point is taken between each of the transmitters on the edge of the work zone and then 2 to 4 more within the work zone in addition to two more points for the scalebar for a total of 8-10 points measured (see Figure A-7). It is important to hold the optical receiver very still during calibration (it is recommended that during calibration the photo detector be placed on a stationary object). It is also important that the receiver be in the vertical orientation.

3DiWorkbench monitors the standard deviation of the measured angles from the transmitters. Each time that a calibration point is collected, a result dialog will display the standard deviation for each transmitter in micro radians. These standard deviations need to be monitored carefully. The nominal value for a successful calibration will be less than 100 microradians. If the displayed standard deviation for any transmitter is in excess of 150 microradians, click the Stop and Reset buttons and recollect the angles for that point.

Scale is introduced into the measurements by using a scalebar. A scalebar is entered by specifying an exact measurement of the distance between two corresponding calibration points in meters. The greater the distance between the 2 points used in conjunction with the scalebar, the more accurate the position measurements will be.

It is recommended that the photo detector used to collect calibration points not be at the same vertical height as the transmitters (see Figure A-6). In other words, try to avoid the plane of the transmitters during calibration. This will provide a more mathematically precise calibration.

Figure A-6. Transmitter Plane

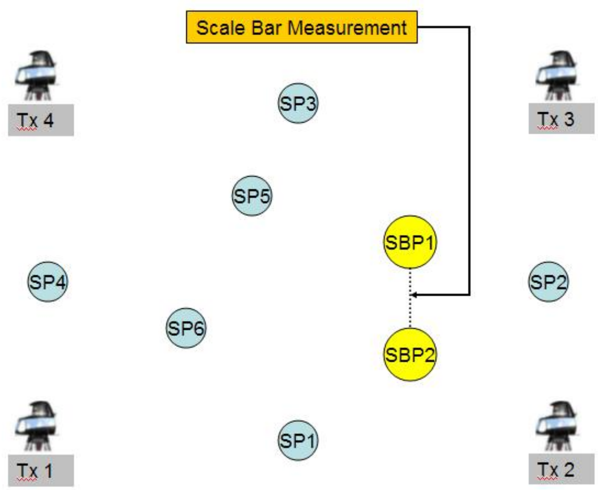


Figure A-7. Example Calibration Point Layout

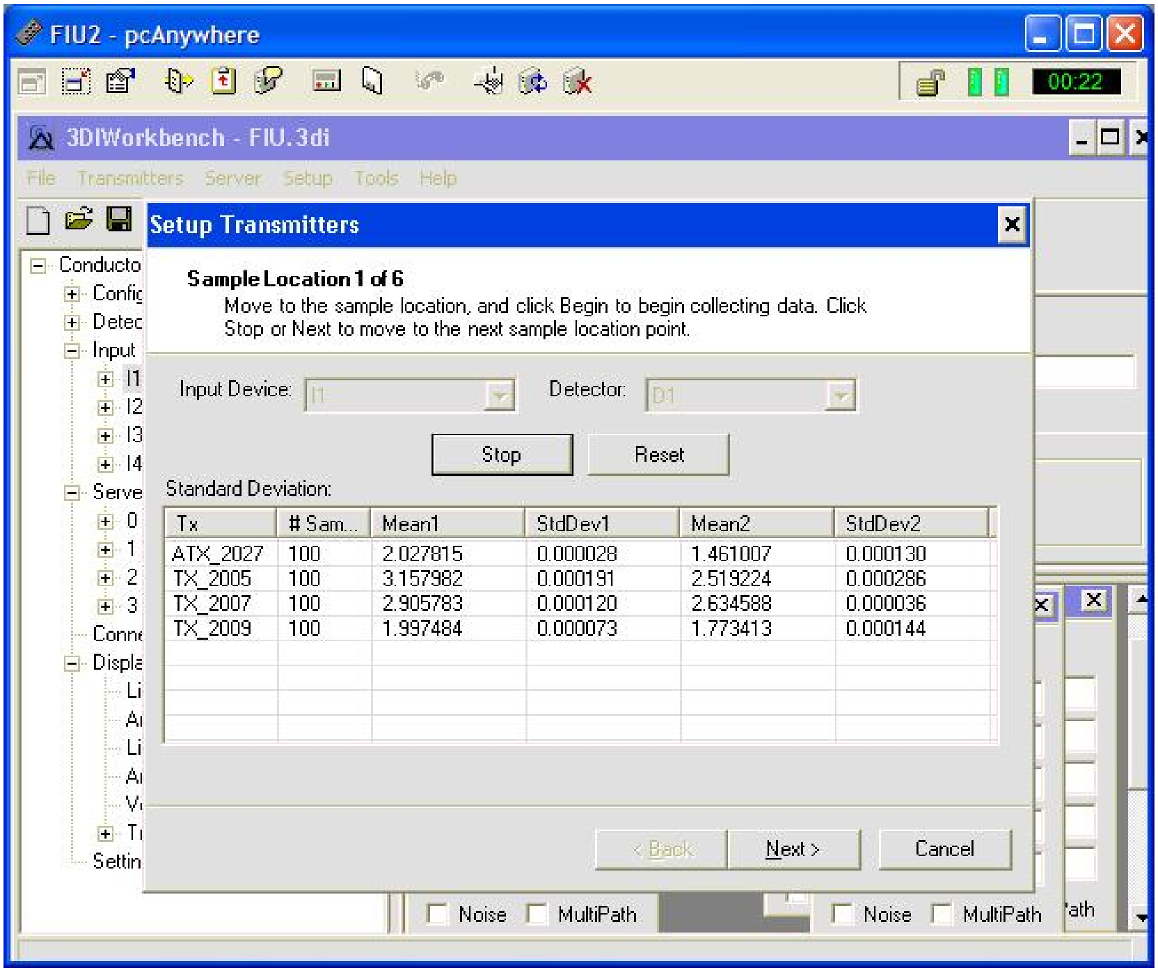


Figure A-8. 3DiWorkbench during Calibration

A.3.2 Calibration Steps

Note: See 3DIWorkBenchUser Guide for information on configuring PCEs, Input Devices and Position Servers.

1. Position the transmitters around the work area and turn them on.
2. Attach a single detector to the left foot port on the FIU (Note: This is the only device that must be attached during the calibration process). Power on the FIU.
3. Power on the Evaluator Workstation. Launch PCAnywhere and establish a connection to the FIU (Note: Subsequent instructions regarding software operations on the FIU imply using the PCAnywhere connection.)
4. On the FIU, launch 3DiWorkbench.
5. Within 3DiWorkbench, from the File menu, select Open. From the resulting file selection dialog, select the file \TMS_Home\TMS_Bin\FIU.3Di.

6. From the 3Di Tree view (left pane) display, click on the Input Device branch. In the resulting Input Devices Property Section (right upper pane), under the Properties tab, click the Start All button. Non-zero position values should appear in the AsiServerSinglePoint dialog entitled “0” (See Figure A-9).

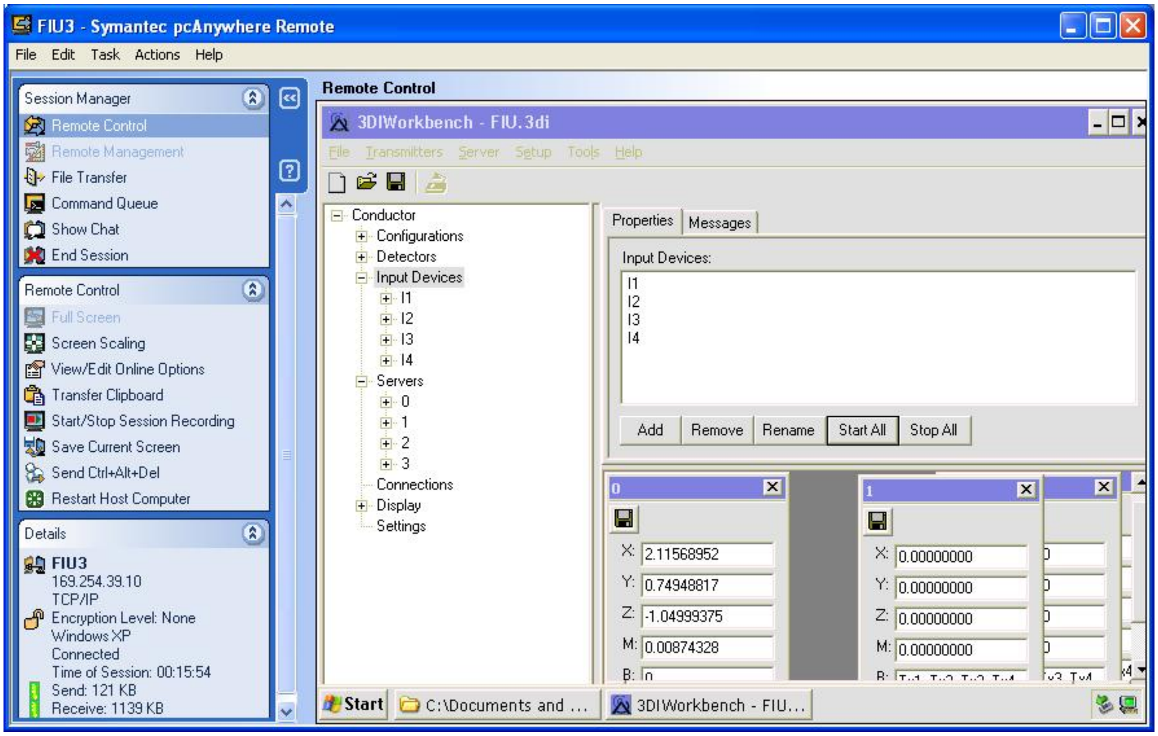


Figure A-9. Example of AsiServerSinglePoint Dialog Entitled “0”

7. Position the detector at a point midway between transmitters 1 and 2, slightly inset into the work area. From 3DiWorkbench, using the “0” dialog, ensure that all transmitters are visible as indicated by the “B” (for blocked) field: 0 should appear if all transmitters are visible, otherwise Tx{n} (where n = transmitter #) will appear if Tx{n} is not visible.
8. Under 3DiWorkbench, from the Setup menu, select Perform Setup…. This should display the 3DiWorkbench Setup Wizard (see Figure A-10). Click Next.

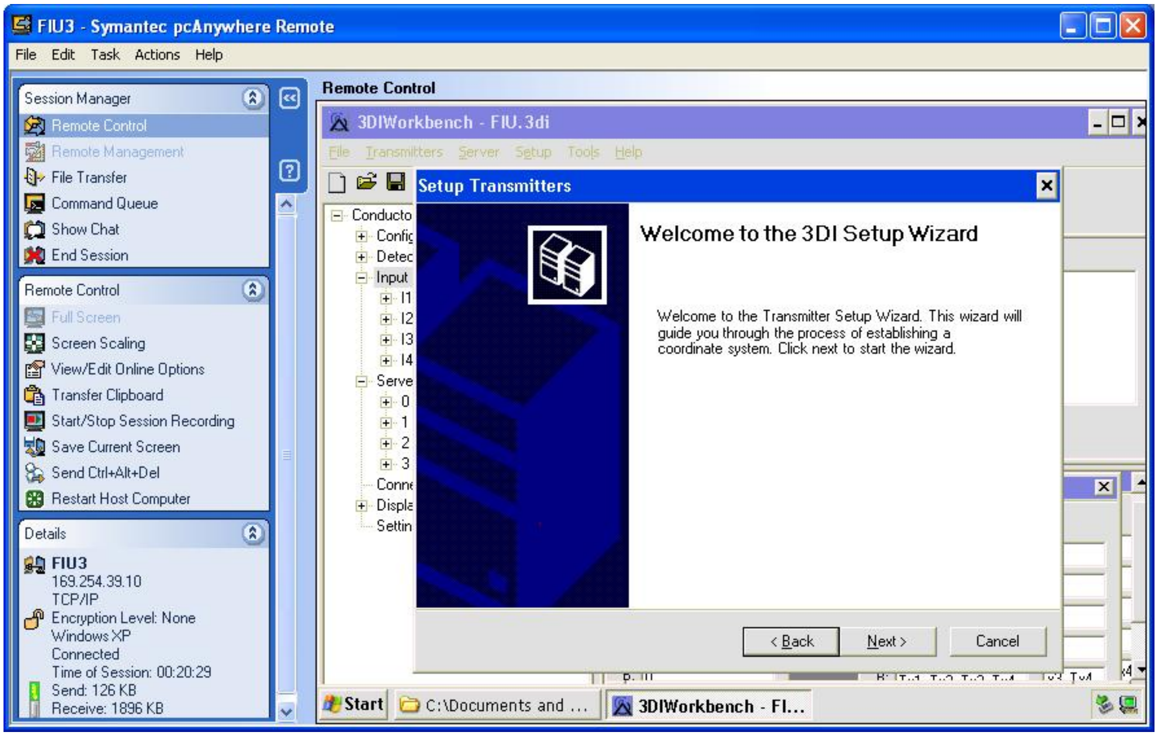


Figure A-10. 3DiWorkbench Setup Wizard

9. On the Step 1: Settings for the Setup page, enter the Number of Sample Locations as 6 and the Number of Scale Bars as 1 (see Figure A-11). Click Next.

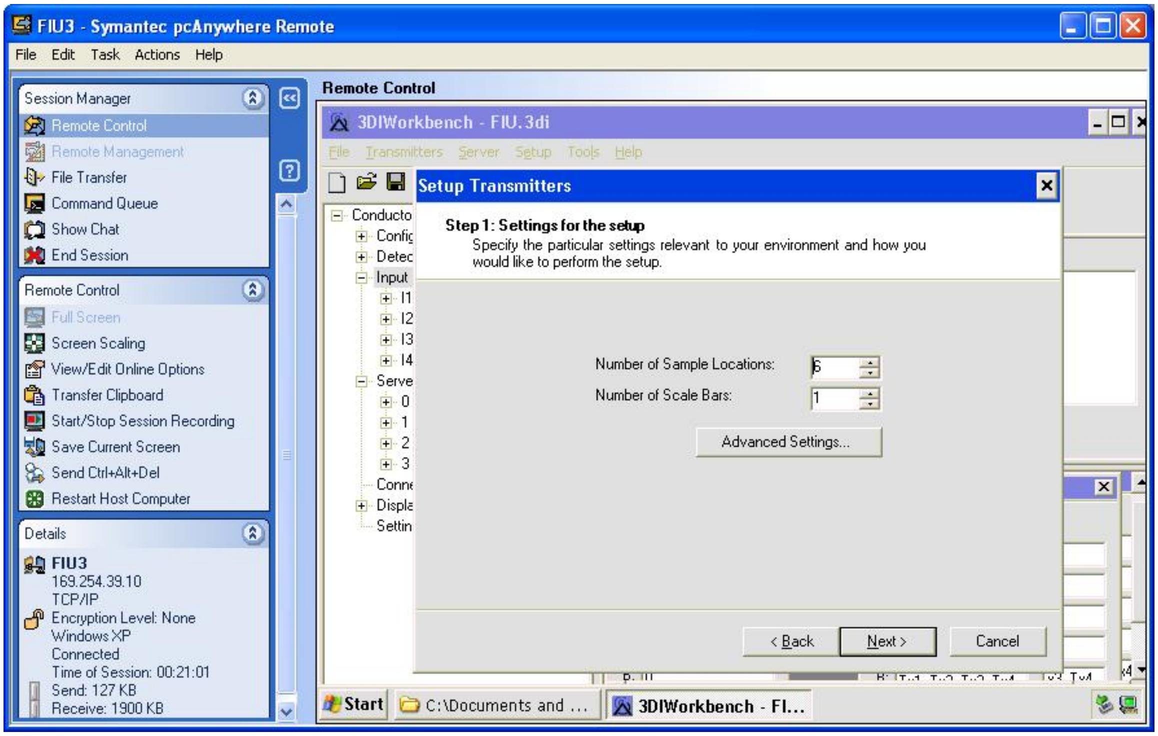


Figure A-11. Step 1: Settings for the Setup Page

10. On the Sample Location 1 of 6 page, verify that Input Device is I1 and Detector is D1. Click the Begin button. Allow the collection of at least 100 samples. While collecting, verify that the displayed value of StdDev2 for each transmitter stays above zero and below 100 microradians (.0001 radians as displayed). Click the Stop button after collecting sufficient samples. If the value of StdDev2 for any transmitter exceeds 100 microradians or any transmitter is indicated as not visible in the “0” dialog during data collection, click the Reset button and recollect the samples for that point. When the sufficient samples for Point 1 have been collected, click the Next button (see Figure A-12).

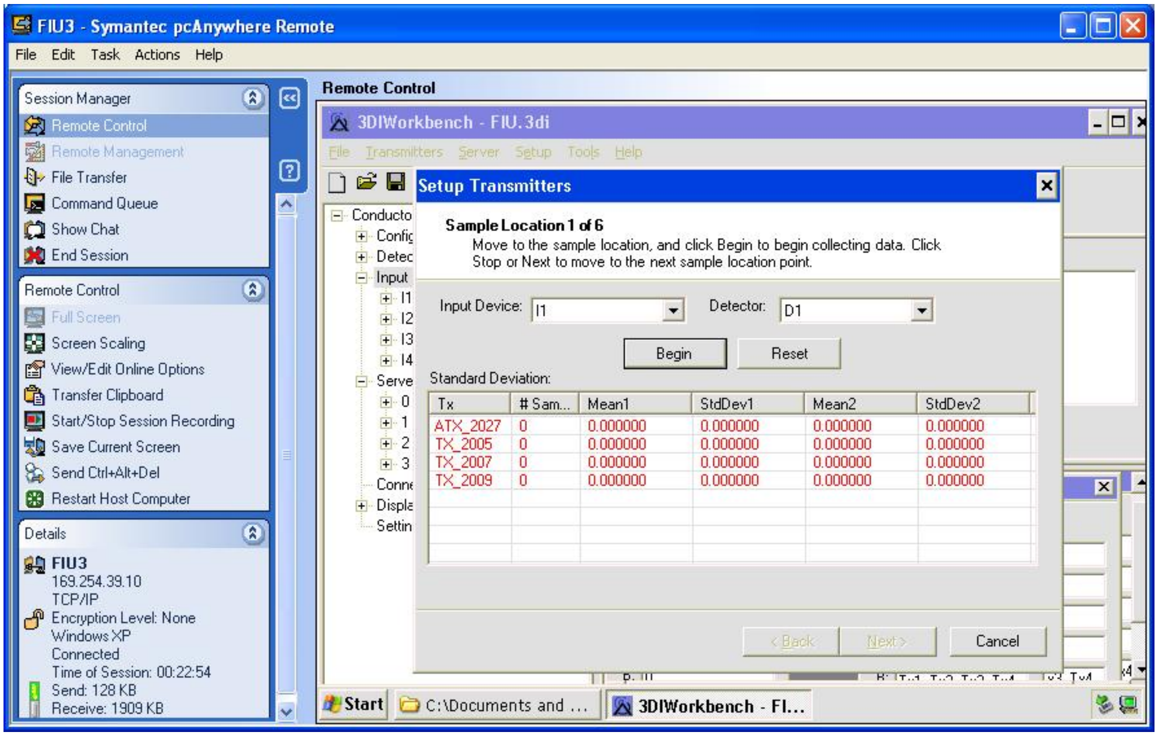


Figure A-12. Sample Location 1 of 6 Page

11. Repeat step 10 for Sample locations 2 – 4, moving the detector between each next successive set of 2 transmitters (e.g. Point 2 between transmitters 2 and 3, Point 3 between transmitters 3 and 4, Point 4 between transmitters 4 and 1).
12. See step 11.
13. See step 11.
14. For Sample Locations 5 and 6, place the detector at any 2 arbitrary points within the work area and collect sample data as described in step 10.
15. See step 14.
16. After collecting Sample Location 6, the Scale Bar 1 Distance page should appear. Mark 2 points within the work area and accurately measure the distance between the points. Enter that value in the Scale Bar Length field (Note: The distance should be at least one meter but need not be greater than three meters (see Figure A-13). Click Next.

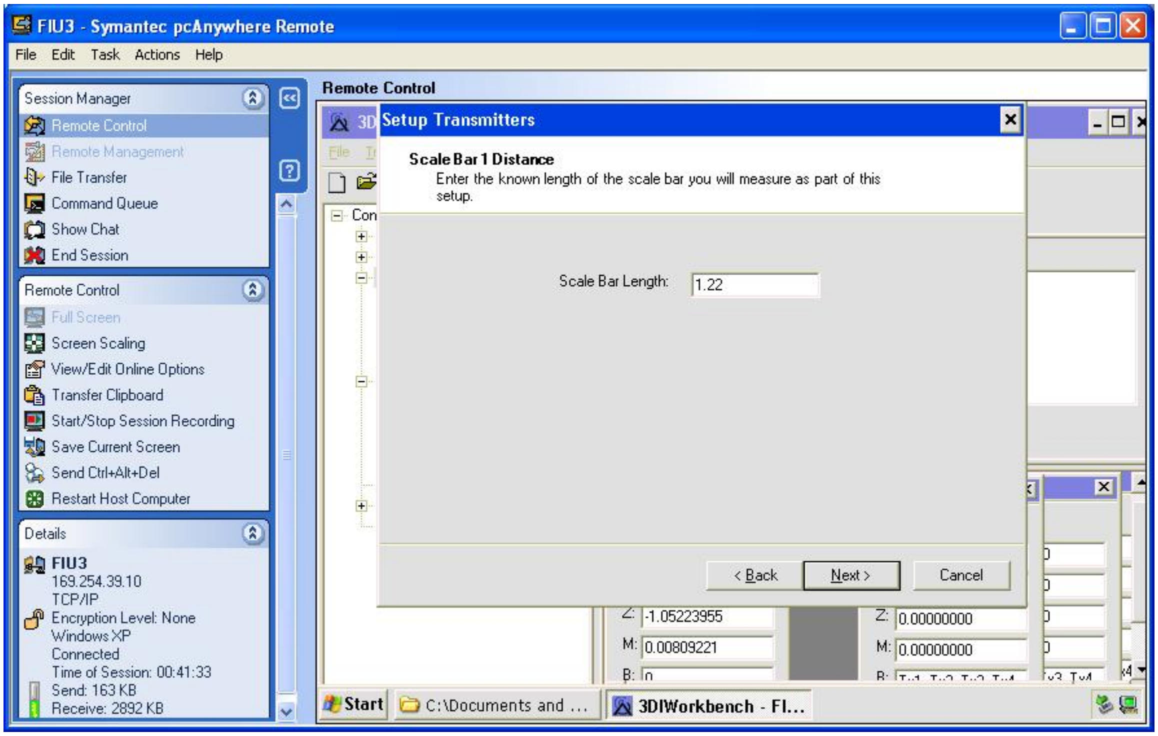


Figure A-13. Scale Bar 1 Distance Page

17. Place the detector on one of the measured points. On the Sample First Point of the Scale Bar 1 of 1 page, click the Begin button, following the procedures in step 10 (see Figure A-14). Click Next.

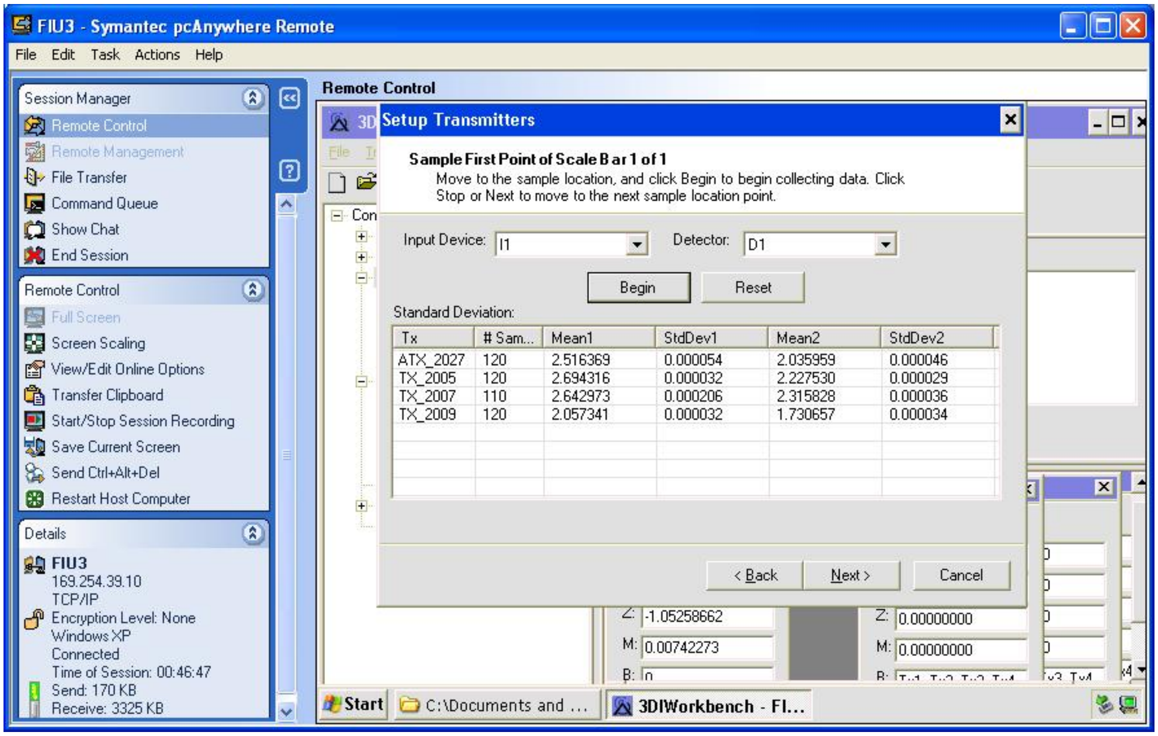


Figure A-14. Sample First Point of the Scale Bar 1 of 1 Page

18. Place the detector on the second of the measured points. Repeat step 17 on the Sample Second Point of Scale Bar 1 of 1 page. Once the sufficient samples are collected, click Next.
19. On the Calculate Setup Bundle page, click the Calculate button. If the collected data is sufficient, a dialog stating that the Bundle Calculation succeeded will be displayed (see Figure A-15). Otherwise, the dialog will indicate that the bundle calculation failed. In this case the setup procedures must be repeated. Click Ok to close the results dialog. Click the Accept Bundle button. A dialog will then appear with a prompt to send the new setup to all connected devices. Click the Yes button (see Figure A-16). Click Next.

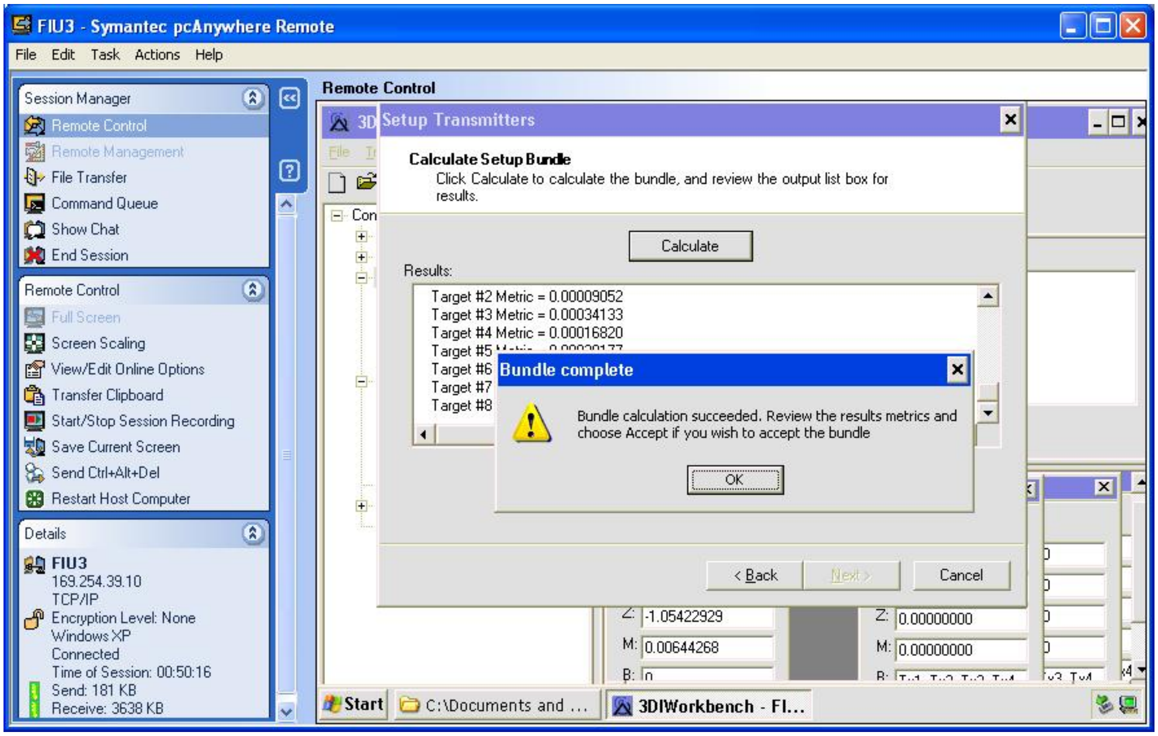


Figure A-15. Calculate Setup Bundle Page

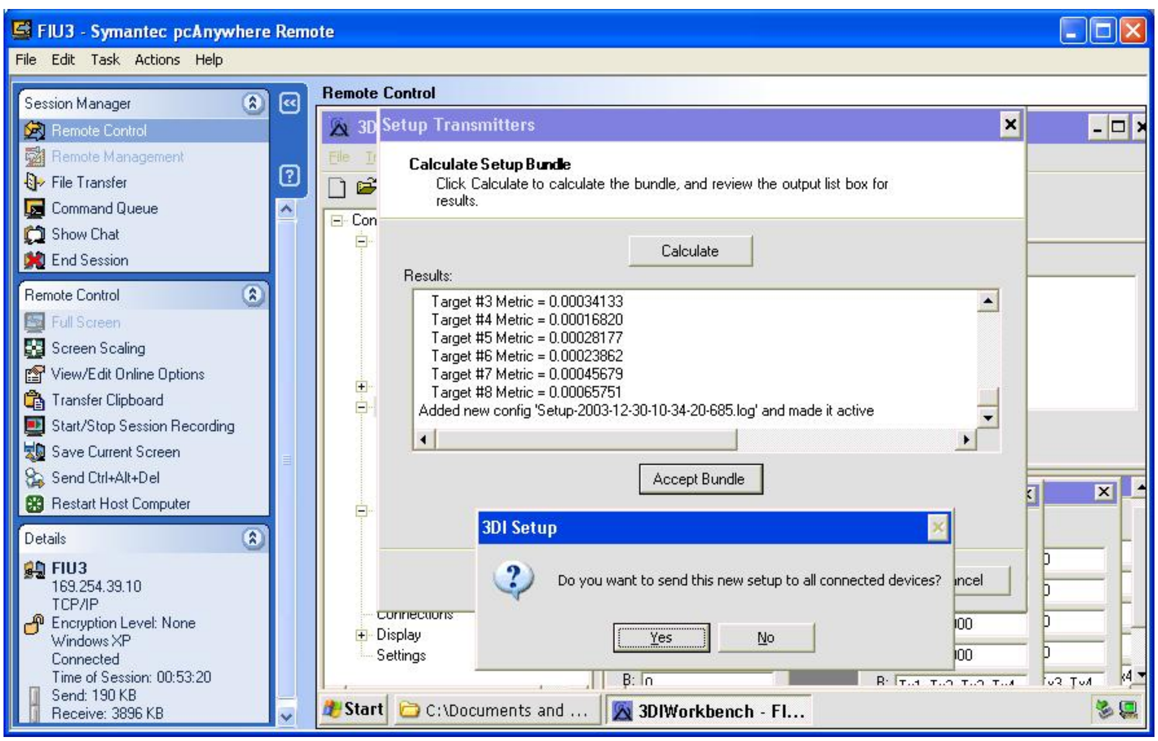


Figure A-16. Prompt to Send Bundle Data to All Connected Devices

20. The final Setup Wizard page will appear (see Figure A-17). Click Finish.

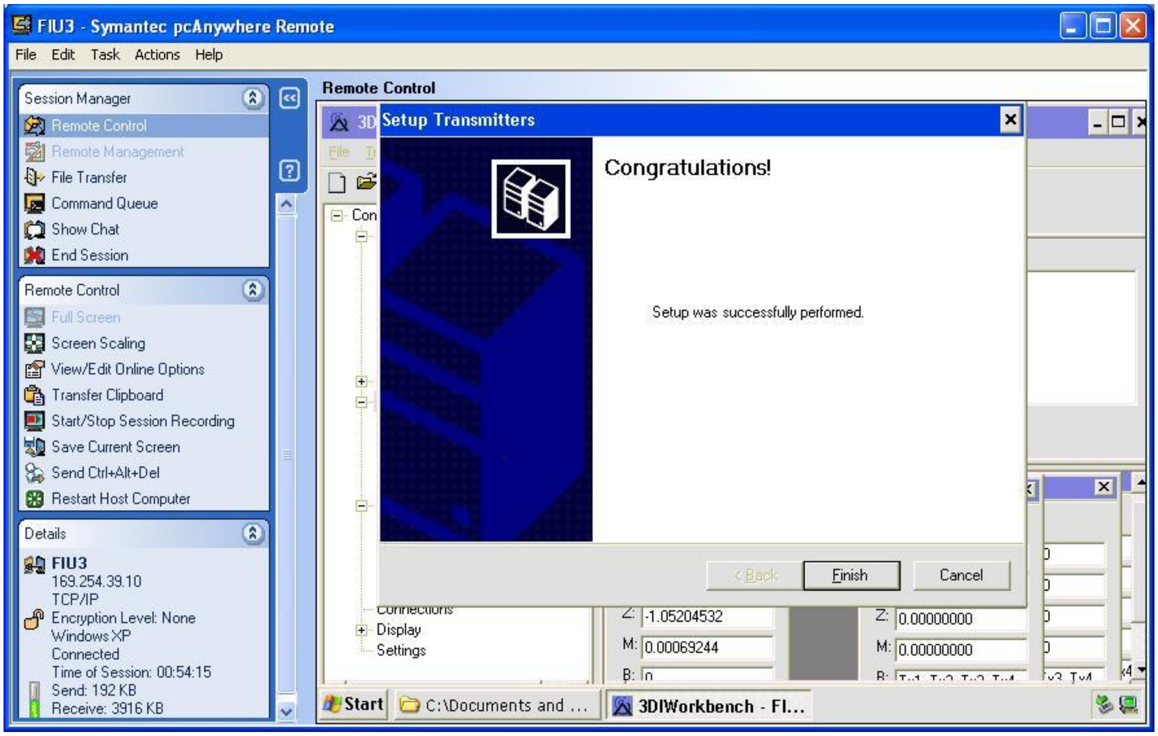


Figure A-17. Setup Wizard Final Page

21. In 3DiWorkbench, in the 3Di Tree view (left pane) display, the Configurations branch should include a Setup entry showing the current data and time.
22. Within 3DiWorkbench, from the File menu, select Save.

This completes the calibration process. The corresponding work area will remain “calibrated” as long as the transmitters are not moved. 3DiWorkbench can be exited at this time if necessary and the FIU shutdown.

Appendix B Demonstration Unit Operations

B.1 Scope

B.1.1 Identification

Scientific Research Corporation (SRC) under Contract DAAH01-00-C-A107 Technical direction Order (TDO) 0029 of the US Army Threat Systems Management Office (TSMO) program, was contracted by TSMO to develop the Threat Minefield System (TMS) Demo Unit (DU) in parallel with the TMS Phase III effort (TDO 0028 of the same contract). This Appendix to the TMS System Users Manual (SUM) in conjunction with the TMS SUM describes in sufficient detail the provided interfaces and procedures necessary for operation of the TMS DU. This Appendix pertains to all computer software configuration items (CSCI) mentioned in section 1.1 of the TMS SUM as well as the following TMS DU specific computer software configuration item applications:

- 7000 Utility version 4.2.0 light controller configuration application

B.1.2 System Overview

The TMS DU is an augmentation of the TMS test and training capabilities. The augmentation facilitates demonstration of the TMS capabilities to audiences either indoors or outdoors using an elevated test lane with audible and visual feedback for exercise events. The TMS DU also facilitates full operation of the single-operator mobile version of the TMS whereby exercises and training can be performed. This includes the application of virtual mines.

The TMS DU represents work performed in all previous and concurrent TMS development phases. As with the primary TMS system, software configuration management (CM) is performed for the US Government by SRC using the Microsoft (MS) CM tool Visual SourceSafe.

The primary hardware components of the TMS DU consist of:

- DataComms / Evaluator Workstation Laptop Computer
- Countermine Test Management System (CTMS) Laptop Computer
- Elevated and Desktop Display Equipment
- Operator Instrumentation
- Position, Locating and Tracking Equipment
- Elevated Test Lane Equipment.

All of the above referenced hardware is common to the single evaluator TMS hardware suite with the exception of the display and elevated test lane equipment.

B.1.3 Appendix Overview

This appendix applies only to the TMS DU audience demonstration functions of the TMS DU product. The single evaluator functions and procedures are documented in the TMS SUM document main body. This appendix has two primary sections. The first section entitled "Hardware Features for Demonstration Unit Operation" provides instructions for the set-up and use of the hardware specific to the TMS DU operation. The second section entitled "Software Features for Demonstration Unit Operation" provides instructions for the initialization and use of the software specific to the TMS DU operation.

B.2 Hardware Features for Demonstration Unit Operation

This section contains descriptions of and instructions on the use of the features of the TMS DU hardware that specifically support operations of the Demonstration Unit. All other hardware operation instructions common to normal operation of the TMS system are provided in the SUM main body.

B.2.1 Elevated Test Lane Equipment

The elevated test lane is composed of a non-metallic structure to support an operator and his gear for TMS demonstration purposes. The test lane supports targets that can be concealed under translucent white acrylic sheets just below the top grating. The lane is configurable in that from 1 to 10 sections of the lane can be assembled to adjust the size of the demonstration platform dependant upon the space available. The elevated test lane drawings are contained within the drawing package provided with the TMS Demo Unit system and will not be duplicated here. However, the assembly and specific parts are readily identifiable in the Hardware Drawing Tree. A description of their use is provided here.

B.2.1.1 Elevated Test Lane Sections

B.2.1.1.1 Geometry

Each elevated test lane section is three feet wide and four feet long. When two sections of three feet width are joined, the intended width of six feet is realized. *It is not recommended that sections be used individually to form a three-foot wide width because of operations and safety issues. The widths of three feet were provided for ease of handling and shipping purposes.* When two sections are joined for a width of six feet, lengths in increments from four feet up to twenty feet can be constructed.

Each elevated test lane section is composed of a frame, a clear acrylic sheet with stand-offs for target support, a translucent white acrylic sheet for covering the targets (if desired), black grating, exterior translucent white side panels with knobs and interconnecting pins. The top acrylic sheet covering the targets is optional depending on the intent of demonstration. If it is desired that the target locations be seen, it can be left off. An isometric of the single cube assembly as is depicted in drawing number 6HTS2-00003 is provided below in **Figure B-1**. It is shown without side panels.

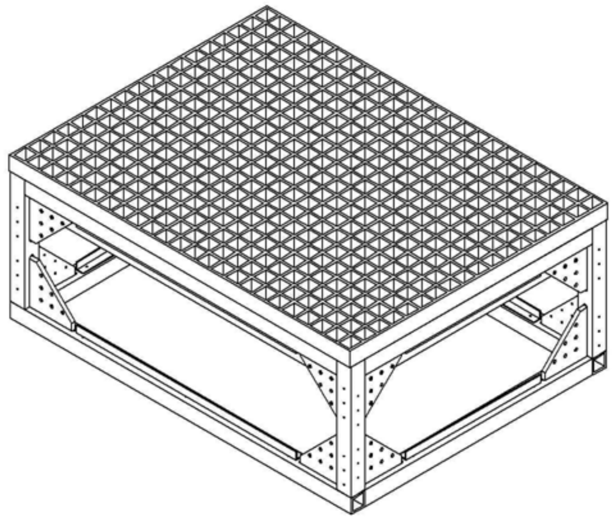


Figure B-1. Elevated Test Lane Cube Assembly without Side Panels

B.2.1.1.2 Target Placement

The targets (mines, simulants or other metallic clutter) may be placed on the clear acrylic sheet before the other white acrylic sheet or grating is put in place. Target depth is controlled by placing non-metallic support under the emplaced target to raise it to the intended depth below the upper surface of the grating. The grating is two inches thick to support an operator and his gear safely and the top white acrylic sheet is 3/16 inch thick. Therefore, any target touching the bottom of the white acrylic top sheet is 2 and 3/16 inches "deep" which is relatively deep for an anti-personnel mine or low-metallic simulant. Alternatively, simulant inserts will fit within the 2-inch by 2-inch grating and will rest on top of the top white acrylic sheet. This will enhance the target response but will expose the target location. Alternatively, coins or other metal may be placed with targets under the top white acrylic sheet to "enhance" the mine detector response to help compensate for the depth.

Suggestion: Before placing the top white acrylic or grating, perform the necessary survey to develop the ground truth file (see Section B.3.2.3). The laser detector used can then be positioned *exactly* where the real or virtual mine is to be placed thereby negating the need to measure any depth offsets.

B.2.1.2 Elevated Test Lane Handrail

The elevated test lane handrail should be used for safety purposes after the position, locating and tracking system is calibrated and all other pre-demonstration work is complete. The handrail serves to help link the exterior of adjoining sections together. *The handrail is not intended to meet any workplace handrail or foot rail requirements and will not support the weight of a human.* The handrail is to serve as a reminder where the edge of the elevated lane is if it is backed into or leaned into. When operating a detector, it is common to lose cognizance of the location of the edge of the platform, as detector operation is mentally absorbing. If it is bumped into, it will serve as a reminder to the operator where the edge is.

At each six-foot wide end of the test lane, the handrail slides open and closed to form a gate of sorts and allow access to the lane. Always remember to close the "gate" as the most important use of the railing is to deter operators from backing up too far. Again, the handrail will not support the weight of an operator but will provide a reminder of where the edge of the test lane is.

The handrail may also undesirably block the position, locating and tracking laser transmitter emissions at certain points on the test lane. Experimenting with transmitter positioning to avoid the "shadowing" that may occur will result is more "intelligent" positioning of the transmitters relative to the test lane and hand railing. Although there are four transmitters simultaneously used, position detectors only need to have two transmitters visible at any one location. Therefore, blocking during operation is not a serious problem but can impact positioning signal processing momentarily resulting in a very short but noticeable positioning "transient". Since positioning system calibration requires line of sight between the calibration detector and all four transmitters simultaneously, the handrail should not be put up before calibration is complete.

B.2.1.3 Light Trees and Controllers

A light tree and controller is used for each elevated test lane segment. Power to the lights are provided through the controller which is controlled by software running on the DataComms / Evaluator workstation laptop. Power and control lines are provided through a "daisy-chain" type of network from one to the other. The light trees, controllers and associated control and power cables should be positioned BEFORE any of the acrylic sheets or grating is put in place.

Each light tree should be placed on the floor and either positioned under the center of the test lane segment or be placed directly under any target (if so desired). If two or more targets are placed within a single section, the light tree will probably be better if placed in the middle of the test lane section. The controller for each can be placed wherever it is convenient but should be placed in the same test lane section. Since the light trees are placed before the targets and supporting acrylic sheets are positioned, fine adjustment of the light tree positions may be necessary via the side of the sections.

Each light tree controller is addressed and correspondingly numbered for software control. Controller 1 MUST be positioned in the test lane section that is closest to Transmitter 1 of the positioning hardware under the LEFT hand three-foot wide section. Controller 2 will be placed under the RIGHT hand three-foot wide section adjacent to Controller 1. The controller placement will then follow the same pattern as indicated in **Figure B-2** below. In the event that fewer than all ten test lane sections are used, the higher numbered controllers will be left out. It is not necessary that the controller data cable and power cables be daisy-chained in numerical order. In fact, the recommended daisy-chain order is from 1 to 3 to 5 and so on around the test lane sections clockwise ending with 6 to 4 to 2.

9	10
7	8
5	6
3	4
1	2

Figure B-2. Light Tree Controller Numbering and Placement

B.2.1.4 Audio Equipment

The audio hardware provided includes a subwoofer, four surround-sound speakers (2-front and 2-rear), a fifth speaker for the center and a controller. The subwoofer chassis contains all the audio electronics for amplifying the sound and distributing the signals to the five ancillary speakers. The audio gear is driven with an input from the speaker jack of the DataComms / Evaluator Workstation laptop. The laptop speaker port is connected to the controller input where the audio is processed. The controller is adjusted for the "Stereo x 2" selection. The .WAV file played during an exercise is that of an explosion if a mine is virtually "detonated" by an operator stepping on it. The controller output is connected to subwoofer for audio amplification.

Each of the four surround sound speakers is provided with mounts that can be mounted on the top corners of the handrail. Fifty feet of speaker wire with banana plug connections are provided for each speaker to allow cable routing as necessary for the demonstration and available space. The speaker mounts do not have to be used but serve as a convenient way to surround the operator. The center and subwoofer speakers should be collocated in close proximity to the evaluator workstation laptop as the controller is connected to the laptop. The controller has knob and pushbutton controls for audio adjustment such as muting, volume, fade and balance.

B.2.2 Elevated Display Equipment

The elevated display equipment is composed of two 42-inch plasma monitors, two 19-inch plasma tabletop monitors, associated stands, video splitters and cables. The monitor stands are designed such that the bases can have wheels mounted to the bottom so the displays can be easily moved. The display bases can be tied together for additional stability and ease of use. The display mounts are adjustable so the display can be easily pivoted around (no tools required) and can be tilted up or down (with loosening and tightening mounting hardware). The display and mounting drawings are contained within the drawing package provided with the TMS Demo Unit system and will not be duplicated here. However, the assembly and specific parts are readily identifiable in the Hardware Drawing Tree. A single elevated display isometric as is provided in drawing number 4HTS2-00007 is provided below in **Figure B-3**. The wheels are shown mounted on the same side of the base as the display. It is possible and may be desirable to mount them on the opposite side to allow the display to roll.

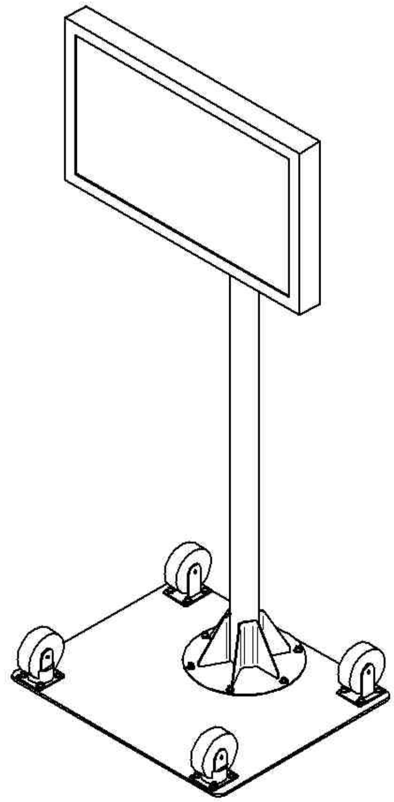


Figure B-3. Single Elevated Display Assembly Isometric

The Evaluator Workstation laptop display output port and CTMS laptop display output port will each be connected to the input of a provided video splitter. The video splitter outputs can be connected to both of the overhead plasma displays as well as to one each of the tabletop displays (when all the displays are used). The video displays used will be a function of how much room is available and the presumed audience size. The displays can be used in any combination and any configuration.

Each of the 42-inch displays supports two display inputs. Through an RS-232 control the displays can be controlled to select which video port to display or simultaneously view both with a "picture in picture" mode. The software to control the displays is installed on the Evaluator Workstation. The additional RS-232 ports are provided through USB adapters and a USB bus extender.

B.3 Software Features for Demonstration Unit Operations

This section contains descriptions of and instructions on the use of the features of the TMS workstation applications that specifically support operations of the DU. The features unique to DU operations are available only when the system is configured in "Demo Mode." The DU utilizes the TMS evaluator workstation applications configured in single evaluator mode.

B.3.1 TMS DataComms

The TMS DataComms application implements the data communications interface through which commands are sent to and responses are received from the DU light controllers. This interface is facilitated through the built-in RS-232 serial port (COM1) of the TMS evaluator workstation. When appropriate exercise events occur as detected by TMS MISP, TMS DataComms sends a set of commands indicating the desired light behavior to the light controller corresponding to the event position on the elevated lane platform.

B.3.1.1 Start Up for Demo Mode

TMS DataComms is initialized for Demo Mode at start up by the use of a command line parameter: /d. TMS DataComms can be started stand-alone or, if it is not currently running, by TMS Master when it is started. To start TMS DataComms stand-alone in Demo Mode, create a Windows shortcut to the TMS DataComms application; right-click on the shortcut and select "Properties"; at the end of the "Target" field on the Shortcut tab, add a space and /d; close the Properties dialog by selecting OK. This step must be performed only once, as long as the shortcut is never deleted. TMS DataComms may then be launched by double clicking the shortcut. Demo Mode configuration is confirmed by "Demo Mode" in the title bar of the TMS DataComms main window. It is also confirmed by opening the About box for TMS DataComms (as well as all other TMS evaluator workstation applications running in Demo Mode). The About box should appear as shown in **Figure B-4**, where Demo Mode is indicated with the version number.

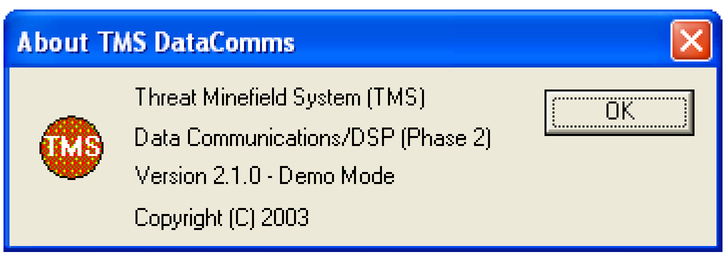


Figure B-4. TMS DataComms About box showing Demo Mode operation.

B.3.1.2 Light Controller Operation Test

Proper configuration and operation of the light controllers for the elevated platform can be confirmed using TMS DataComms by selecting the “Test Light Controllers…” item of the System menu. Upon selection of this item (which is enabled only when no exercise is currently configured on the workstation), the dialog in Figure B-5 is displayed.

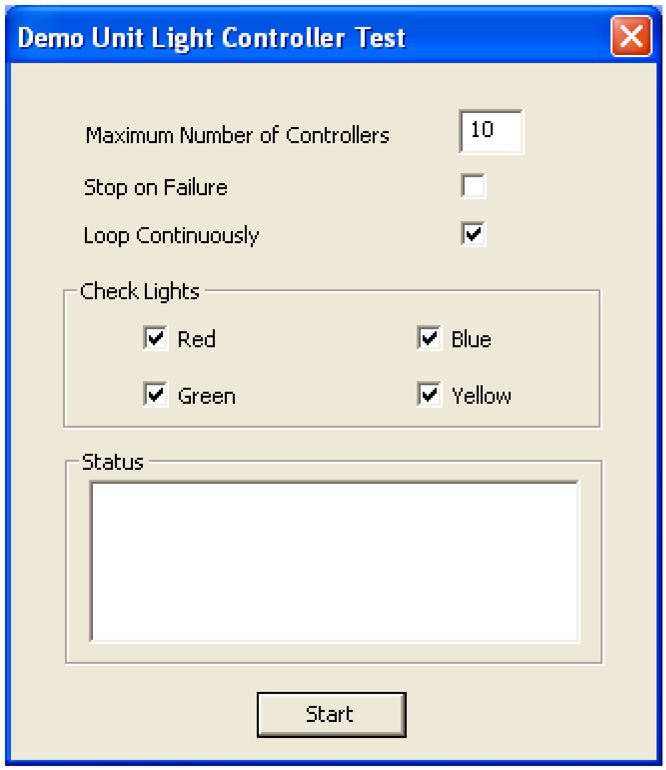


Figure B-5. TMS DataComms Demo Mode light controller test dialog.

The user input items on this dialog allow the specification of the number of light controllers to test (which should correspond to the number of elevated lane segments) as well as which lights should be illuminated by each controller. Any or all of the lights may be selected. In addition, it allows the optional specification of whether the test should stop on any failure and whether the test should loop continuously until stopped by the user. Clicking on the Start button initiates the test. (After the test is started, the Start button becomes the Stop button.) The test can be stopped at any time by clicking the Stop button or by closing the dialog. The status of each command sent to each controller is displayed in the Status list box. Note: a command will fail if a light controller is missing or not properly connected; a command will not fail if the corresponding light bulb is not powered, missing or inoperable.

Additional light controller diagnostics may be performed using the 7000 Utility application provided by the light controller manufacturer. This application is installed on the DU evaluator workstation. It provides an online Help feature for usage instructions. Note: this application is also used to program the “address” of each controller; the address corresponds to the ID number of the controller indicated on its outer case. Normal DU operations will not require that the controller addresses be re-programmed.

B.3.1.3 Instrumentation Survey Interface

TMS DataComms implements the Instrumentation Survey (“Instr Survey”) data communications interface to support test lane ground truth file creation using the Arc Second positioning system in conjunction with the TMS FIU. Ground truth files used in Demo Mode exercises can be created using the Survey operation of TMS Master where the survey entity used is an FIU connected through an Instr Survey interface. Prior to initiating the Survey operation, create the interface to the FIU as an Instr Survey interface. If an interface of another type to the FIU currently exists, that interface must first be deleted. The details of creating a ground truth file for a Demo Mode exercise are provided in the following section on TMS Master.

B.3.2 TMS Master

The TMS Master application includes Demo Mode capabilities specific to executing an exercise on the elevated platform.

B.3.2.1 Start Up for Demo Mode

TMS Master is initialized for Demo Mode at start up by the use of a command line parameter: /d. To start TMS Master in Demo Mode, create a Windows shortcut to the TMS Master application; right-click on the shortcut and select “Properties”; at the end of the “Target” field item on the Shortcut tab, add /d and close the Properties dialog by selecting OK. This step must be performed only once, as long as the shortcut is never deleted. TMS Master may then be launched by double clicking the shortcut. Demo Mode configuration is confirmed by “Demo Mode” initially in the title bar of the TMS Master main window. It is also confirmed by opening the About box for TMS Master as described previously. TMS Master will launch TMS DataComms in Demo Mode if it was not started stand-alone.

B.3.2.2 Elevated Platform Test Lane Dimensions

The dimensions of the “test lane” represented by the elevated platform must be specified prior to conducting exercises. After it is launched, TMS Master will display the dialog shown in Figure B-6.

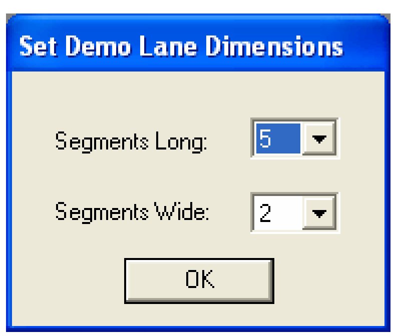


Figure B-6. Set Demo Lane Dimensions dialog

This dialog allows the specification of the dimensions of the elevated platform test lane in terms of segments. The default dimensions are five segments long by two segments wide. The dimensions specified at this time will be in effect for the duration of the TMS execution session.

B.3.2.3 Elevated Platform Test Lane Survey

The ground truth data used in a Demo Mode exercise conducted on the elevated platform is collected using the Survey operation of TMS Master. Prior to initiating the Survey, an Instrumentation ("Instr") Survey data communications interface to the DU FIU must be established within TMS DataComms. Refer to the previous section on TMS DataComms for more information on Instr Survey interfaces. Refer to section 5.3.2.2.4 of the System Users Manual on TMS Master Survey operations for general information on configuring and conducting survey operations. The position data received from an FIU connected through an Instr Survey interface used for ground truth object measurements corresponds to that obtained through the Arc Second sensor designated as "Left Foot."

The boundaries of the test lane associated with the elevated platform are designated using the standard lane boundary marker types. These markers may coincide with the platform corners or they may be inset from the corners. In the latter case, the corners can be marked using a pre-defined set of Landmark identifiers. These are, specifically, "DEMO_F_L" (front left), "DEMO_F_R" (front right), "DEMO_B_L" (back left) and "DEMO_B_R" (back right). If specified, the overall platform area will be calculated using these landmarks; otherwise, the platform area will be calculated using the beginning- and end-of-lane markers.

Once the lane boundary locations are measured, the location of virtual mines may be specified manually within the Survey operation. Double clicking on the Survey grid display will open a Create New Object dialog with the northing and easting values filled in for the location clicked. The altitude value is by default set to that specified for the survey data reference point. The survey data reference point may be set from measured position data using the Message button on the Survey Data modification dialog. The altitude value for the reference point provided from the measured data must then have subtracted from it the height of the center of the Arc Second sensor above the platform grid. Assuming that the platform is relatively level, the altitude value for a manually entered virtual mine can be specified as the default altitude value less the desired "burial depth." Note: per convention, the burial depth value is specified in inches, the altitude is specified in meters.

B.3.2.4 Metal Detector Background Calibration

An environment that contains a greater number of metal objects (such as inside an office building with metal framed walls and concrete floors containing rebar) than would normally be encountered during the use of a metal detector outdoors will produce an elevated level of background "noise." This background noise may completely obscure the detector responses to low metal content objects, such as anti-personnel mines. In order to compensate for this situation, TMS Master includes a metal detector calibration feature. This feature allows the calculation of an offset value that takes into account the measured background noise level at a specific location. The calibration feature may be initiated at any time prior to starting a configured exercise by selecting the "MD Background Cal…" item of the File menu during an

Exercise operation. In addition, if a calibration has not been performed prior to starting an exercise in Demo Mode, the user will be prompted to do so when metal detector data is first available. In this case, the dialog shown in Figure B-7 is first presented to the user.

Figure B-7. Metal Detector Background Calibration prompt dialog

Selecting Yes, or selecting the “MD Background Cal…” File menu item, will open a dialog that displays the current received metal detector data necessary for calculating the background noise calibration value. The specific contents of this dialog and corresponding calculation method are dependent upon the type of mine detector used in the exercise. **Figure B-8** shows the dialog for an AN/PSS-12 detector. This dialog displays in strip chart format the current values received from the FIU representing the background noise level measured by the metal detector. The detector operator should be instructed to hold the detector away from all metal objects and to set the metal detector sensitivity as low as possible to just barely indicate a response, if applicable. To begin the calibration process, click the Start button. The current value of the calculated offset is displayed at the top of the dialog. Also displayed is any previously calculated value. Once the current value becomes acceptably steady, click the Stop button. If the resulting value is considered acceptable, click the Send button. This will send the offset value to the FIU for application to the metal detector. The metal detector output should then be reduced by the value of the offset. To recalculate the offset value, click the Re-Start button. A calibration value should be sent to the FIU prior to starting each Demo Mode exercise. To reuse a value for all subsequent exercises, click the checkbox at the bottom of the dialog. Doing so will automatically send that value to the FIU at the beginning of subsequent Demo Mode exercises. If the reuse option is selected, the calibration value will also be available in subsequent TMS execution sessions. If the reuse option is not selected, the user will be prompted to perform background calibration at the start of all subsequent exercises.

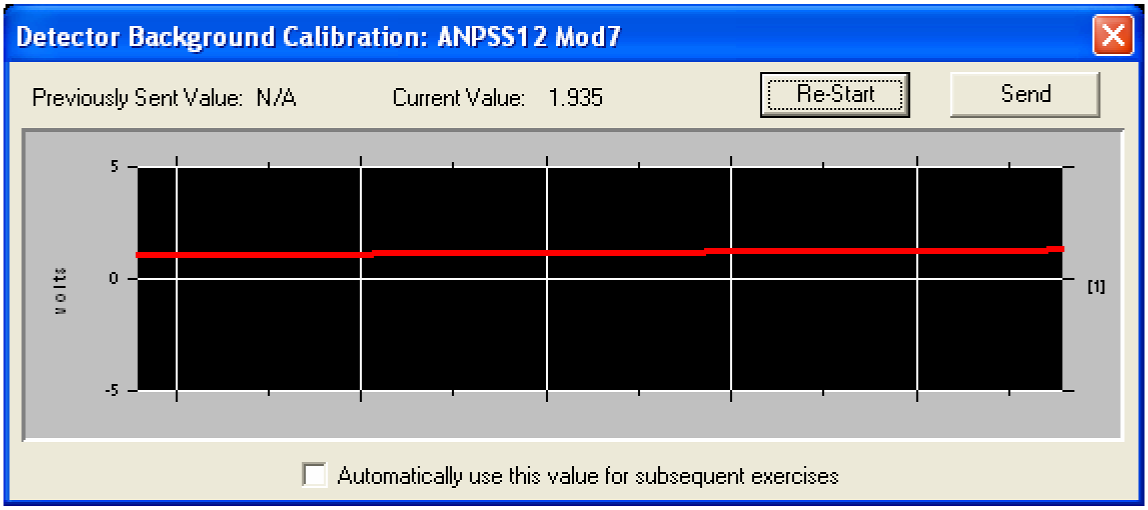


Figure B-8. AN/PSS-12 Detector Background Calibration dialog.

B.3.3 TMS MISP

The TMS Mine Interactive Simulation Program (MISP) application includes Demo Mode capabilities specific to generating exercise events that will be indicated on the elevated platform. However, there are no unique Demo Mode features implemented within TMS MISP requiring or involving user interaction.

B.3.3.1 Start Up for Demo Mode

TMS MISP is initialized for Demo Mode at start up by the use of a command line parameter: /d. In all cases, TMS Master launches TMS MISP. Demo Mode configuration of TMS MISP is confirmed by opening the About box for TMS MISP as described previously.

B.3.3.2 Demo Mode Exercise Events

The following table indicates the exercise events detected by TMS MISP and the resulting DU light behavior. In all cases, the specified light behavior will occur for approximately seven seconds. At the end of this period the lights involved will be commanded off.

Event	Light Behavior
Real Mine Alarm	Constant green light
Virtual Mine Alarm	Flashing green light
Clutter Alarm	Constant blue light
Clutter Alarm on Mine	Constant blue light and constant (real mine) or flashing (virtual mine) green light
Near Miss Mine Alarm	Constant amber light and constant (real mine) or flashing (virtual mine) green light
Far Miss Mine Alarm	Constant amber light
Mine Detonation	Constant red light and flashing amber light

Table B-1. Demo Mode Exercise Events and Corresponding Light Behavior

APPENDIX J. TMS DETAILED PROCEDURES

TMS Operator Overview

The TMS system will be operated and maintained on-site by members of the ATC Geodetics team. These individuals are highly skilled specialists in the field of surveying and geophysical mapping. Team members are fluent with traditional theadolite as well as modern RTK GPS methodologies. The geodetics crew will set up, operate, and maintain the TMS system for daily operations. A minimum crew of two members will be required for this test.

TMS Operator Daily Procedures

1. Start generator, and allow it to warm up. Prime as required. Verify Fuel level and report if fuel will be required for day's operations. Allow voltage and frequency to maintain 220 V and 60 Hz, respectively.
2. Unlock data van and turn on data terminal power center. Allow lights, heating/cooling, and all auxiliary hardware to power on. Initiate the UPS from the standby. Turn on the console computers, which include the data comms server and workstations 1 and 2.
3. Set up outdoor transmitter equipment. This consists of four ArcSecond laser transmitters. Transmitters 1 and 2 are positioned based on known survey control points. These units are then turned on, and operation is verified by a rotating turret. This allows the transmitters to blanket the test grid with a 3-D laser volume.
4. Power up FIU. Operation is verified by a red light emitting diode (LED) contained on the FIU on/off switch. Run FIU remotely from within the datacomms server using "PC Anywhere" remote access software. Establish basic connection from the FIU to the datacomms server.
5. Run "3Di Workbench" (software is housed in the FIU) and begin sensor calibration. Only one crystal may be used for the calibration, preferably the same crystal for each daily calibration throughout the test. Continue calibration by choosing six random positions and two observed positions over a known baseline length. Perform calibration every time transmitters are moved (daily before test, after major weather delays).
6. Verify 3Di software captures data on all points within the calibration procedure and completes a bundle calculation. Check that calibration calculations are operating within predetermined-allowable errors. If the error is within the desired accuracy range, the software passes the resulting data and transmits the info to the FIU. If the error exceeds allowable standards, the calculation will fail and must be performed again until a satisfactory error has been achieved.
7. Shut down Field Instrumentation Unit (FIU). Attach all sensors and cameras to FIU. After all sensors have been connected to inputs on the FIU, the FIU is restarted by pushing the "on" button and verifying that the red LED indicator is on.
8. Re-establish WI-FI connection with "PC Anywhere". Restart 3Di workbench software and monitor sensor outputs for possible laser dropout. This can be caused by weather or blocking line-of-site.
9. Enable (OPCLIENT) in DOS prompt. At this point, the system is ready for test operator.
10. Assist in outfitting test subject with sensors and FIU wagon. Verify after outfitting that all sensors are operational.

11. Prepare for first lane of test. Use TMS software and set up “mission area” for specific lane. Access ground truth of UXO targets and paste into lane area within TMS and CTMS. Verify that TMS master has acquired operator near first lane. Check that all sensors are being acquired and no blockage has occurred. Confirm video stream feed is operational.
12. Have operator place detector on right lane boundary marker. Visually check that detector is in-fact, above marker when instructed by operator. Manually record target over marker as a baseline measurement.
13. Begin recording data and instruct test subject to begin locating UXO.
14. When test participant declares a target, manually capture alarm by declaring a target within the TMS software. Verify target was accepted and saved onto real-time mapping of grid area (red “x”). Communicate to test participant that run may continue.
15. Upon completion of the lane, archive telemetry under the appropriate operator, date, and time.
16. Upon completion of test grid area, survey all pin flags using RTK GPS system. Remove pin-flags once surveyed and return to data van for reuse.

Lane 1 Preparation.

The data van uses the TMS software at this point to set up a mission in the particular lane or location. Ground truth of the location or lane is then accessed and pulled into a “run”. The TMS master will then acquire an operator in the field, this allows you to see on screen and in real time the location of the operator’s feet and the detector superimposed over the lane as well as the location of potential targets. The TMS master will then record the beginning of the lane right marker, which allows for a QC check that the detector is, in-fact where the tracking system records. The alarm is verified on the corner reference and observed to be directly over the lane boundary marker. (Hence the note in the TMS alarm files: the first alarm is always the beginning of the lane). The GPS alarms file only contains pin-flags.

Logging.

From the TMS console, the mission is initiated and data strings are saved, as well as streaming video.

Encounters.

When an operator locates a possible target for marking, the operator communicates to the TMS operator via radio while placing the head of the detector on the ground directly over the target to be marked. The TMS operator then manually presses a key on the TMS keyboard which captures the alarm location. This location shows up as a distinct mark (red x) on the TMS as well as the CTMS host. Once the TMS operator verifies that the target has been saved, a communication is made to the test subject and he/she may continue the run. Upon completion of the lane, the telemetry is archived and saved, and the alarms are saved under the appropriate operator/date/time etc. TMS alarms and video data are also saved at this point. Saving occurs after every lane. At the end of the day, all pin-flags are surveyed using RTK GPS and saved as backups to the TMS alarms. These files do not contain the beginning right boundary maker of each lane.

For each following lane, appropriate ground truth, operator, and video acquisition must be required. This process is estimated to have the duration of no more than 2 minutes.

APPENDIX K. DIFFERENCES USING 0.5m HALO VERSUS 1.0m HALO

CSTE-DTC-AT-AD-R 16 January 2007

MEMORANDUM FOR CHIEF, Military Environmental Technology Demonstration Center Team, ATTN: Chris Appelt

SUBJECT: Performance Characteristics and Measurements of Operators without TMS Instrumentation, Difference using 0.5m Halo versus 1.0m Halo.

1. Reference: Analytical Team Report 06-ADA-026, "Performance Characteristics and Measurements of Operators without TMS Instrumentation", dated May 2006.

2. The same data from the 2006 Operator Performance Test was recalculated using a 0.5-meter radius halo. (If a finding made by an operator was within a 0.5-meter radius halo of the ground truth, it was considered a hit. Findings outside this radius were considered false alarms. If there were multiple findings within a halo, only one was counted as a hit, while the others were not considered false alarms.) The previous report used a radius of 1.0-meters. The recalculated probabilities of detection (Pd) and false alarm rates (FAR) for the twelve operators (five experts, five novices, and two quality control operators) with 0.5m halo, along with the previously calculated Pd and FAR with 1.0m halo are presented in Table 1. Plots of Pd versus FAR for the data with 0.5m halo and 1.0m halo are presented in Figures 1 and 2, respectively.

3. The Chi-Square Test for differences in proportions and the Mann-Whitney test were used to statistically compare the performance data with 0.5m halo versus data with 1.0m halo. Using the Chi-Square Distribution at 0.05 significance level, Pd of the experts and novices between 0.5m halo and 1.0m halo were not found to be significantly different. Using the Mann-Whitney Test at the 0.05 significance level, no significant differences were found between the number of false alarms between the 0.5m halo and 1.0m halo of either the novices or experts.

4. It is interesting to note that with the smaller halo size, three operators that previously had 100% Pd, now do not. Also, using the Mann-Whitney test at the 0.05 significance level, there are significantly less multiple hits with the smaller halo size.

5. This memorandum is referenced as 07-ADA-009, and the point of contact is Selena Bednarz, 3-4528.

REVIEWED BY:

BARBARA J. GILLICH
Technical Lead, Analytical Team

APPROVED BY:

NELLIE M. DUPREY
Chief, RAM/ILS Engineering
and Analysis Division

Table 1. Summary Table of Operators Lanes 1-33 with Uninstrumented Data with 0.5 m Halo and 1.0 m Halo.

Operator		0.5 m halo			1.0 m halo			DIFFERENCE (0.5m halo - 1.0m halo)		
		Point Estimate Probability of detection (P_d)	False Alarm Rate, cnts/sq m[a]	No. of Multiple Hits	Point Estimate Probability of detection (P_d)	False Alarm Rate, cnts/sq m[a]	No. of Multiple Hits	Point Estimate Probability of detection (P_d)	False Alarm Rate, cnts/sq m[a]	No. of Multiple Hits
Experts	E-1	0.950	0.178	2	1.000	0.154	26	-0.050	0.024	-24
	E-2	0.900	0.077	2	0.917	0.072	7	-0.017	0.005	-5
	E-3	0.983	0.098	1	1.000	0.087	12	-0.017	0.011	-11
	E-4	0.900	0.039	0	0.933	0.034	4	-0.033	0.005	-4
	E-5	0.900	0.099	1	0.933	0.090	9	-0.033	0.009	-8
	Mean	**0.927**	**0.098**	**1.2**	**0.957**	**0.087**	**11.6**	**-0.030**	**0.011**	**-10.4**
Novices	N-1	0.967	0.072	1	1.000	0.057	16	-0.033	0.015	-15
	N-2	0.933	0.036	2	0.983	0.028	8	-0.050	0.008	-6
	N-3	0.917	0.058	8	0.950	0.047	19	-0.033	0.011	-11
	N-4	0.983	0.191	8	0.983	0.168	34	0.000	0.023	-26
	N-5	0.867	0.022	4	0.933	0.017	6	-0.067	0.005	-2
	Mean	**0.933**	**0.076**	**4.6**	**0.970**	**0.063**	**16.6**	**-0.037**	**0.013**	**-12.0**
Overall Mean		**0.930**	**0.087**	**2.9**	**0.963**	**0.075**	**14.1**	**-0.033**	**0.012**	**-11.2**
QC	W-1	0.917	0.084	4	0.950	0.073	14	-0.033	0.011	-10
	W-2	0.850	0.072	9	0.917	0.064	14	-0.067	0.008	-5

[a]length x width of Lanes 1-20 is 23.70m x 1.5m, Lanes 21-26 is 17.55m x 1.5m, Lanes 27-33 is 25.00m x 1.5m

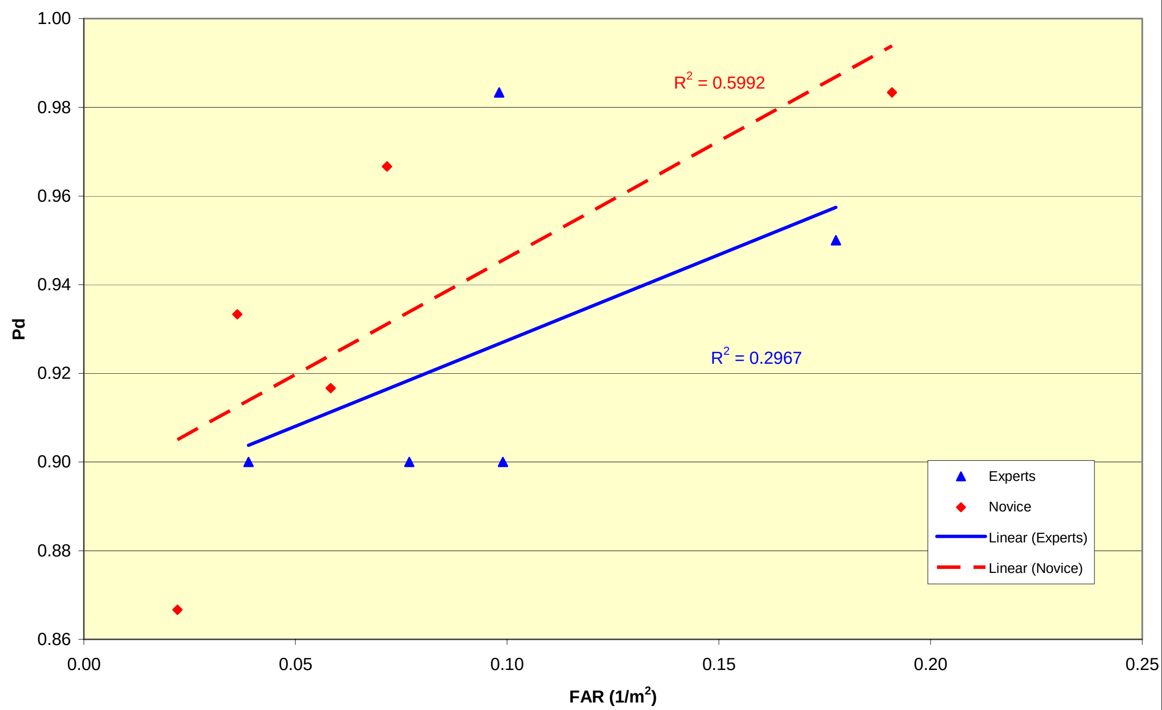


Figure 1. Probability of Detection vs. False Alarm Rate for unintstrumented data with 0.5m halo.

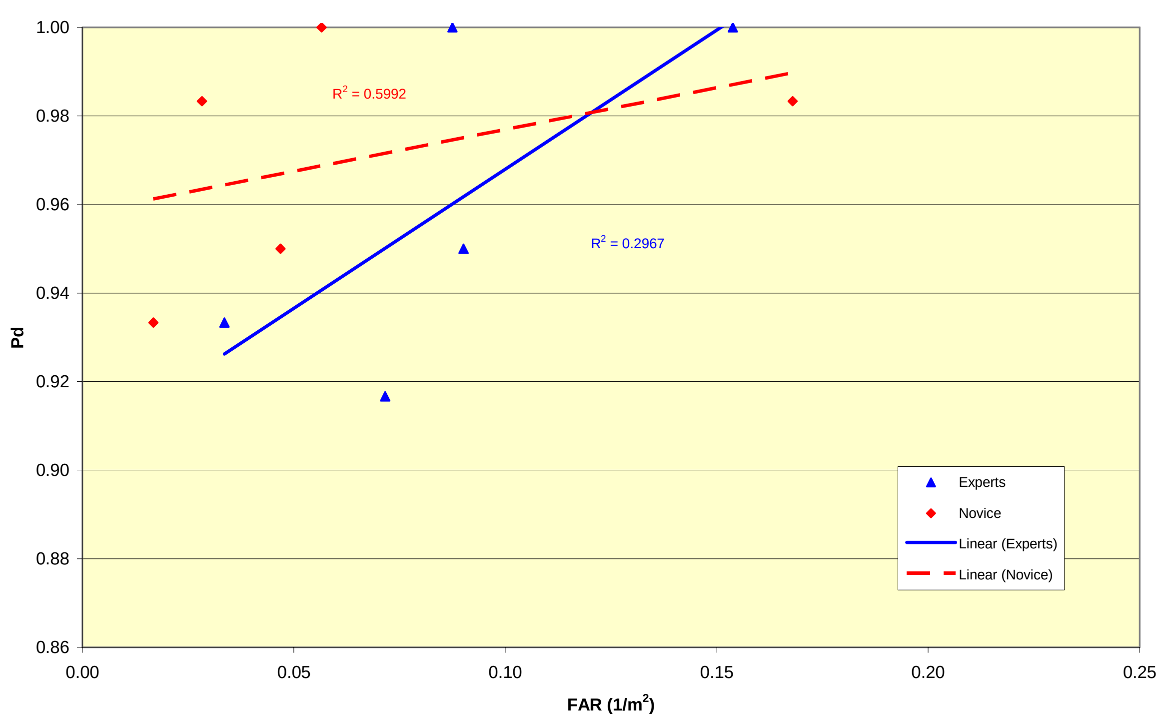


Figure 2. Probability of Detection vs. False Alarm Rate for unintstrumented data with 1.0m halo.

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APPENDIX L. PERFORMANCE AND MEASUREMENTS OF OPERATORS WITH TMS

Final Report for Operator Influence on UXO Sensor Technologies Data Analysis

September 1, 2006

Contract Number W91ZLK-04-F-0348

Prepared for:

U.S. Army Aberdeen Test Center
358 Colleran Road
APG, MD 21005-5059

Prepared by:

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100 CTC Drive
Johnstown, PA 15904

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EXECUTIVE SUMMARY

The U.S. Army Environmental Center (USAEC) through the Environmental Quality Technology (EQT) Program requested Aberdeen Test Center's (ATC) Military Environmental Technology Demonstration Center (METDC) to develop and execute a plan to ascertain and document, if it exists, a level of influence that operators may have on unexploded ordnance (UXO) detection technology results. The primary objective of the test is to determine this level of influence and to perform an analysis of operators' detection activities to identify the factors that produce variations in operator performance.

Until recently, the UXO and Countermine communities both have relied on anecdotal evidence to account for the widely differing levels of detection achieved from various operators. However, recent empirical investigations of operator influence in the countermine community have discovered substantial variability in detection performance between operators of both currently fielded equipment (AN19/PSS-12) and an advanced technology then under development (HSATMIDS/PSS-14).

To date, there has been no similar attempt to define objectively the level of operator influence in the UXO arena. This effort seeks to determine if similar individual differences in operator performance exist and, if so, to identify their bases. As in the Countermine work, this effort will also seek an explicit description of the human factors producing any differences found. Such a description, which could be cast as a cognitive model, holds potential to serve as a resource for designing operator training that can maximize the potential of fielded UXO detection tools and improve detection.

ATC tested 10 geophysical detector operators (5 novices and 5 experts). The experts had more experience with geophysical detection than did the novices.

The testing indicated anomalies in some of the results relating to expert vs. novice performance. The overall performance of the novices was better than the performance of the experts. The variability of the novices' probability of detection (P_D) results was less affected by factors such as detector head height and velocity than the variability of the experts' results. In addition, P_D was affected oppositely by detector head height for the novices vs. the experts. These results indicate that perhaps periodic refresher training would be beneficial to expert operators to improve their results in the field.

PERFORMANCE CHARACTERISTICS AND MEASUREMENTS

Of the ten operators who completed the test grid, five were classified as "Experts" and five were classified as "Novices" based upon their experience. Information on the ten operators is provided in Table 1.

Table 2: Operator Demographics

	Operator	Age	Race	Gender	Marital Status	Years of Education	Months of EOD Experience	Months of UXO Experience	Months of Schonstadt Experience	Prior Military Experience	Health	Smoker (packs/day)	Height (in)	Weight (lbs)
Experts	E-1	34	Caucasian	Male	Married	12	120	48	48	Yes	Excellent	No	72	245
	E-2	37	Caucasian	Male	Divorced	12	156	72	72	Yes	Good	No	72	260
	E-3	28	Caucasian	Male	Single	13	102	96	84	Yes	Excellent	No	69	180
	E-4	43	Caucasian	Male	Married	12	252	42	42	Yes	Excellent	No	67	200
	E-5	25	Other	Female	Single	14	78	12	12	Yes	Excellent	No	64	130
Novices	N-1	31	Native American	Male	Single	16	0	0	0.25	No	Good	No	67	160
	N-2	53	Native American	Male	Married	16	0	0	0	No	Good	No	73	220
	N-3	22	Pacific Islander	Male	Single	12	0	0	0	No	Good	Yes (1)	70	223
	N-4	40	Caucasian	Male	Married	12	0	0	0	Yes	Good	No	70	230
	N-5	24	Pacific Islander	Male	Single	16	0	1.5	1.5	No	Good	No	70	210

Using the Schonstadt magnetometer, each operator completed 33 lanes, which contained a total of 60 targets buried at depths ranging from six to 30 inches. Test observers maintained a daily log to record test data and conditions. In addition, the Schonstadt was equipped with two sensors that allowed the TMS system to track and record the coordinates of the sensors at a rate of ten hertz. Four performance characteristics were obtained for each operator:

1) **Lane Velocity:** The time operators took to complete each lane was manually recorded on the daily log. Time delays due to equipment issues or data recording were also recorded and then subtracted from the total lane time. This "corrected" lane length was then divided by the lane time. The result was defined as the Lane Velocity.
2) **Percent of Lane Area Covered:** Using the TMS data, the lateral distance between the detector head and each point on a 0.25 meter grid within the lane was calculated for each recorded coordinate of the detector head. The number of points on the grid of which the detector head came within 0.25 meters at some point during the run was divided by the total number of points on the grid and multiplied by 100. The result was defined as the Percent of Lane Area Covered.
3) **Detector Head Height:** Using the TMS data, the two sensors' positions were used to calculate a vector to determine the position of the detector head. The ground altitude at the nearest surveyed point was then subtracted from the altitude of the calculated detector head position. The result was defined as the Detector Head Height.
4) **Detector Head Velocity:** Using the TMS data, the incremental distance traveled by the detector head was calculated by taking the calculated detector head position at each instance and subtracting the calculated detector head position at the previous instance. The incremental distance traveled was then divided by the time lapse (normally 0.1 seconds). The result was defined as the Detector Head Velocity.

These four performance characteristics can then be compared to the two performance measurements – the Probability of Detection (Pd) and the False Alarm Rate (FAR). In addition, a third performance measurement was calculated to combine both the Pd and FAR and facilitate comparisons to the performance characteristics.

1) **Probability of Detection (Pd):** For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If the distance was less than one meter, then the target was considered detected no matter in which lane the target was actually located. Multiple detections of the same target were ignored. The number of detected targets in the field was divided by the total number of targets in the field (60 targets) and multiplied by 100. The result was defined as the Pd.
2) **False Alarm Rate (FAR):** For each alarm an operator noted in the lane, the distance between each of the targets in the field and the alarm was calculated. If no target was within one meter of the alarm, then the alarm was considered a False Alarm. The total number of False Alarms was divided by the area of the field (1131.5 square meters). The result was defined as the FAR.
3) **Distance Receiver Operating Characteristics (ROC):** A ROC curve is an industry standard that is used to compare the performance of operators and equipment in UXO and mine detection. It consists of the FAR on the x-axis versus the Pd on the y-axis. Curves nearer the upper left-hand corner of the chart are considered better. Therefore, in order to compare the operators' performance versus each of the characteristics, the Distance ROC was calculated as the distance from the upper left-hand corner (coordinates 0,1) that an operators' point (FAR,Pd) is on the ROC curve, as shown in the following equation:

$$Dist\_ROC = \sqrt{(1-Pd)^2 + (0-FAR)^2}$$

RESULTS OF EXPERTS VERSUS NOVICES

The original hypothesis of the test was that the experts would perform better than the novices. The performance characteristics of the experts could then be compared to the novices to determine what accounted for the better results. However, as Figure 1 shows, the opposite results were observed.

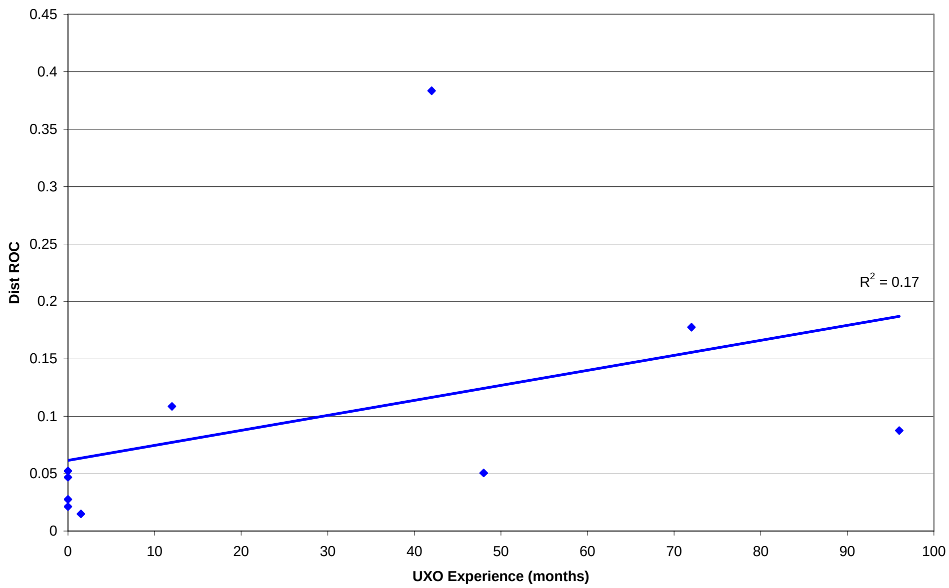

Figure 1: Dist ROC vs. UXO Experience

Table 3 provides a summary of the performance measurements for each of the operators, as well as the means for the Novices and Experts as a group.

Table 3: Performance Measurements of Experts and Novices

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance
Experts	E-1	98.33%	0.0477	0.0506
	E-2	83.33%	0.0610	0.1775
	E-3	100.00%	0.0875	0.0875
	E-4	61.67%	0.0124	0.3835
	E-5	95.00%	0.0963	0.1085
	Mean	**87.67%**	**0.0610**	**0.1615**
Novices	N-1	98.33%	0.0221	0.0277
	N-2	98.33%	0.0133	0.0213
	N-3	95.00%	0.0159	0.0525
	N-4	100.00%	0.0468	0.0468
	N-5	100.00%	0.0150	0.0150
	Mean	**98.33%**	**0.0226**	**0.0327**

As the table illustrates, the novice group performed considerably better than the expert group. The lowest novice Pd was greater than or equal to three of the experts. Only one expert achieved a lower FAR than any of the novices. On average, this produced results that, when plotted on a standard ROC curve as shown in Figure 2, were five times closer to the upper left-hand corner, indicating superior performance.

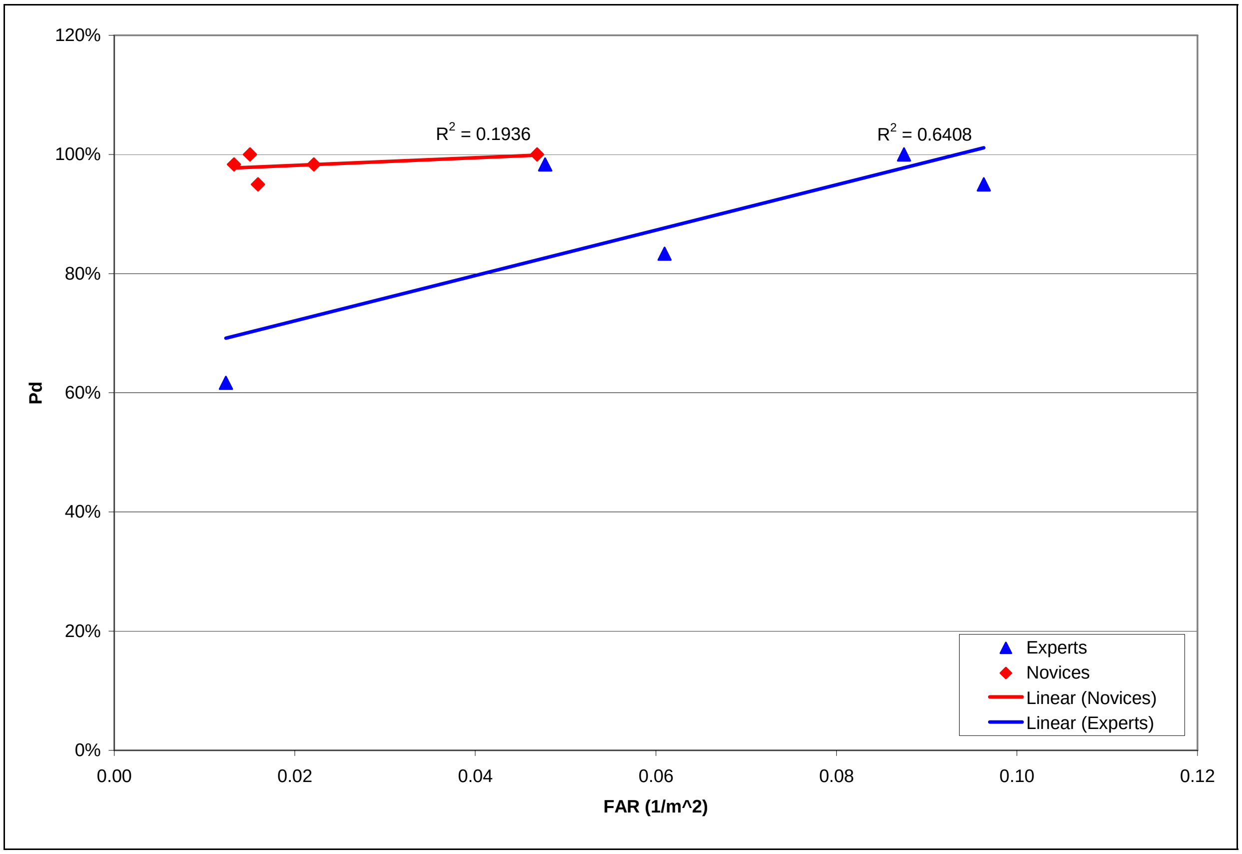

Figure 2: Experts vs. Novices ROC Curve

In order to understand why the novices performed better than the experts, each of the three performance measurements can be compared individually against the four performance characteristics – Detector Head Height, Detector Head Velocity, Lane Velocity, and Percent of Lane Area Covered. Figure 3 through Figure 6 compares Pd versus the four characteristics, while Figure 7 through Figure 10 compares FAR versus the four characteristics. Figure 11 through Figure 14 compares the Distance ROC versus the four characteristics.

Generally, the results as a whole (independent of the experts/novices classification) are not surprising. As Figure 3 through Figure 5 indicate, the novices' performance as measured by Pd was closely grouped, so the dependency upon the performance characteristics is difficult to discern. However, for the experts, Pd performance is shown to suffer as the height and velocity of the detector head increased. In addition, though the correlation was not as significant, Pd performance also decreased as the lane velocity increased.

As Figure 7 through Figure 9 show, the number of false alarms by both experts and novices' generally decreased as the lane velocity, detector head height, and detector head velocity increased. However, the data is widely scattered, and the linear regression does not match the data very closely with the exception of the data for the novices and lane velocity.

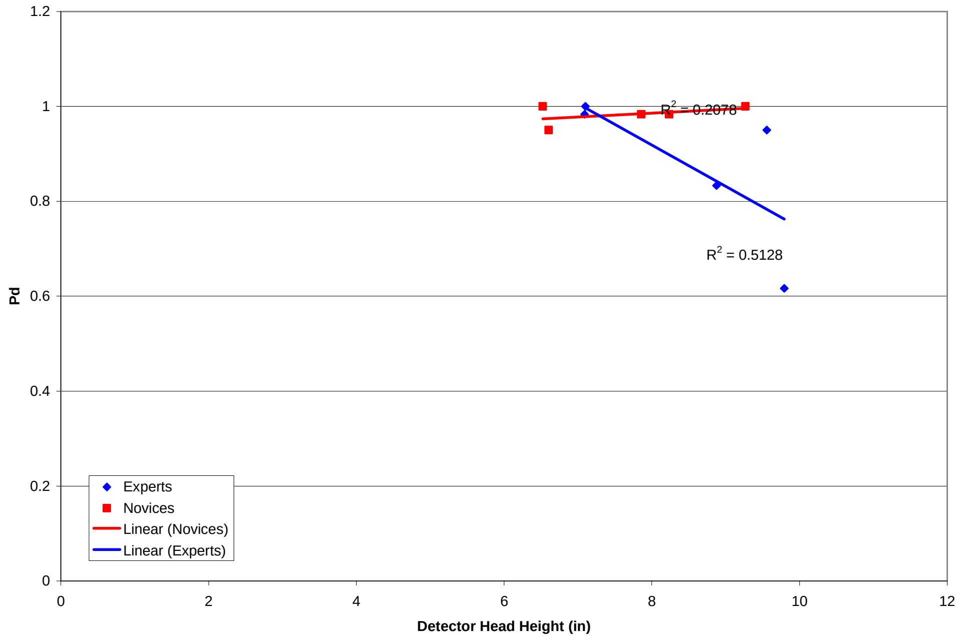

Figure 3: Experts & Novices - Pd vs. Detector Head Height

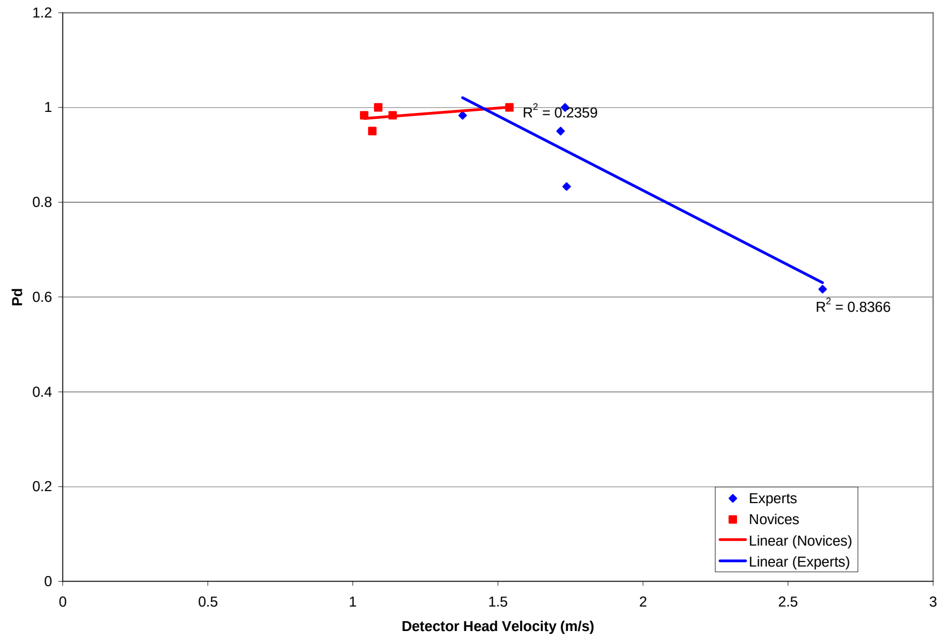

Figure 4: Experts & Novices - Pd vs. Detector Head Velocity

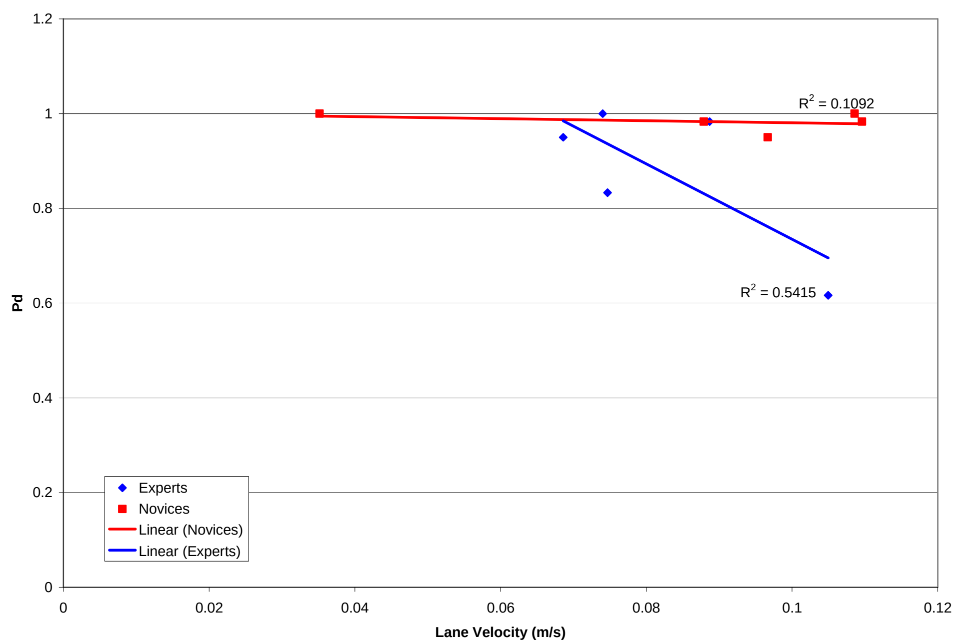

Figure 5: Experts & Novices - Pd vs. Lane Velocity

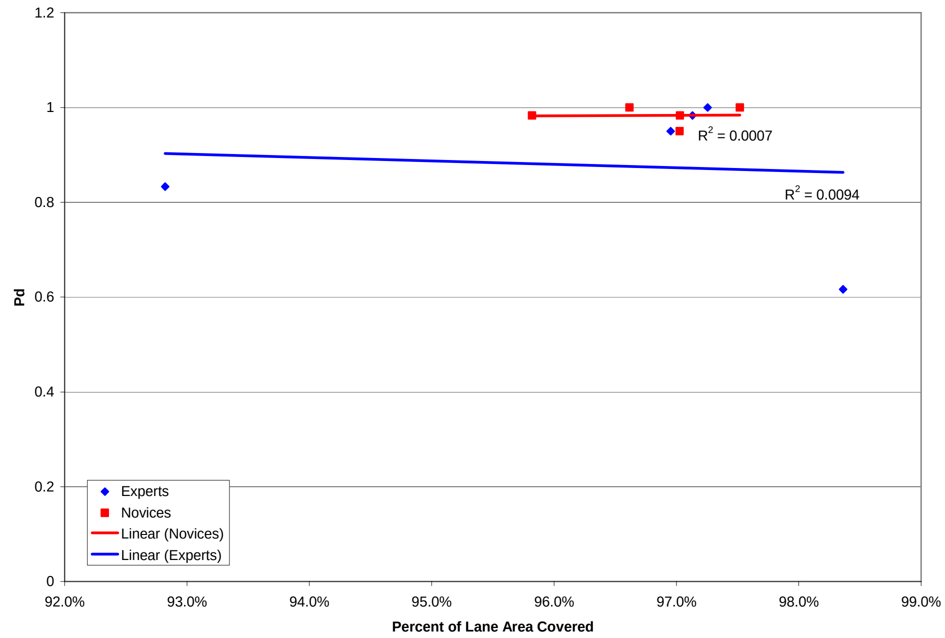

Figure 6: Experts & Novices - Pd vs. Percent of Lane Area Covered

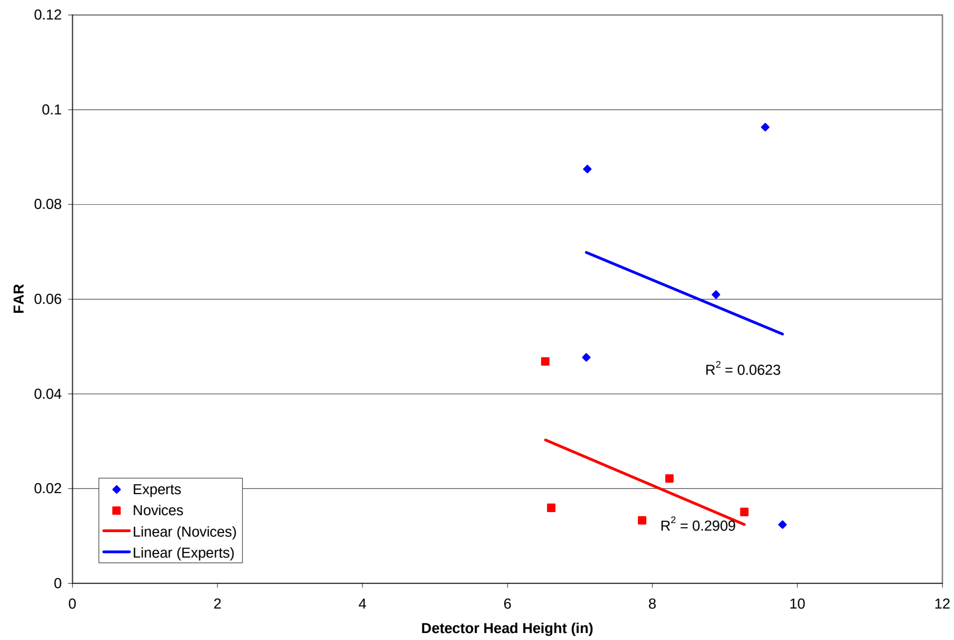

Figure 7: Experts & Novices - FAR vs. Detector Head Height

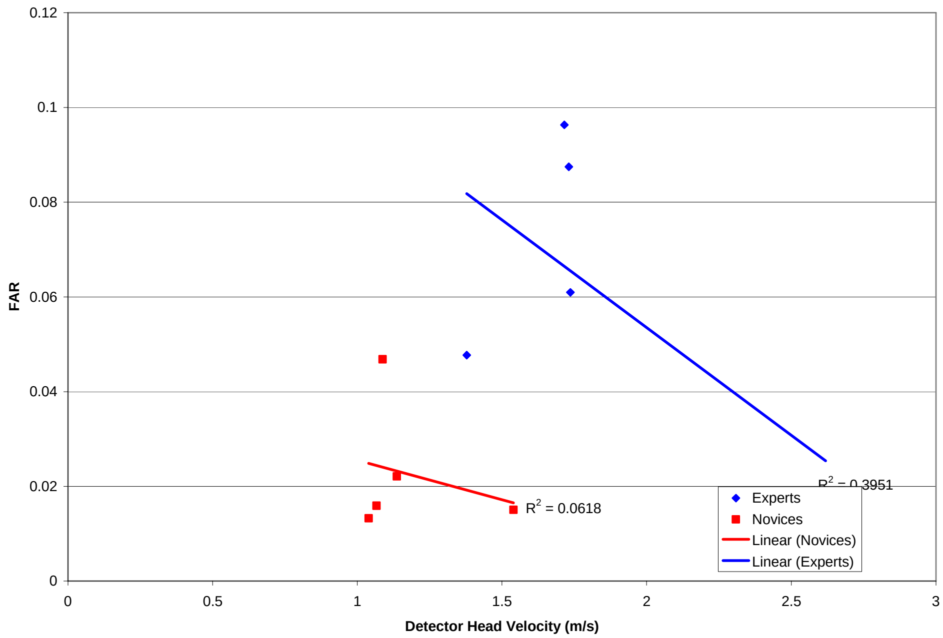

Figure 8: Experts & Novices - FAR vs. Detector Head Velocity

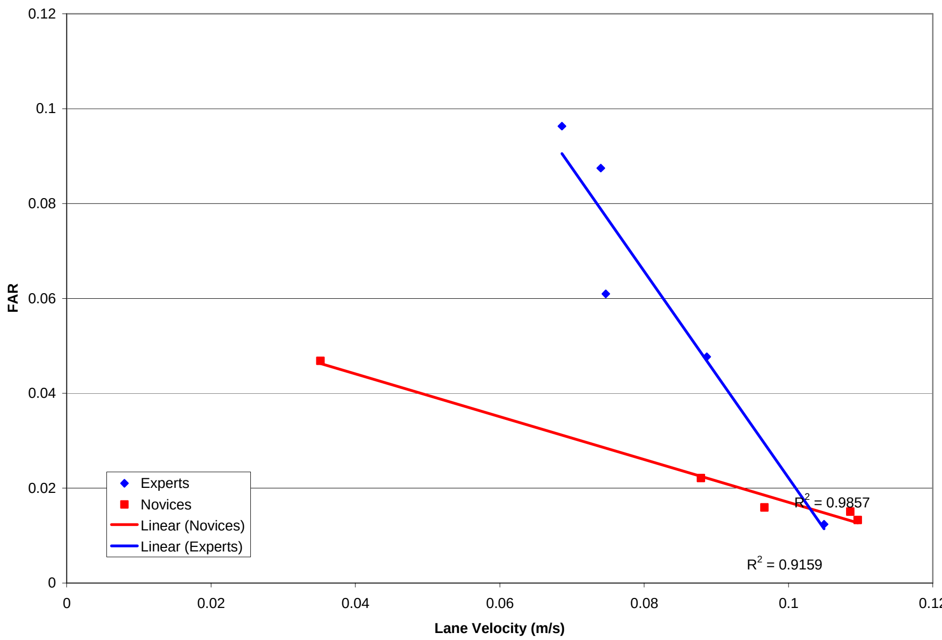

Figure 9: Experts & Novices - FAR vs. Lane Velocity

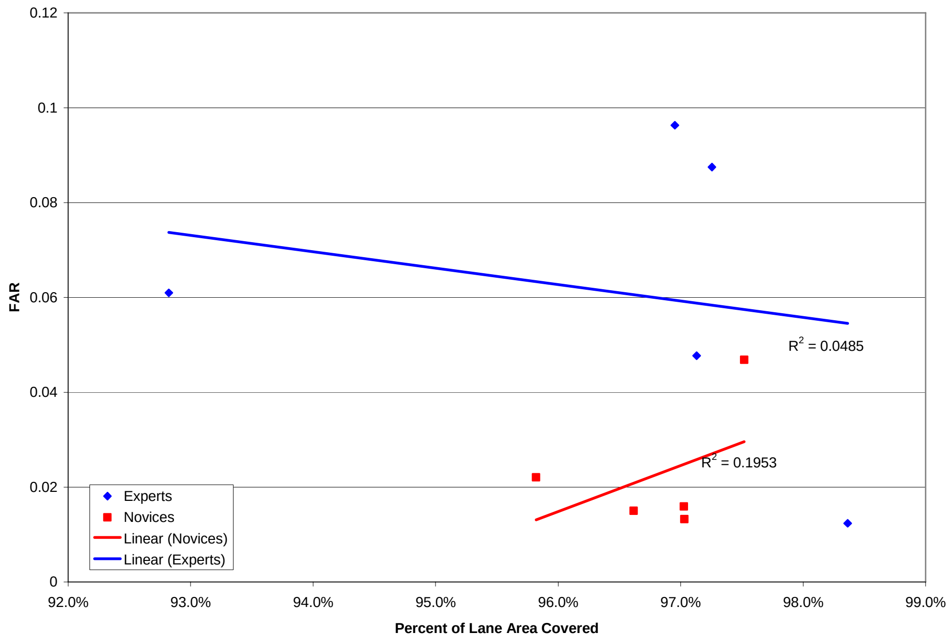

Figure 10: Experts & Novices - FAR vs. Percent of Lane Area Covered

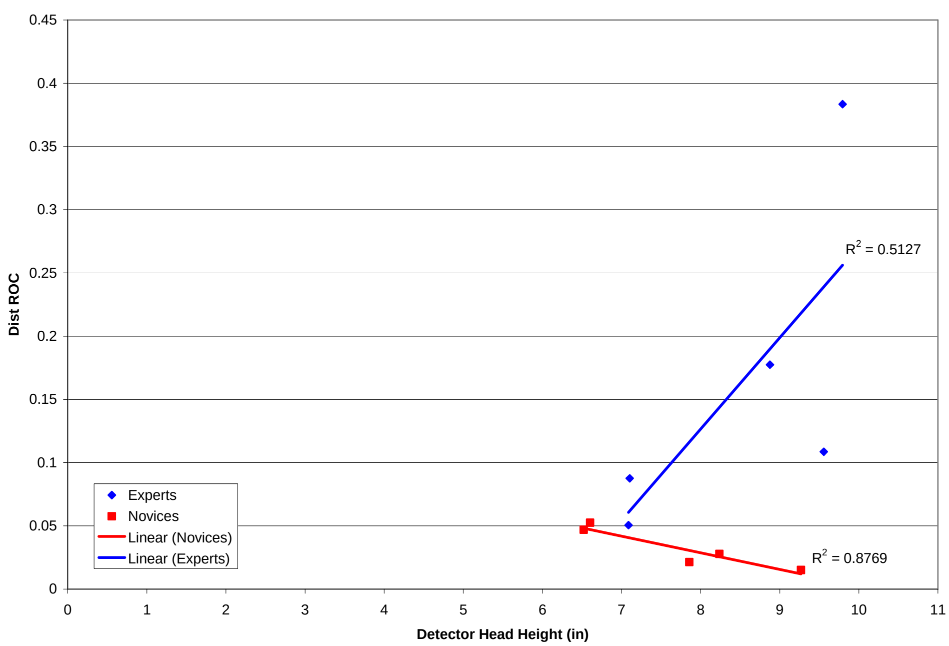

Figure 11: Experts & Novices - Dist ROC vs. Detector Head Height

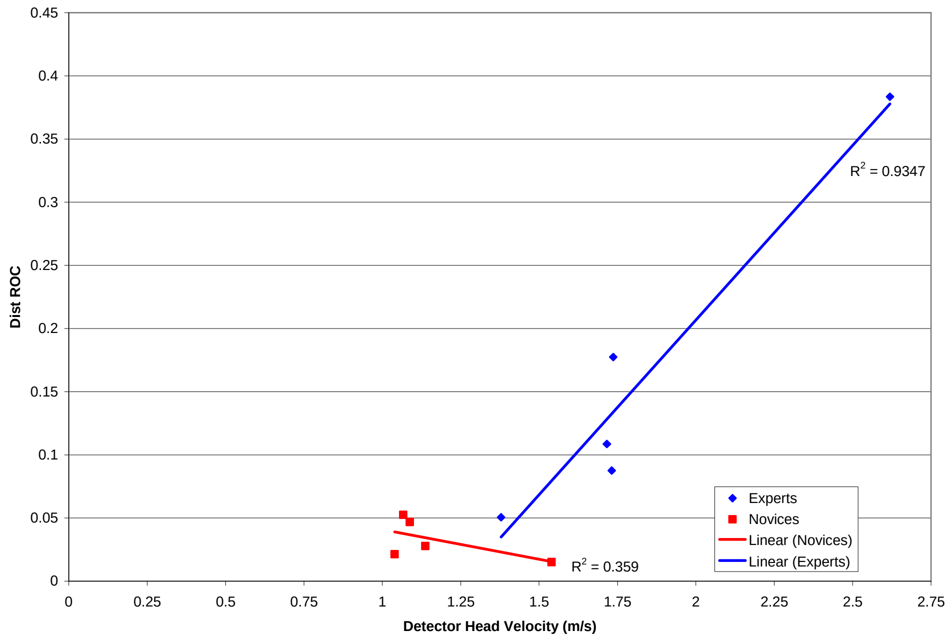

Figure 12: Experts & Novices - Dist ROC vs. Detector Head Velocity

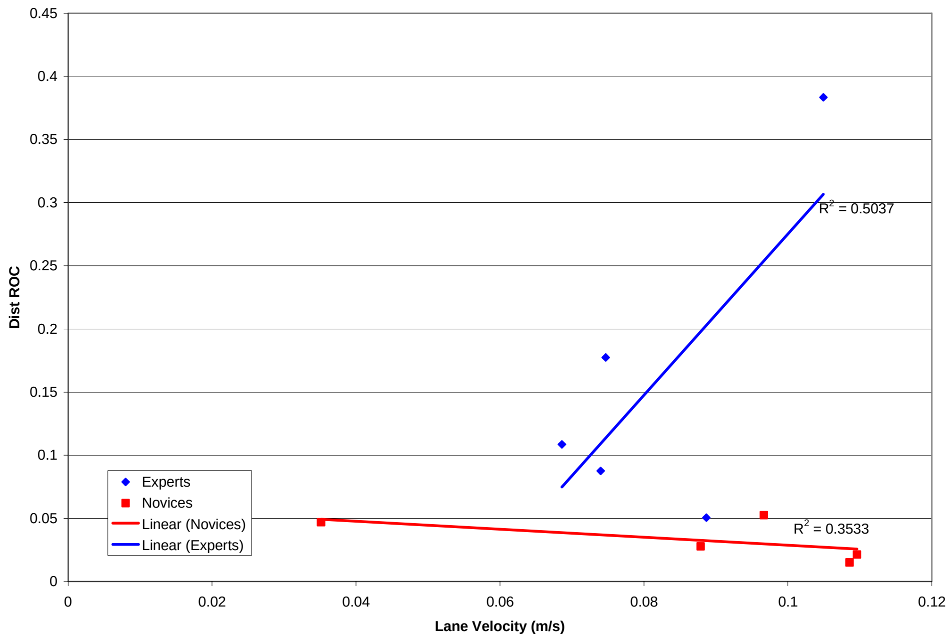

Figure 13: Experts & Novices - Dist ROC vs. Lane Velocity

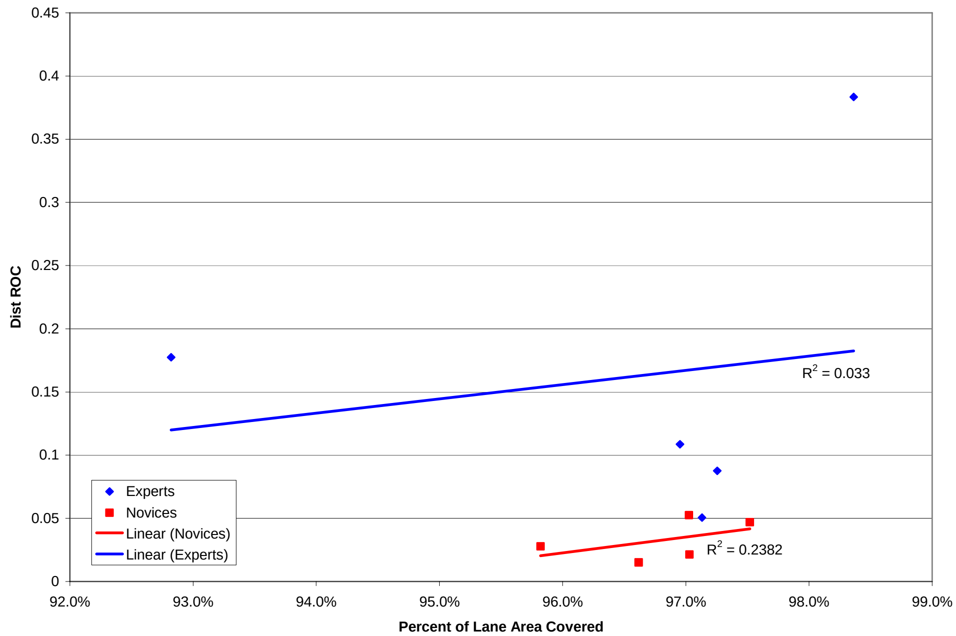

Figure 14: Experts & Novices - Dist ROC vs. Percent of Lane Area Covered

Once the two performance measurements are combined into the Distance ROC, differences between the experts and novices begin to appear. As Figure 11 shows, the novices performed better as the detector head height increased, while the experts' performance deteriorated as the detector head height increased. This should only be true for the novices up to a critical detector head height value, after which performance should decrease due to reduced received signal strength. A similar result is shown in Figure 12 and Figure 13, but the coefficients of determination (R^2 values) do not indicate a close fit for the linear regressions with the exception of the line for the experts and detector head velocity in Figure 12. The closer the R^2 values are to 1.00, the greater the correlation of the x and y axis data.

Both the novices and the experts covered the lane area fairly equally with little variation. This translated into no significant correlation between that characteristic and Pd, FAR, and Dist ROC as shown Figure 6, Figure 10, and Figure 14.

Table 4 summarizes both the performance measurements and characteristics for each operator and the groups.

Table 4: Summary of Data for Experts and Novices

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance	Lane Velocity (m/s)	Percent of Lane Area Covered	Detector Head Height (in)	Detector Head Velocity (m/s)
Experts	E-1	98.33%	0.0477	0.0506	0.09	97.13%	7.09	1.38
	E-2	83.33%	0.0610	0.1775	0.07	92.82%	8.88	1.74
	E-3	100.00%	0.0875	0.0875	0.07	97.26%	7.10	1.73
	E-4	61.67%	0.0124	0.3835	0.10	98.36%	9.79	2.62
	E-5	95.00%	0.0963	0.1085	0.06	96.95%	9.56	1.72
	Mean	**87.67%**	**0.0610**	**0.1615**	**0.08**	**96.50%**	**8.48**	**1.84**
	St. Dev.	**0.159**	**0.034**	**0.132**	**0.016**	**0.021**	**1.311**	**0.463**
Novices	N-1	98.33%	0.0221	0.0277	0.09	95.82%	8.24	1.14
	N-2	98.33%	0.0133	0.0213	0.11	97.03%	7.86	1.04
	N-3	95.00%	0.0159	0.0525	0.10	97.03%	6.61	1.07
	N-4	100.00%	0.0468	0.0468	0.04	97.52%	6.52	1.09
	N-5	100.00%	0.0150	0.0150	0.11	96.62%	9.27	1.54
	Mean	**98.33%**	**0.0226**	**0.0327**	**0.09**	**96.80%**	**7.70**	**1.17**
	St. Dev.	**0.020**	**0.014**	**0.016**	**0.031**	**0.006**	**1.157**	**0.208**

General observations from

Table 4:

- The novices' performance measurements had relatively little variation between themselves when compared to the experts' performance.
- The novices had considerably less false alarms than the experts.
- There was less variation in the pace at which the expert operators completed the lanes as compared to the novices (operator N-4 skewed the novice data since this person was between two and three times slower than the others).
- The novices tended to hold the detector head three quarters of an inch lower than the experts, on the average.
- The novices swung the detector head approximately 40 percent slower than the experts.

The results seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements.

Group 1 versus Group 2

Since the originally hypothesis proved to be incorrect. The operators were grouped based upon their performance as measured by Dist ROC rather than experience. The five operators with the lowest Dist ROC are Group 1, while the five operators with the highest Dist ROC are Group 2. Group 1 consists of four novices and one expert, while Group 2 consists of four experts and one novice. Table 5 summarizes the performance measurements for the two groups.

Table 5: Performance Measurements of Group 1 and Group 2

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance
Group 1	N-5	100.00%	0.0150	0.0150
	N-2	98.33%	0.0133	0.0213
	N-1	98.33%	0.0221	0.0277
	N-4	100.00%	0.0468	0.0468
	E-1	98.33%	0.0477	0.0506
	Mean	**99.00%**	**0.0290**	**0.0323**
Group 2	N-3	95.00%	0.0159	0.0525
	E-3	100.00%	0.0875	0.0875
	E-5	95.00%	0.0963	0.1085
	E-2	83.33%	0.0610	0.1775
	E-4	61.67%	0.0124	0.3835
	Mean	**87.00%**	**0.0546**	**0.1619**

Reclassifying the operators in this manner resulted in further widening the gap in the mean Pd measurement, while narrowing the gap in the mean FAR. Only one operator in Group 2 achieved a Pd equal to or greater than any of the operators in Group 1, while two operators in

Group 2 achieved a FAR less than the average FAR in Group 1. When plotted on a standard ROC curve as shown in Figure 15, Group 1 was on average five times closer to the upper left-hand corner than Group 2, indicating superior performance.

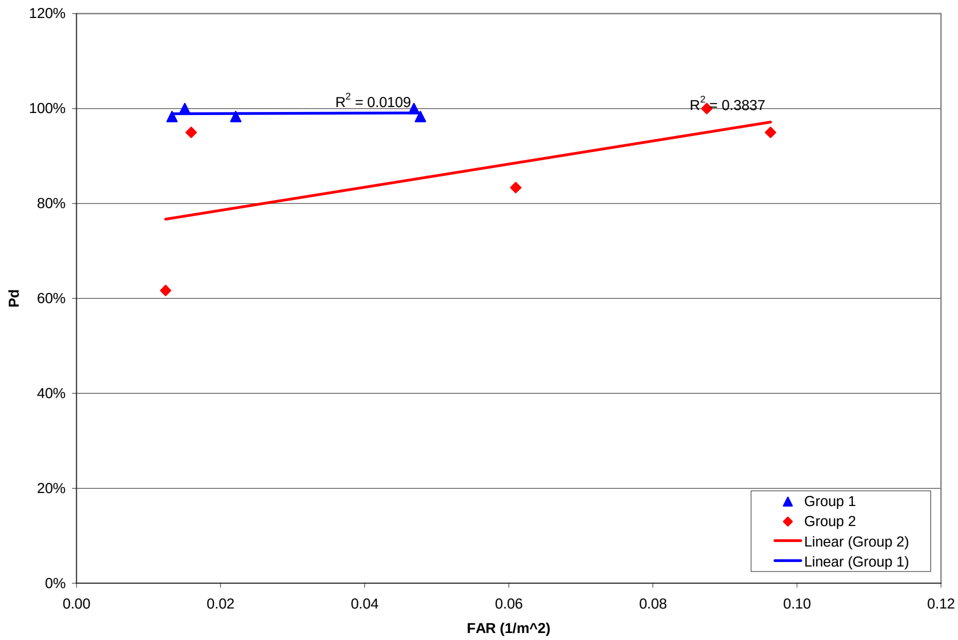

Figure 15: Group 1 vs. Group 2 ROC Curve

Figure 16 through Figure 19 compare Pd versus the four characteristics, while Figure 20 through Figure 23 compare FAR versus the four characteristics. Figure 24 through Figure 27 compare the Distance ROC versus the four characteristics.

As Figure 16 through Figure 18 indicate, Group 1's performance as measured by Pd was closely grouped, so the dependency upon the performance characteristics is difficult to discern. However, for Group 2, Pd performance is again shown to suffer as the height and velocity of the detector head increased. In addition, Pd performance also decreased as the lane velocity increased. The graphs are very similar to those for the novices and experts with the exception that the coefficient of determination for the regression lines deteriorated.

As Figure 20 through Figure 22 show, the number of false alarms by Group 1 generally decreased as the lane velocity, detector head height, and detector head velocity increased. The same held true for Group 2 in terms of detector head velocity and lane velocity. On the other hand, the number of false alarms by Group 2 generally increased as the detector head height increased. However, the data is widely scattered, and the linear regression does not match the data very closely with the exception of data for Group 1 and the detector head height.

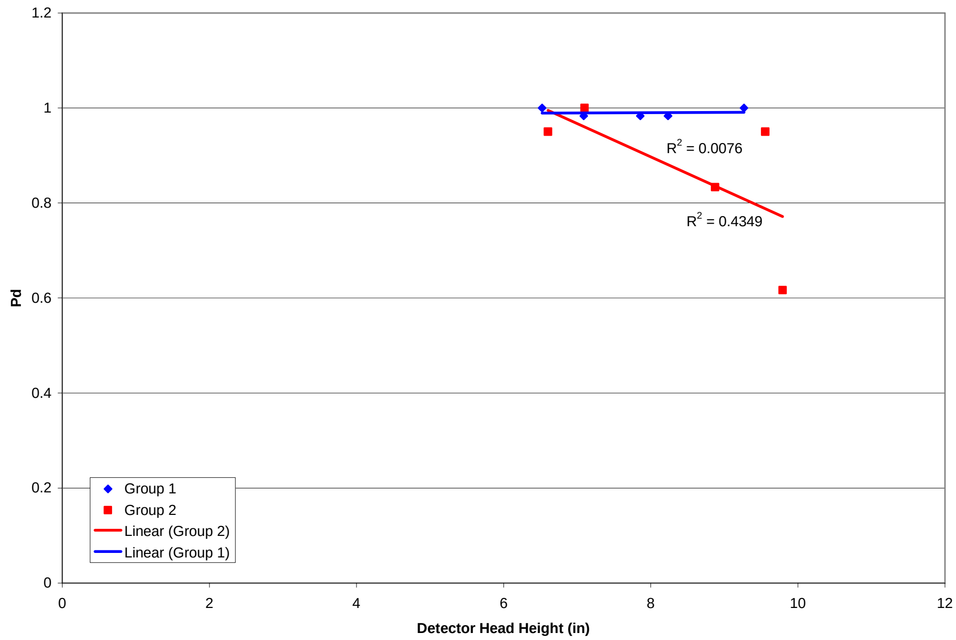

Figure 16: Group 1 & Group 2 - Pd vs. Detector Head Height

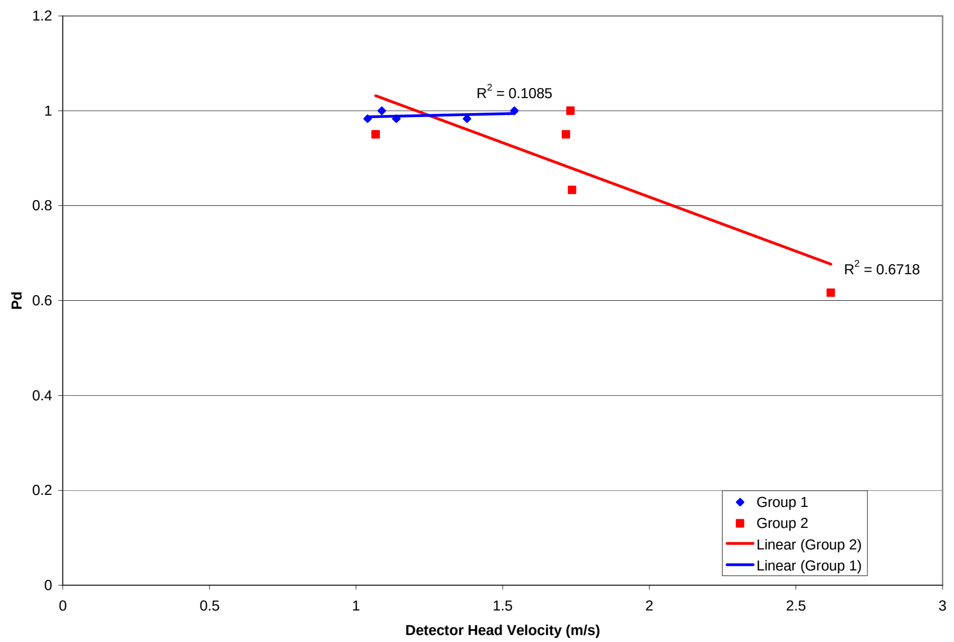

Figure 17: Group 1 & Group 2 - Pd vs. Detector Head Velocity

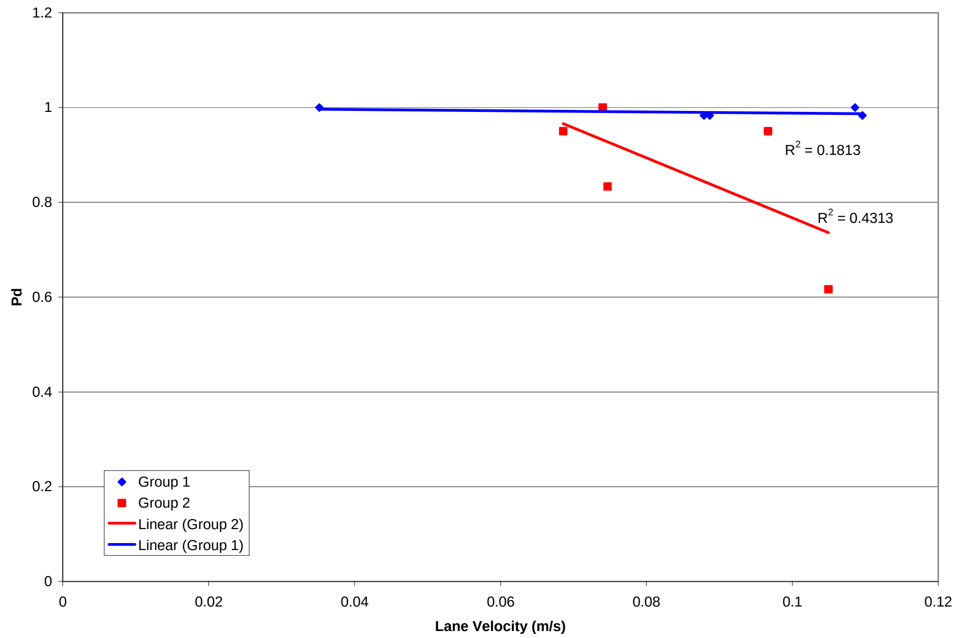

Figure 18: Group 1 & Group 2 - Pd vs. Lane Velocity

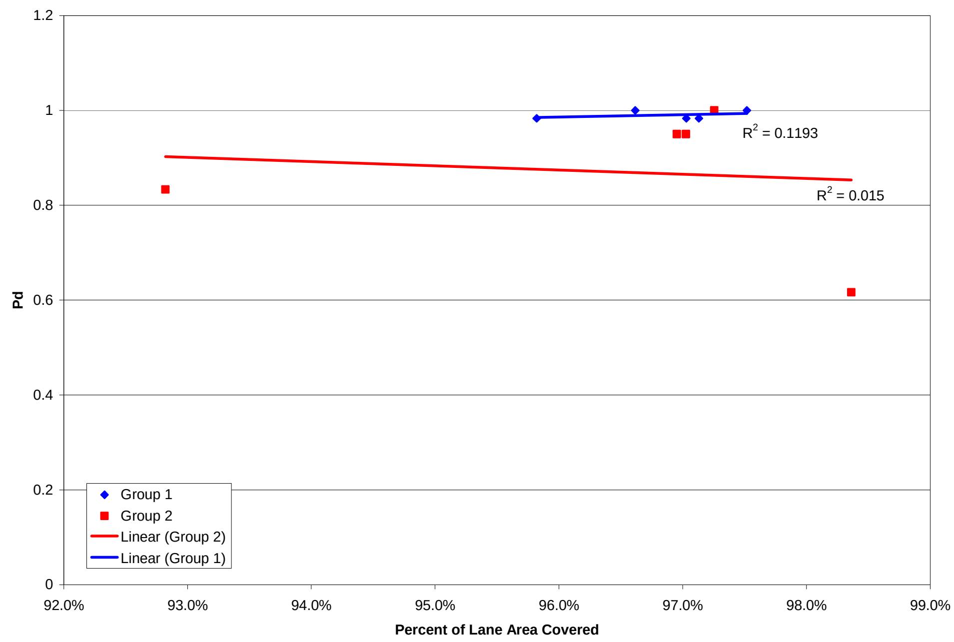

Figure 19: Group 1 & Group 2 - Pd vs. Percent of Lane Area Covered

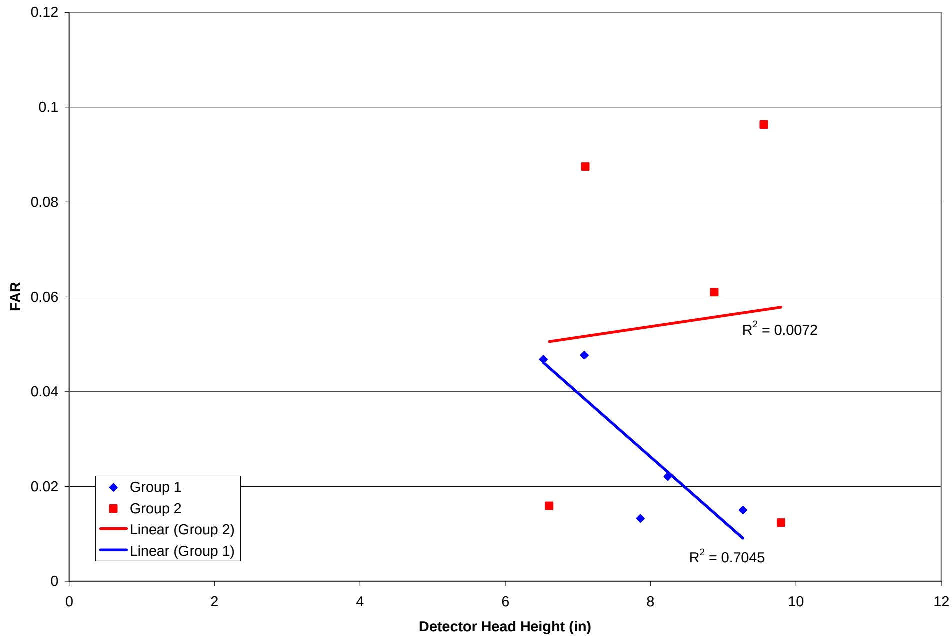

Figure 20: Group 1 & Group 2 - FAR vs. Detector Head Height

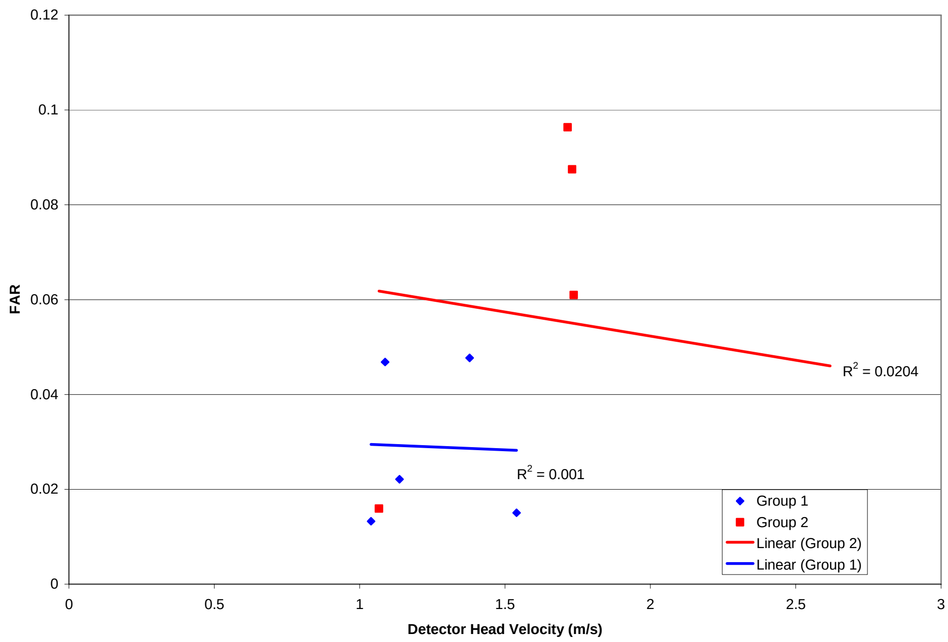

Figure 21: Group 1 & Group 2 - FAR vs. Detector Head Velocity

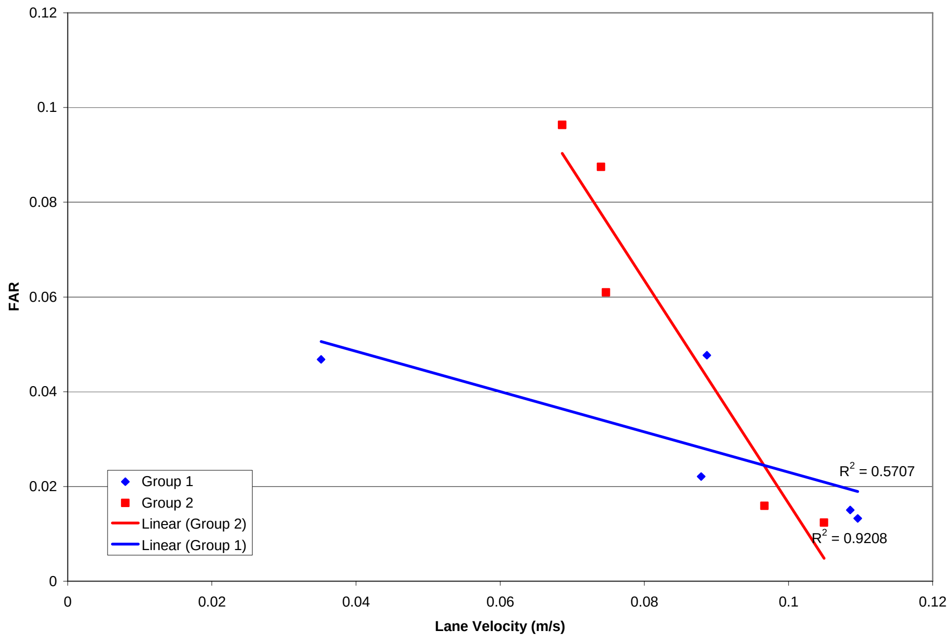

Figure 22: Group 1 & Group 2 - FAR vs. Lane Velocity

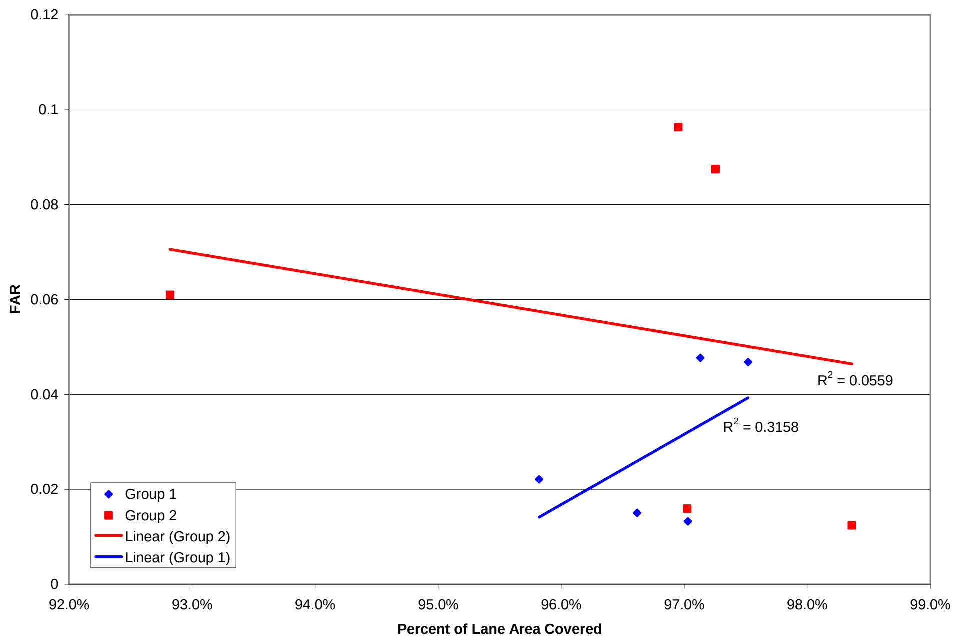

Figure 23: Group 1 & Group 2 - FAR vs. Percent of Lane Area Covered

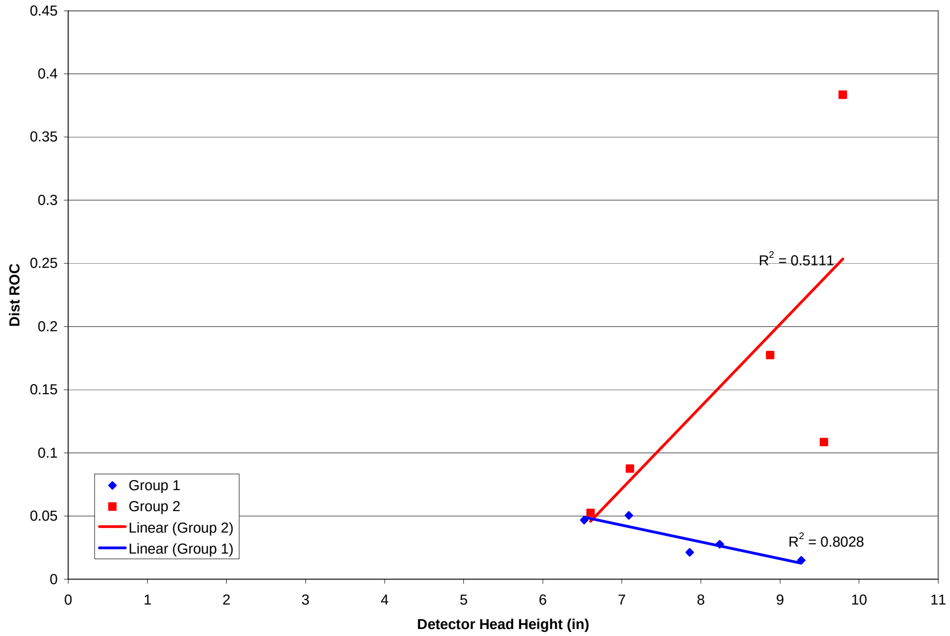

Figure 24: Group 1 & Group 2 - Dist ROC vs. Detector Head Height

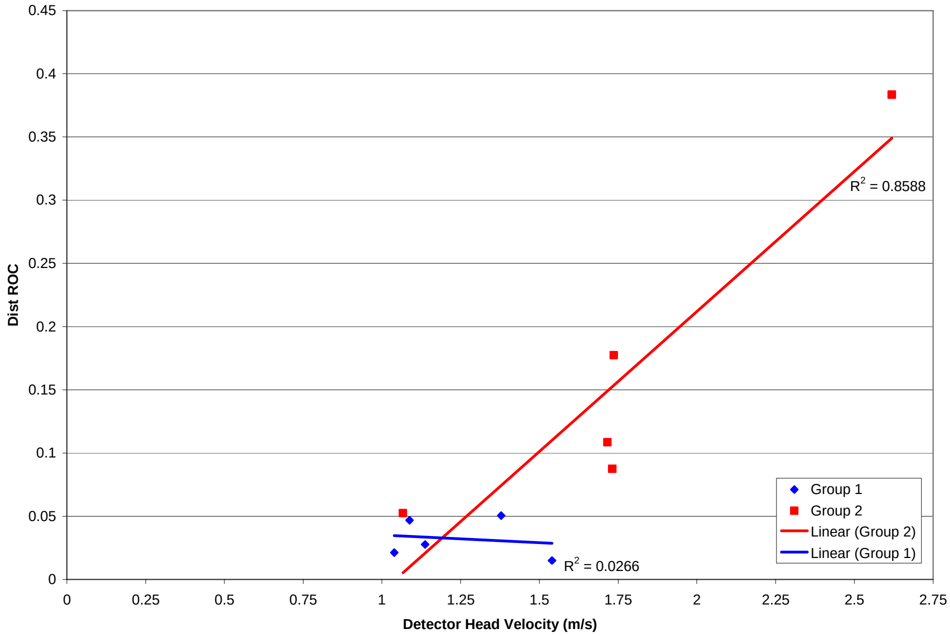

Figure 25: Group 1 & Group 2 - Dist ROC vs. Detector Head Velocity

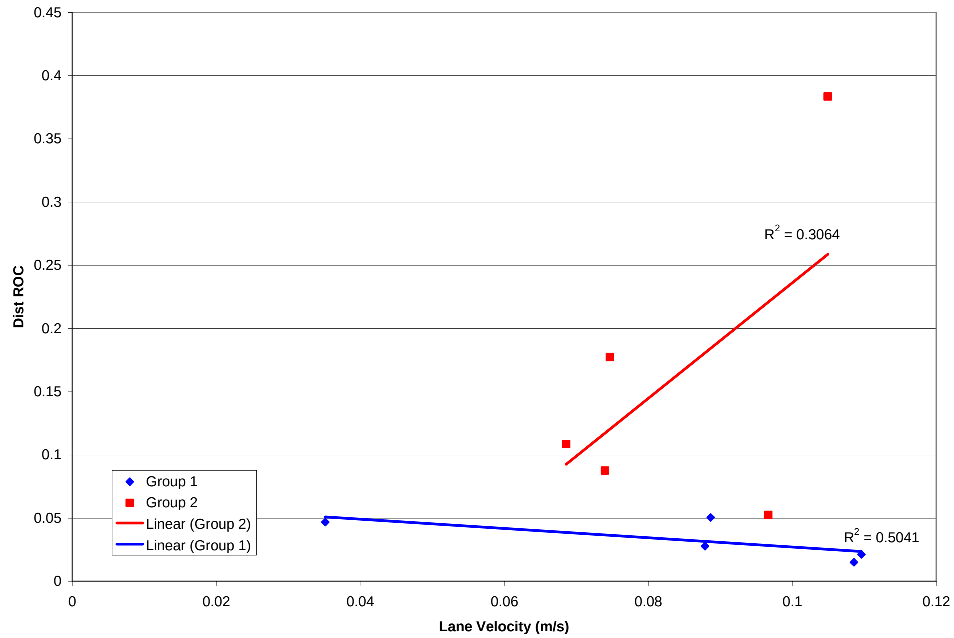

Figure 26: Group 1 & Group 2 - Dist ROC vs. Lane Velocity

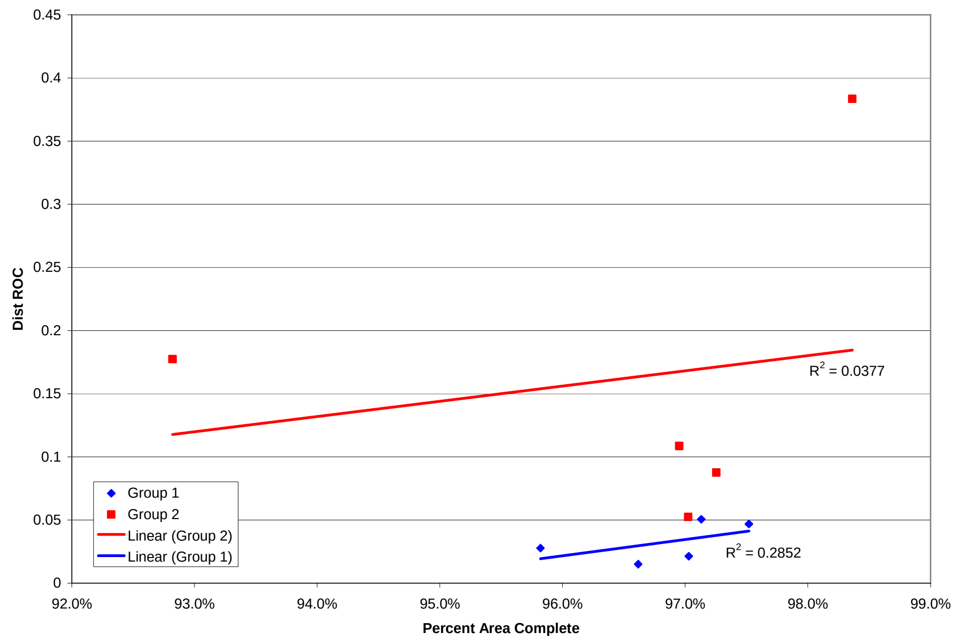

Figure 27: Group 1 & Group 2 - Dist ROC vs. Percent of Lane Area Covered

Again, once the two performance measurements are combined into the Distance ROC, differences between the groups begin to appear. As Figure 24 shows, Group 1 performed better as the detector head height increased, while Group 2's performance deteriorated as the detector head height increased. A similar result is shown in Figure 25 and Figure 26.

Both groups also covered the lane area fairly equally with little variation. This translated into no significant correlation between that characteristic and Pd, FAR, and Dist ROC as shown in Figure 19, Figure 23, and Figure 27.

Table 6 summarizes both the performance measurements and characteristics for each operator and the groups.

Table 6: Summary of Data for Group 1 and Group 2

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance	Lane Velocity (m/s)	Percent of Lane Area Covered	Detector Head Height (in)	Detector Head Velocity (m/s)
Group 1	N-5	100.00%	0.0150	0.0150	0.11	96.62%	9.27	1.54
	N-2	98.33%	0.0133	0.0213	0.11	97.03%	7.86	1.04
	N-1	98.33%	0.0221	0.0277	0.09	95.82%	8.24	1.14
	N-4	100.00%	0.0468	0.0468	0.04	97.52%	6.52	1.09
	E-1	98.33%	0.0477	0.0506	0.09	97.13%	7.09	1.38
	Mean	**99.00%**	**0.0290**	**0.0323**	**0.09**	**96.82%**	**7.80**	**1.24**
	St. Dev.	**0.009**	**0.017**	**0.016**	**0.030**	**0.006**	**1.059**	**0.214**
Group 2	N-3	95.00%	0.0159	0.0525	0.10	97.03%	6.61	1.07
	E-3	100.00%	0.0875	0.0875	0.07	97.26%	7.10	1.73
	E-5	95.00%	0.0963	0.1085	0.06	96.95%	9.56	1.72
	E-2	83.33%	0.0610	0.1775	0.07	92.82%	8.88	1.74
	E-4	61.67%	0.0124	0.3835	0.10	98.36%	9.79	2.62
	Mean	**87.00%**	**0.0546**	**0.1619**	**0.08**	**96.48%**	**8.39**	**1.77**
	St. Dev.	**0.154**	**0.039**	**0.132**	**0.017**	**0.021**	**1.450**	**0.552**

General observations from

Table 6:

- The lane velocity and percent area covered again remained close between the groups.
- As seen with the novices and experts, the better performing group (in this case Group 1) held the detector head lower (~0.6 inches) and swung it slower (~30%).
- However, Group 1 on average held the detector head slightly higher than the novices and swung it slightly faster.

The results again seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements.

Group 1, Group 2, and Group 3

In an effort to further highlight differences, the data for the operators were divided into three groups based upon their performance as measured by Dist ROC. The three operators with the lowest Dist ROC are Group 1; the three operators with the highest Dist ROC are Group 3; while the four operators with the middle Dist ROC are Group 2. Group 1 consists of three novices; Group 2 consists of two novices and two experts; while Group 3 consists of three experts. Table 7 summarizes the performance measurements for the three groups.

Table 7: Performance Summary of Group 1, Group 2, and Group 3

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance
Group 1	N-5	100.00%	0.0150	0.0150
	N-2	98.33%	0.0133	0.0213
	N-1	98.33%	0.0221	0.0277
	Mean	**98.89%**	**0.0168**	**0.0213**
Group 2	N-4	100.00%	0.0468	0.0468
	E-1	98.33%	0.0477	0.0506
	N-3	95.00%	0.0159	0.0525
	E-3	100.00%	0.0875	0.0875
	Mean	**98.33%**	**0.0495**	**0.0593**
Group 3	E-5	95.00%	0.0963	0.1085
	E-2	83.33%	0.0610	0.1775
	E-4	61.67%	0.0124	0.3835
	Mean	**80.00%**	**0.0566**	**0.2232**

Reclassifying the operators in this manner resulted in further widening the gap between the best and the worst performers in the mean Pd and FAR measurements. Only one operator in Group 3 achieved a FAR less than the lowest operator's FAR in Group 1. All other performance measurements for Group 1 were notably better than those for Group 2. When plotted on a standard ROC curve as shown in Figure 28, Group 1 was on average more than ten times closer to the upper left-hand corner than Group 3, indicating superior performance. Group 2 was on average three times farther from the upper left-hand corner than Group 1, but nearly four times closer than Group 3.

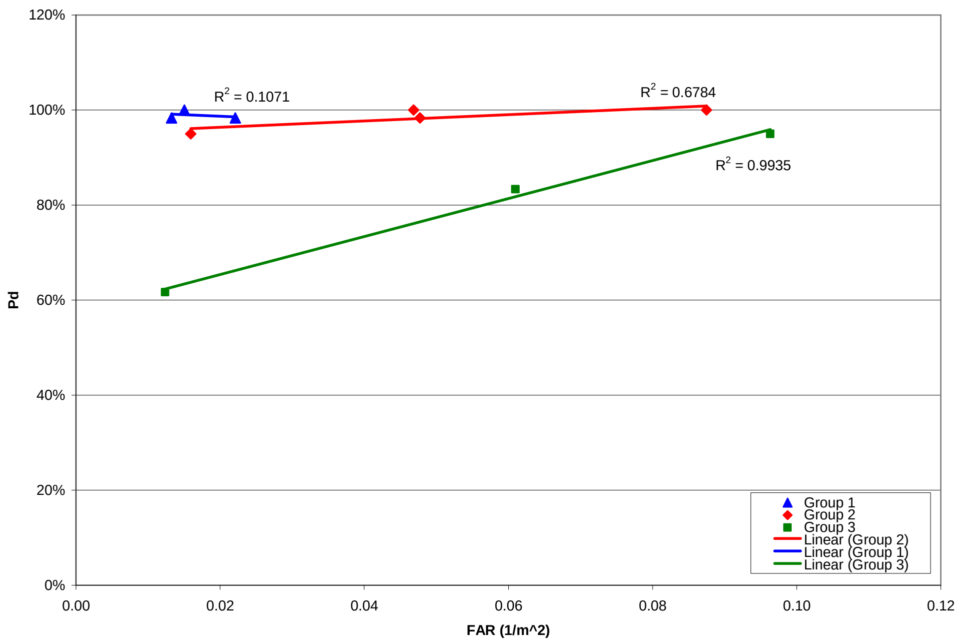

Figure 28: Group 1 vs. Group 2 vs. Group 3 ROC Curves

Figure 29 through Figure 32 compare Pd versus the four characteristics, while Figure 33 through Figure 36 compare FAR versus the four characteristics. Figure 37 through Figure 40 compare the Distance ROC versus the four characteristics.

As Figure 29 through Figure 30 indicate, Group 1 and Group 2's data indicates that performance improved as the detector head height and velocity increased, counter to that observed in the previous groupings. On the other hand, for Group 3, Pd performance is again shown to suffer as the height and velocity of the detector head increased. However, the data for Group 3 and detector head height is widely scattered. In addition, Pd performance also decreased as the lane velocity increased for all three groups as shown in Figure 31. This result has been consistently observed.

As Figure 33 and Figure 34 show, the data for FAR versus detector head height and velocity is quite dissimilar for each group. The number of false alarms by Group 1 generally decreased slightly as the detector head height and velocity increased, while the number of false alarms by Group 3 decreased drastically as the detector head height and velocity increased. Meanwhile, the opposite result is observed for Group 2. The number of false alarms increased drastically as the detector head height and velocity increased. However, large variations exist in the data, so only the linear regressions for Group 2 and Group 3 for FAR versus detector head velocity are good fits. Again, FAR performance also improved as the lane velocity increased for all three groups as shown in Figure 35.

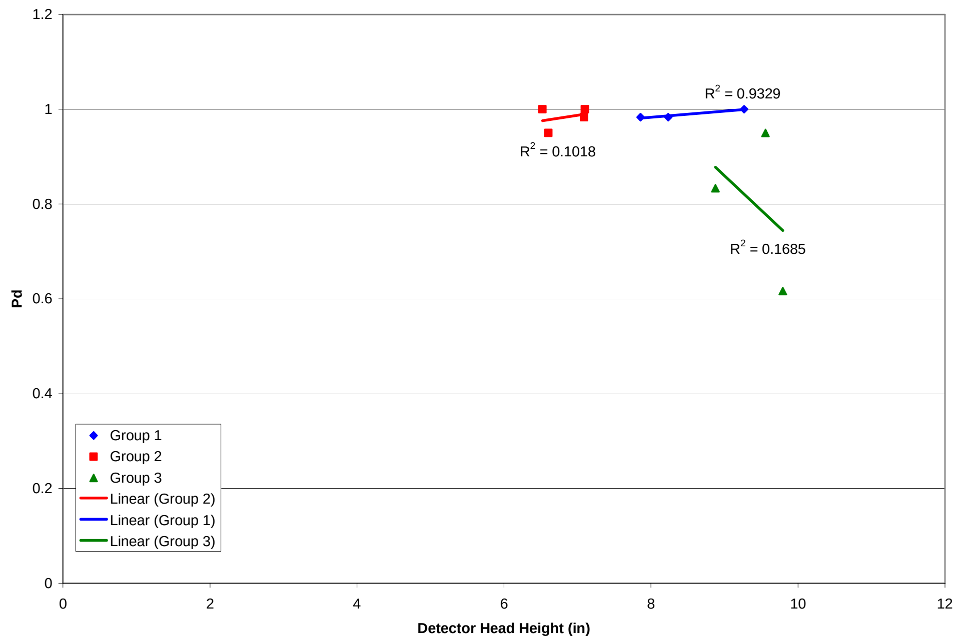

Figure 29: Groups 1-3 - Pd vs. Detector Head Height

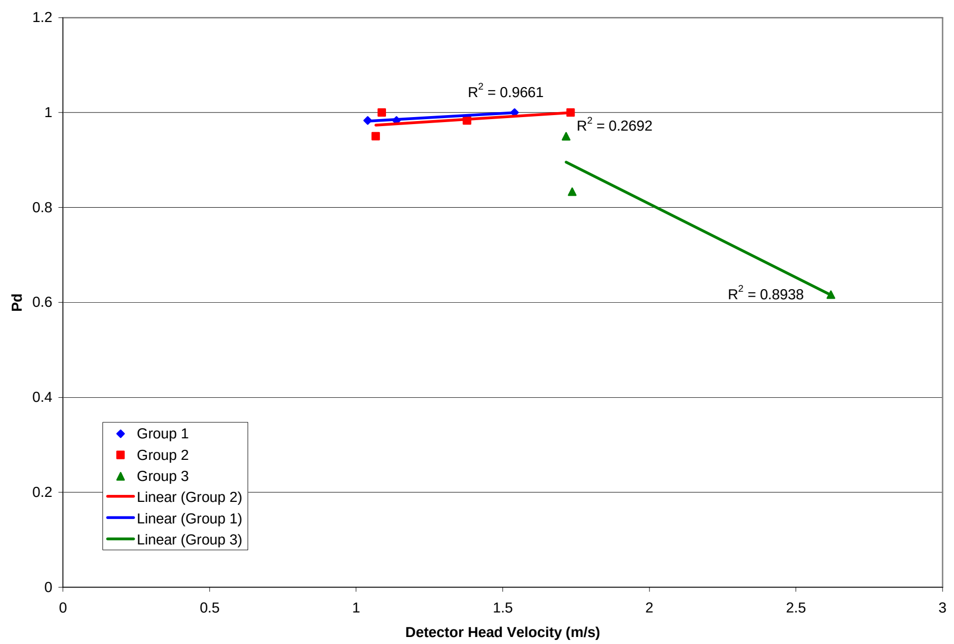

Figure 30: Groups 1-3 - Pd vs. Detector Head Velocity

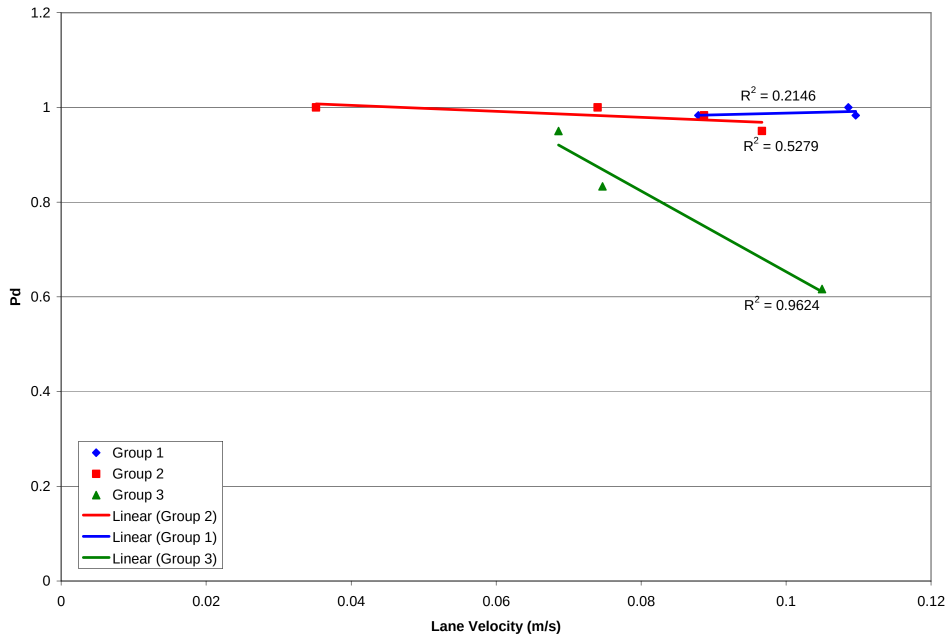

Figure 31: Groups 1-3 - Pd vs. Lane Velocity

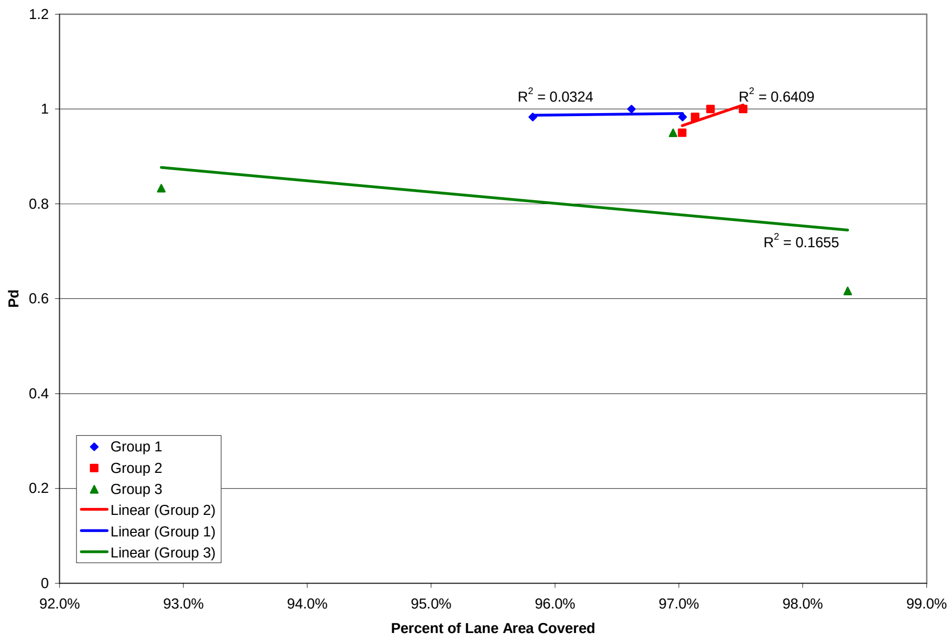

Figure 32: Groups 1-3 - Pd vs. Percent of Lane Area Covered

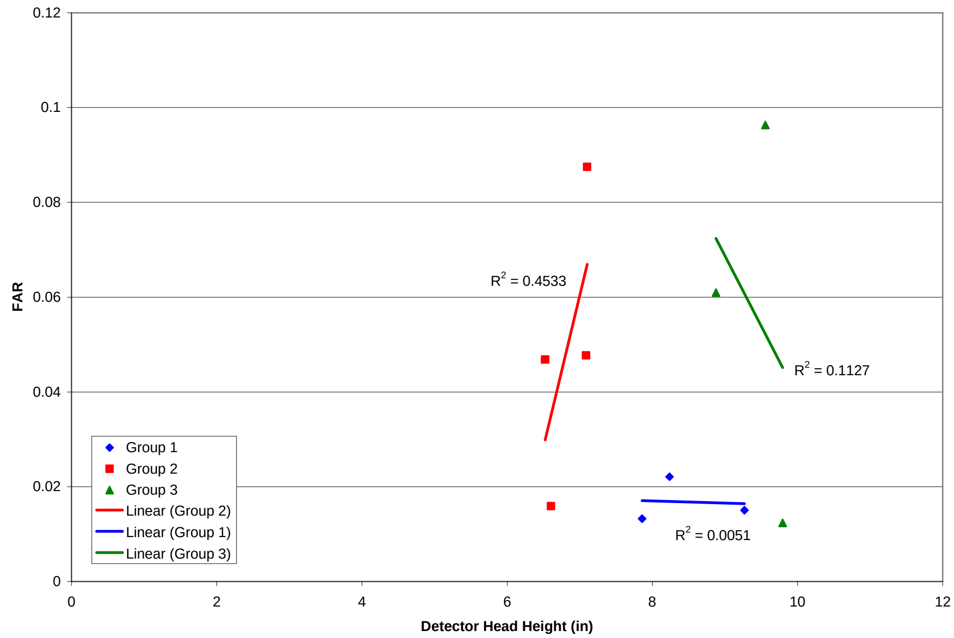

Figure 33: Groups 1-3 - FAR vs. Detector Head Height

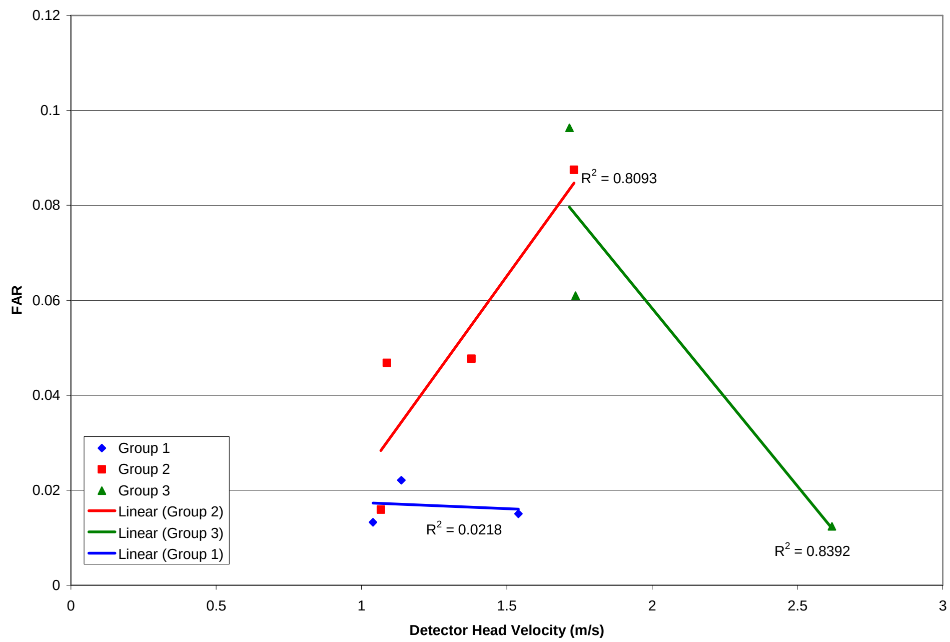

Figure 34: Groups 1-3 - FAR vs. Detector Head Velocity

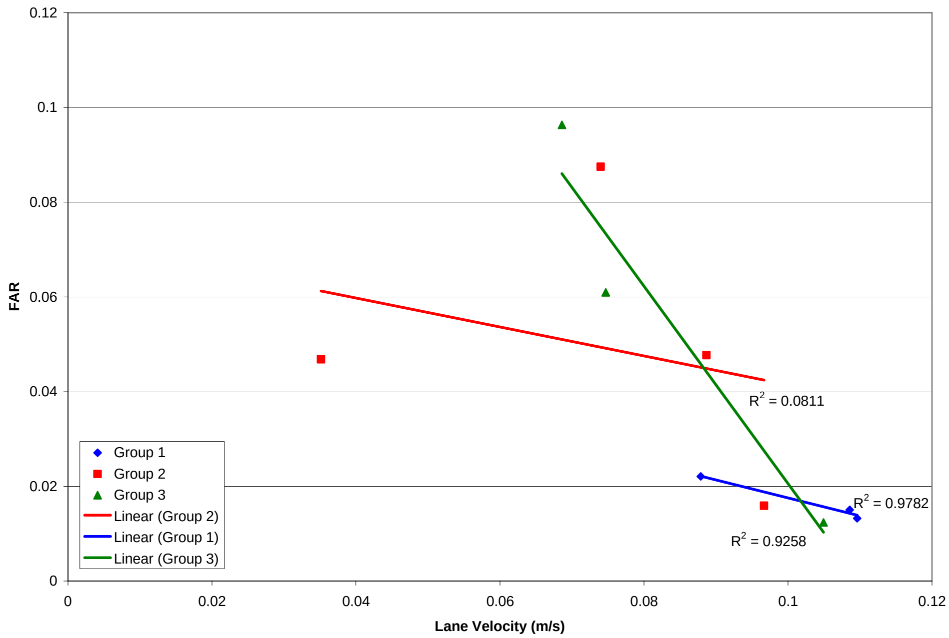

Figure 35: Groups 1-3 - FAR vs. Lane Velocity

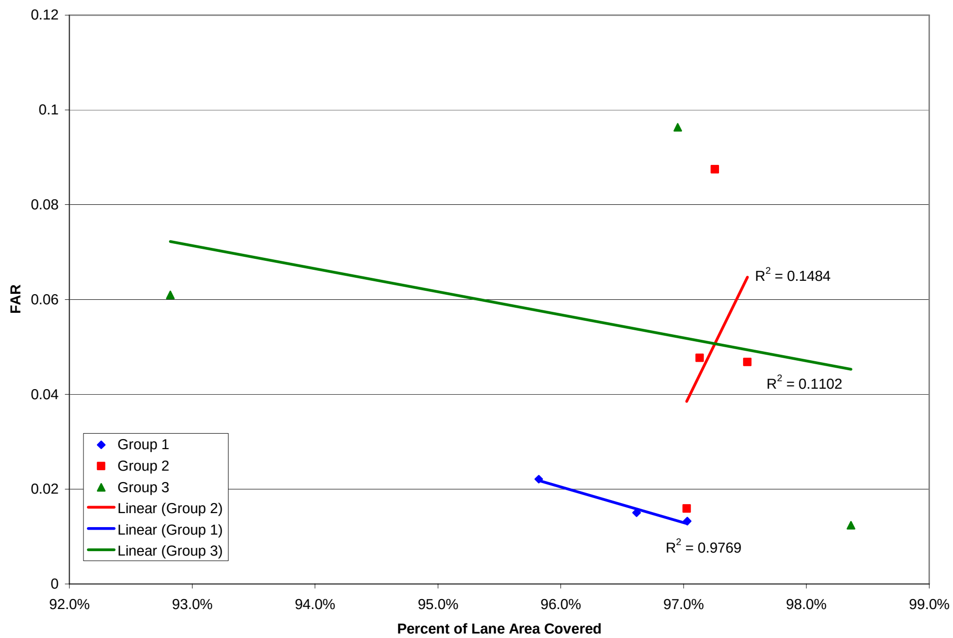

Figure 36: Groups 1-3 - FAR vs. Percent of Lane Area Covered

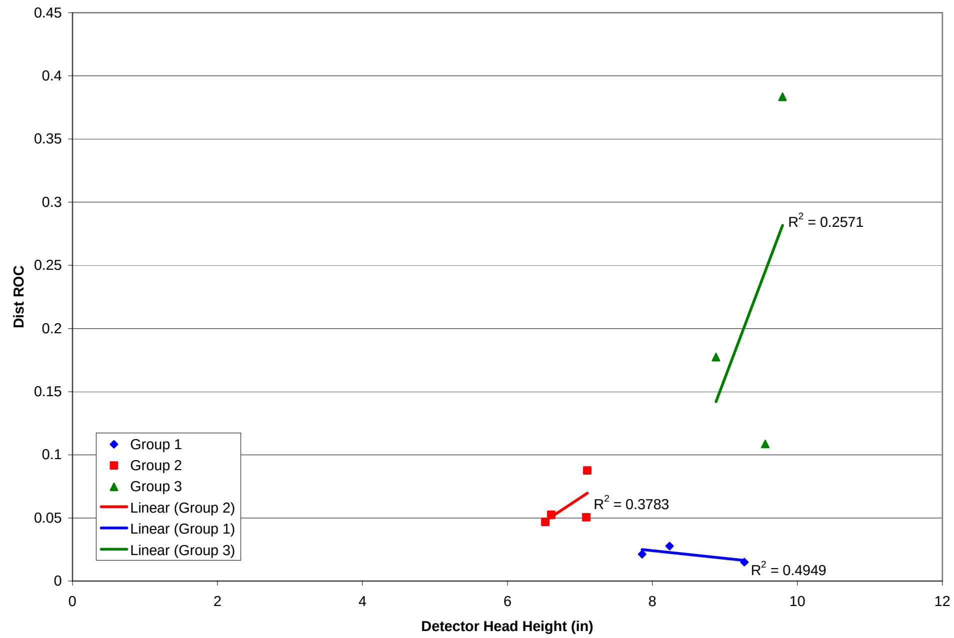

Figure 37: Groups 1-3 - Dist ROC vs. Detector Head Height

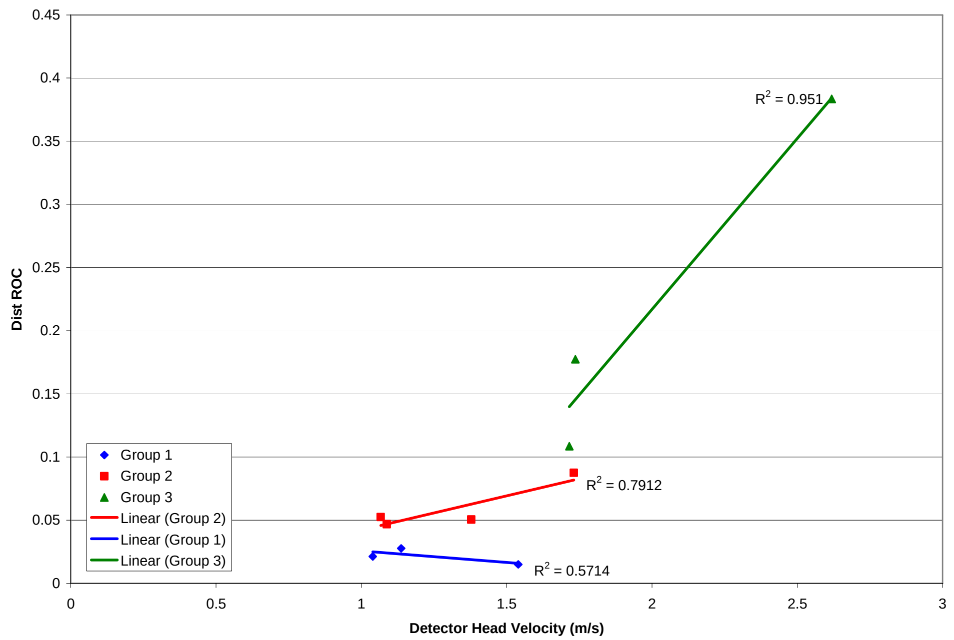

Figure 38: Groups 1-3 - Dist ROC vs. Detector Head Velocity

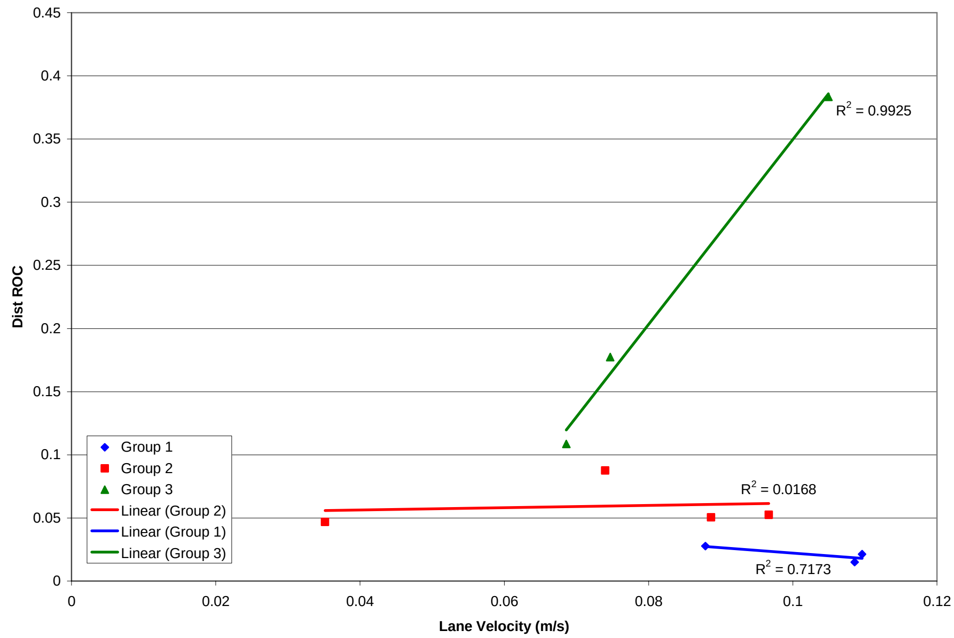

Figure 39: Groups 1-3 - Dist ROC vs. Lane Velocity

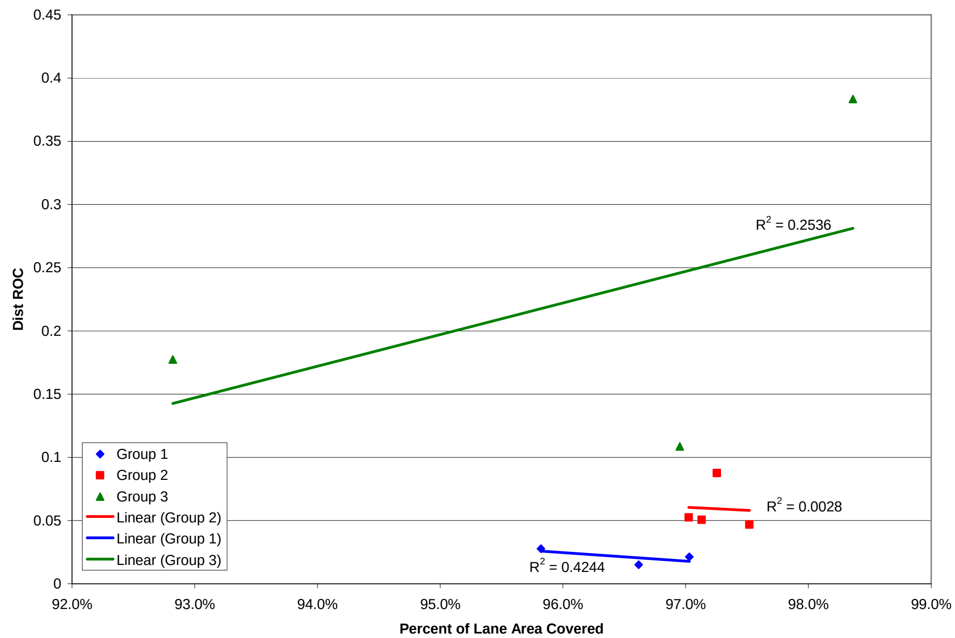

Figure 40: Groups 1-3 - Dist ROC vs. Percent of Lane Area Covered

Again, once the two performance measurements are combined into the Distance ROC, greater differences between the groups can be observed. In Figure 37 and Figure 38, Group 2 and Group 3 show improved performance as detector head height and velocity decrease, while Group 1 shows slightly improved performance as they increase. In Figure 39, Group 1 displays better performance as the lane velocity increases, while Group 2 and Group 3 display worse performance as it increases. All of the results imply that there may be a middle range for each performance characteristic that leads to improved performance measurements.

All three groups also covered the lane area fairly equally with little variation. This translated into no significant correlation between that characteristic and Pd, FAR, and Dist ROC as shown in Figure 32, Figure 36, and Figure 40. Table 8 summarizes both the performance measurements and characteristics for each operator and the groups.

Table 8: Summary of Data for Groups 1-3

	Operator	**Probability of Detection (Pd)**	**False Alarm Rate (1/m^2)**	**ROC Distance**	**Lane Velocity (m/s)**	**Percent of Lane Area Covered**	**Detector Head Height (in)**	**Detector Head Velocity (m/s)**
Group 1	N-5	100.00%	0.0150	0.0150	0.11	96.62%	9.27	1.54
	N-2	98.33%	0.0133	0.0213	0.11	97.03%	7.86	1.04
	N-1	98.33%	0.0221	0.0277	0.09	95.82%	8.24	1.14
	Mean	**98.89%**	**0.0168**	**0.0213**	**0.10**	**96.49%**	**8.45**	**1.24**
	St. Dev.	**0.010**	**0.005**	**0.006**	**0.012**	**0.006**	**0.730**	**0.265**
Group 2	N-4	100.00%	0.0468	0.0468	0.04	97.52%	6.52	1.09
	E-1	98.33%	0.0477	0.0506	0.09	97.13%	7.09	1.38
	N-3	95.00%	0.0159	0.0525	0.10	97.03%	6.61	1.07
	E-3	100.00%	0.0875	0.0875	0.07	97.26%	7.10	1.73
	Mean	**98.33%**	**0.0495**	**0.0593**	**0.07**	**97.23%**	**6.83**	**1.32**
	St. Dev.	**0.021**	**0.029**	**0.017**	**0.011**	**0.001**	**0.237**	**0.274**
Group 3	E-5	95.00%	0.0963	0.1085	0.06	96.95%	9.56	1.72
	E-2	83.33%	0.0610	0.1775	0.07	92.82%	8.88	1.74
	E-4	61.67%	0.0124	0.3835	0.10	98.36%	9.79	2.62
	Mean	**80.00%**	**0.0566**	**0.2232**	**0.08**	**96.05%**	**9.41**	**2.02**
	St. Dev.	**0.169**	**0.042**	**0.143**	**0.021**	**0.029**	**0.476**	**0.515**

General observations from Table 8:

- The average lane velocity and percent area covered remained close between Group 1 and Group 3 and was slightly slower than in the previous groupings; however, Group 2 traveled the lane at a faster pace.
- As seen with the novices and experts, the better performing group (in this case Group 1) held the detector head lower (~1 inch) and swung it slower (~40%) than worse performing group (Group 3). Interestingly, Group 2 on average held the detector head approximately 1.6 inches lower than Group 1 and swung the detector slightly faster (~6%).

The results again seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements. Furthermore, the relationship does not seem to be necessarily linear, since Group 1's performance measurements were better with a mean detector head height of 8.45 inches as compared to Group 2 and Group 3's mean of 6.83 and 9.41 inches, respectively.

Detector Head Height and Velocity

All of the results seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements. To investigate this further, the detector head height and velocity data was plotted against the performance measurements without the novice, experts, and groups classifications. Since the range of mean heights and velocities of the best and worst groups indicated the curves may be parabolic, either a linear or parabolic regression was inserted to fit the data as best as possible. The results are shown in Figure 41 through Figure 46.

Figure 43 indicates that the relationship between the detector head height and the Dist ROC data may be approximated by a parabolic curve with the better Dist ROC measurements achieved in the seven to eight inches range. Breaking the Dist ROC measurement into its individual parts, Figure 41 reveals that the detector head height correlates to the Pd measurement more than the FAR measurement as shown in Figure 42. Therefore, this suggests that an operator may improve their Pd by maintaining the Schonstadt detector head between seven and eight inches off the ground; however, this will not necessarily improve their FAR.

With the high coefficient of determination, the parabolic curve in Figure 46 fits the data well. The curve suggests that the best performance can be achieved by swinging the Schonstadt so that the detector head is traveling at a velocity between one and 1.25 meters per second. The curves in Figure 44 and Figure 45 imply that the correlation is more related to Pd performance than FAR performance, but both may be optimized by maintaining a velocity in this range.

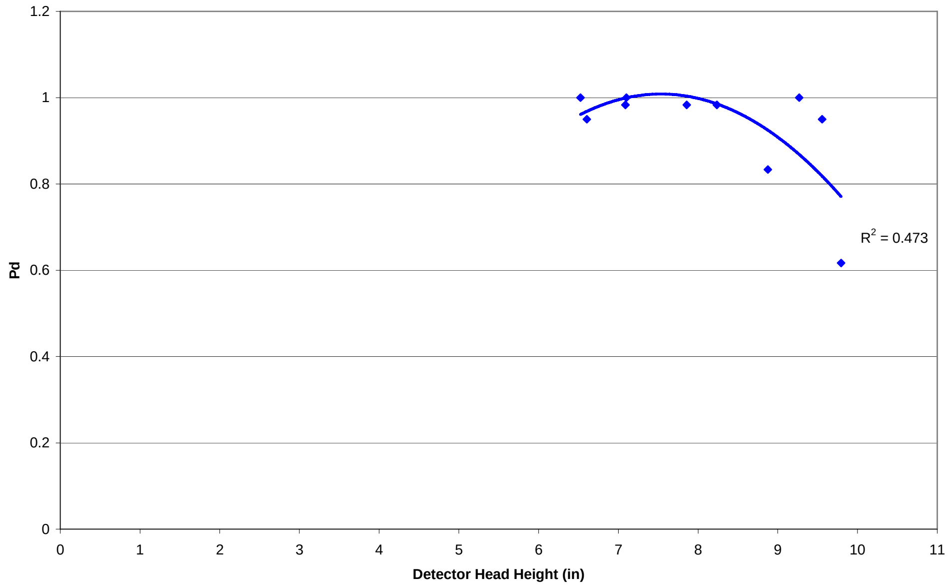

Figure 41: Pd vs. Detector Head Height

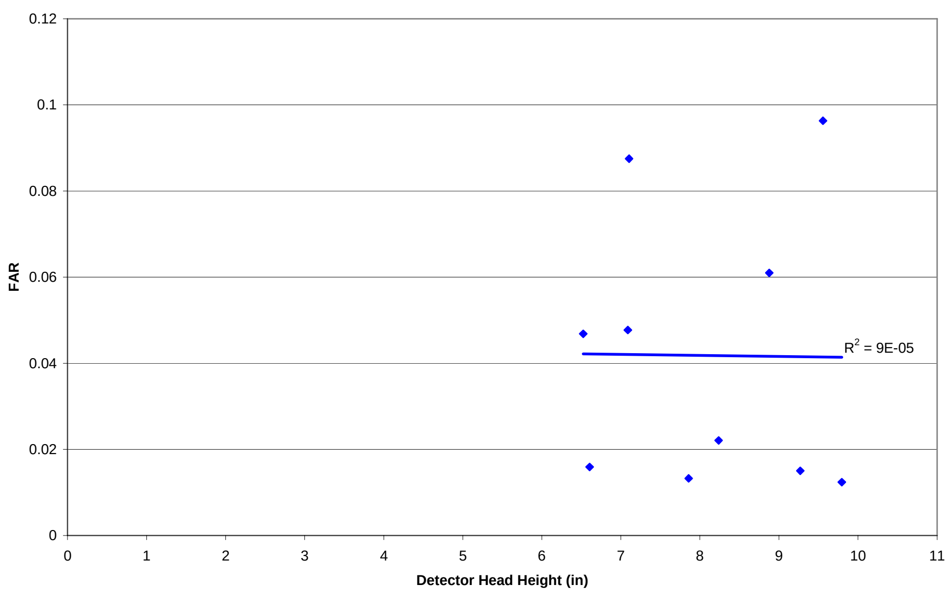

Figure 42: FAR vs. Detector Head Height

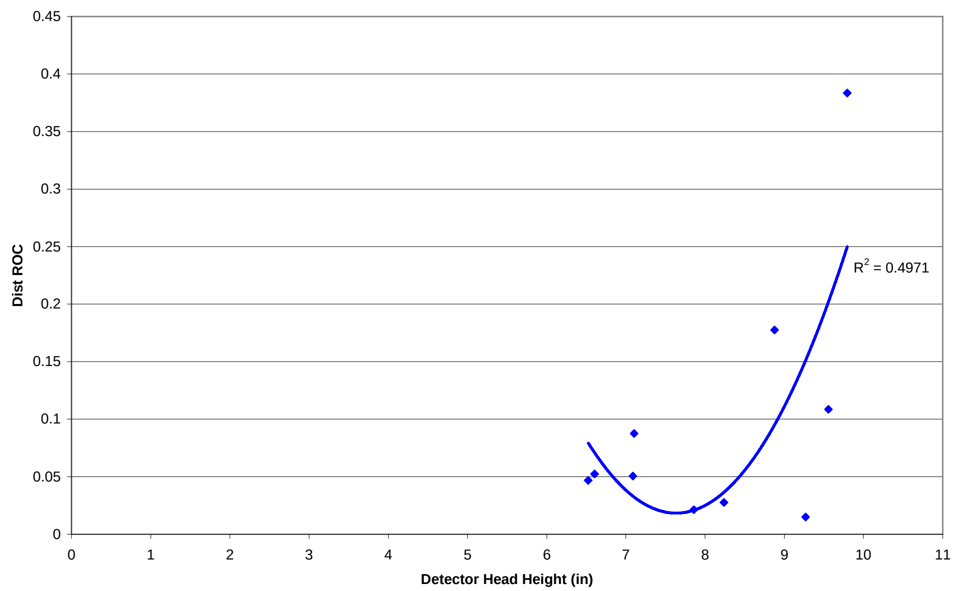

Figure 43: Dist ROC vs. Detector Head Height

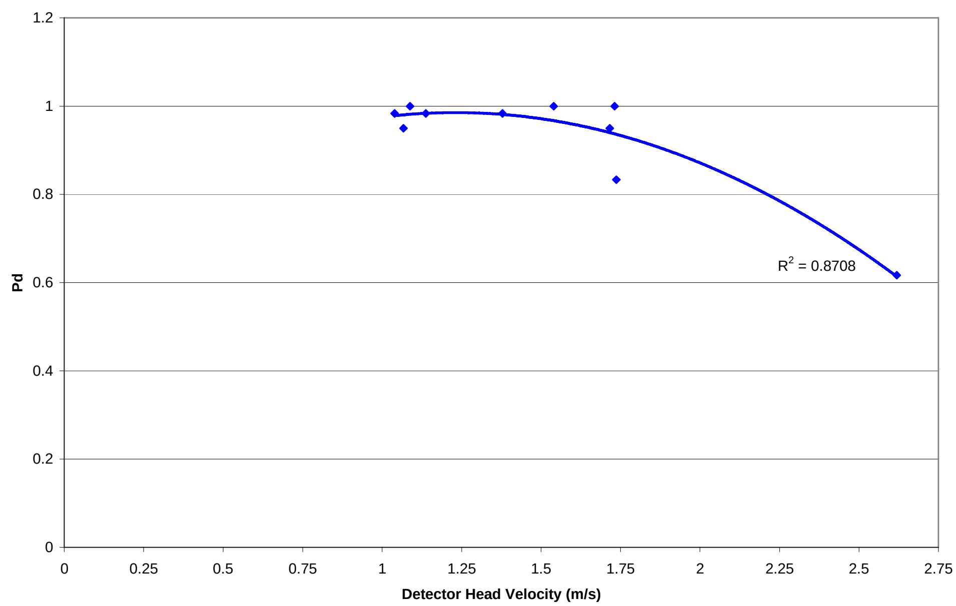

Figure 44: Pd vs. Detector Head Velocity

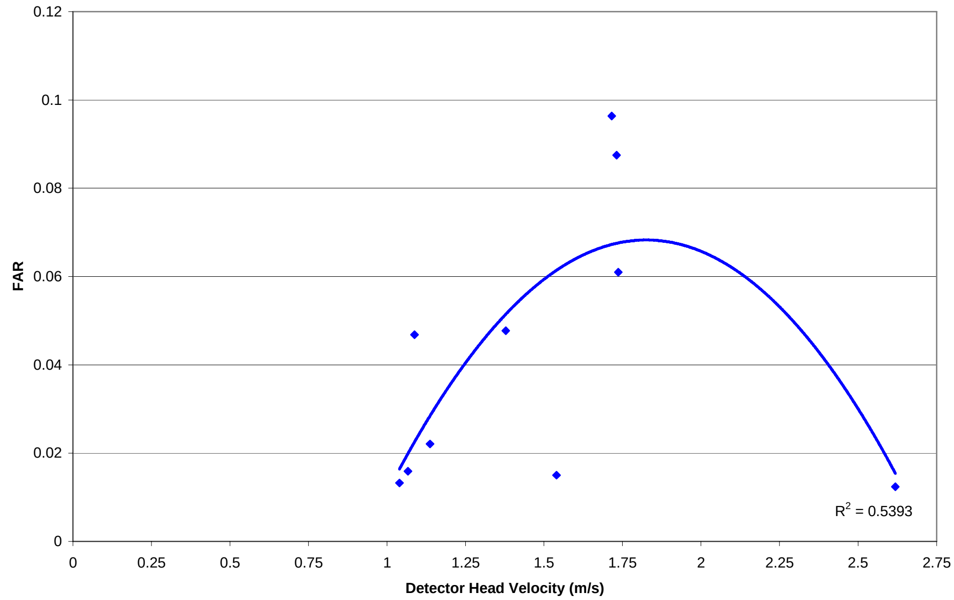

Figure 45: FAR vs. Detector Head Velocity

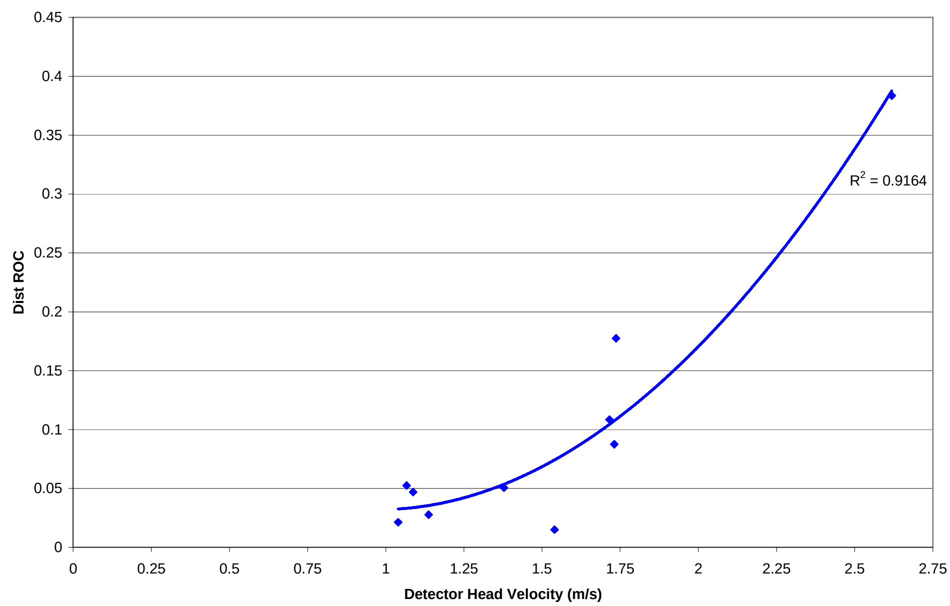

Figure 46: Dist ROC vs. Detector Head Velocity Ordnance Type, Depth, and Orientation

Five different ordnance types were used – 40mm, 60mm, 81mm, 105mm, and 155mm. Each type was buried at a specific depth – 6, 12, 18, 24, and 30 inches, respectively. The ordnance were placed in both the horizontal and vertical orientations. Table 9 provides the Pd measurements for each ordnance type, depth, and orientation. For the most part, ordnance of the same type were more likely to be detected when oriented vertically rather than horizontally. However, the 155mm was the exception, since those in the horizontal orientation had a higher Pd. In the case of the 40mm round, both orientations had a 100 percent Pd, while the 81mm round had the lowest Pd for both the horizontal and vertical orientations.

Table 9: Pd by Ordnance Type, Depth, and Orientation

Type	Depth (in.)	Horizontal	Vertical	Total
40mm	6	100.0%	100.0%	100.0%
60mm	12	86.0%	97.1%	92.5%
81mm	18	83.3%	85.7%	84.6%
105mm	24	90.0%	100.0%	96.2%
155mm	30	96.7%	91.4%	93.8%
Total		**90.8%**	**94.7%**	**92.7%**

Table 10 divides the data into the expert and novice groups. As the table shows, the novices achieved a perfect 100 percent Pd for all the ordnance in the vertical orientation. The experts were only able to detect the 155mm round in the horizontal orientation better than the novices. The experts were able to equal the novices' performance on the 40mm horizontal and vertical rounds and the 105mm vertical round. On average, the novices achieved Pd's ten percentage points higher than the experts.

Table 10: Experts & Novices - Pd by Ordnance Type and Orientation

	Type	Novices	Experts	Total
Horizontal	40mm	100.0%	100.0%	100.0%
	60mm	92.0%	80.0%	86.0%
	81mm	96.7%	70.0%	83.3%
	105mm	100.0%	80.0%	90.0%
	155mm	93.3%	100.0%	96.7%
	Total	**96.2%**	**85.4%**	**90.8%**
Vertical	40mm	100.0%	100.0%	100.0%
	60mm	100.0%	94.3%	97.1%
	81mm	100.0%	71.4%	85.7%
	105mm	100.0%	100.0%	100.0%
	155mm	100.0%	82.9%	91.4%
	Total	**100.0%**	**89.4%**	**94.7%**

Table 11 divides the data into the Group 1 and Group 2 classifications. As the table shows, Group 1 achieved a perfect 100 percent Pd for all the ordnance except the 60mm horizontal and the 81mm vertical rounds. Group 2 did not detect any of the ordnance types better than Group 1; however, Group 2 did equal Group 1 with 100 percent Pd for the 40mm horizontal and vertical and 105mm vertical rounds. On average, Group 1 achieved Pd's 15 percentage points higher than Group 2 for the horizontal ordnance and nine percentage points higher for the vertical ordnance.

Table 11: Group 1 & Group 2 - Pd by Ordnance Type and Orientation

	Type	Group 1	Group 2	Total
Horizontal	40mm	100.0%	100.0%	100.0%
	60mm	92.0%	80.0%	86.0%
	81mm	100.0%	66.7%	83.3%
	105mm	100.0%	80.0%	90.0%
	155mm	100.0%	93.3%	96.7%
	Total	**98.5%**	**83.1%**	**90.8%**
Vertical	40mm	100.0%	100.0%	100.0%
	60mm	100.0%	94.3%	97.1%
	81mm	97.1%	74.3%	85.7%
	105mm	100.0%	100.0%	100.0%
	155mm	100.0%	82.9%	91.4%
	Total	**99.4%**	**90.0%**	**94.7%**

Table 12 divides the data into the Group 1, Group 2, and Group 3 classifications. As the table shows, Group 1 achieved a perfect 100 percent Pd for all the ordnance except the 60mm horizontal. Group 2 achieved a better Pd for the 60mm horizontal and equaled Groups 1 with 100 percent Pd on seven others. Group 3 realized lower Pd's than both Group 1 and Group 2 on all the ordnance types with the exception of the 40mm horizontal and vertical and the 105mm vertical, which all operators detected 100 percent. On average, Group 1 achieved Pd's 22 percentage points higher than Group 3 for the horizontal ordnance and 17 percentage points higher for the vertical ordnance. However, Group 1 only realized Pd's slightly higher Pd's than Group 2 for both orientations.

Table 12: Groups 1, 2, & 3 - Pd By Ordnance Type and Orientation

	Type	Group 1	Group 2	Group 3	Total
Horizontal	40mm	100.0%	100.0%	100.0%	100.0%
	60mm	86.7%	100.0%	66.7%	86.0%
	81mm	100.0%	95.8%	50.0%	83.3%
	105mm	100.0%	100.0%	66.7%	90.0%
	155mm	100.0%	91.7%	100.0%	96.7%
	Total	**97.4%**	**97.1%**	**75.6%**	**90.8%**
Vertical	40mm	100.0%	100.0%	100.0%	100.0%
	60mm	100.0%	100.0%	90.5%	97.1%
	81mm	100.0%	96.4%	57.1%	85.7%
	105mm	100.0%	100.0%	100.0%	100.0%
	155mm	100.0%	100.0%	71.4%	91.4%
	Total	**100.0%**	**99.3%**	**83.3%**	**94.7%**

In summary, the data indicates that the 60mm horizontal and the 81mm in both orientations proved to be the most difficult ordnance types to locate. The superior performances by the novices and Group 1 can be attributed to their performance on these ordnance types and orientations. Table 13 provides the difference between the Pd of the best and worst group for each of the three classifications for these ordnance types and orientations.

Table 13: Pd Differences

	60mm Horizontal	81mm Horizontal	81mm Vertical
Novices vs. Experts	12.0%	26.7%	28.6%
Group 1 vs. Group 2	12.0%	33.3%	22.9%
Group 1 vs. Group 3	20.0%	50.0%	42.9%

2.0 CONCLUSIONS

Contrary to the original hypothesis of the experiment, the operators classified as Novices achieved better performance results than those classified as Experts. After a review of the data, the following characteristics were observed:

- Both the novices and the experts covered the lane area fairly equally with little variation.
- The novices had considerably less false alarms than the experts.
- The novices tended to hold the detector head three quarters of an inch lower than the experts.
- The novices swung the detector head approximately 40 percent slower than the experts.

The results seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements.

When divided into two groups based upon their performance measurements, Pd performance is again shown to suffer as the height and velocity of the detector head increased. In addition, Pd performance also decreased as the lane velocity increased. The number of false alarms generally decreased as the lane velocity and detector head velocity increased. The better performing group (in this case Group 1) held the detector head lower (~0.6 inches) and swung it slower (~30%). However, Group 1 performed better as the detector head height increased, while Group 2's performance deteriorated as the detector head height increased. The results again seem to indicate that the position and speed of the Schonstadt detector head impact the performance measurements

When divided into three groups based upon their performance measurements, Group 1 and Group 2's data indicates that performance improved as the detector head height and velocity increased, counter to that observed in the previous groupings. On the other hand, for Group 3, Pd performance is again shown to suffer as the height and velocity of the detector head increased. The number of false alarms by Group 1 generally decreased slightly as the detector head height and velocity increased, while the number of false alarms by Group 3 decreased drastically as the detector head height and velocity increased. Meanwhile, the opposite result is observed for Group 2. The number of false alarms increased drastically as the detector head height and velocity increased. As seen with the novices and experts, the better performing group (in this case Group 1) held the detector head lower (~1 inch) and swung it slower (~40%) than worse performing group (Group 3). Interestingly, Group 2 on average held the detector head approximately 1.6 inches lower than Group 1 and swung the detector slightly faster (~6%). All of the results imply that there may be a middle range for each performance characteristic that leads to improved performance measurements.

Due to the many uncontrolled variables in this experiment, no firm conclusion can be drawn about these performance characteristics. However, the data suggests that operators who maintain the detector head seven to eight inches from the ground while swing the detector head at a velocity between one and 1.25 meters per second will have a better performance than those who have performance characteristics outside of this range.

APPENDIX M. HRED STRESS AND WORKLOAD ASSESSMENT SUMMARY

Operator Influence on UXO Sensor Technology: US Army Research Laboratory HRED Stress and Workload Assessment Summary

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Background

The U. S. Army Research Laboratory (ARL) has developed a stress assessment battery, Stress Assessment and Monitoring System (SAMS) that measures individual reactions to both physical and mental stressors using non-invasive methods that cause little or no interference to the performance of a variety of tasks. This battery of psychological questionnaires has proved its sensitivity to the degree of stress experienced in a variety of situations and includes several standardized measures that have demonstrated construct validity within the stress research literature. SAMS uses a standardized methodology that has been validated using military and civilian populations. The battery provides overall measures of stress and subcomponents of stress. Identifying subcomponents related to stress provides insight concerning why the individual is experiencing stress and possible solutions to alleviate the stress.

Salivary amylase concentrations are predictive of plasma catecholamine levels and can be used as a measure of stress (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996). Salivary amylase and cortisol provide a non invasive, objective, physiological measure of overall stress.

The objective of this field experiment was to provide quantifiable measures of the psychological and physiological stress induced by UXO clearance operations.

Methods

Participants

Test participants were 10 civilian employees, 5 experts and 5 student novices. Experts consisted of 4 males and 1 female and had an average age of 33.4 years (SD=7.2 years) with an average education of 12.6 years (SD=0.9 years). All of the experts had prior military experience. Experts had a mean of 11.8 years (SD=5.7 years) of EOD experience and 4.5 years (SD=2.6 years) of UXO experience, with a mean of 4.3 years (SD=2.3 years) using the Schonstedt sensor. Student novices were all males with an average age of 34 years (SD=12.7 years) and an average education level of 14.4 years (SD=.9 years) One student novice had prior military experience.

Apparatus

Batteries of standardized psychological trait and state questionnaires were used in conjunction with noninvasive physiological stress measures, salivary amylase and salivary cortisol. The battery of psychological questionnaires has proved its sensitivity to the degree of stress experienced in a variety of situations and includes several standardized measures that have demonstrated construct validity within the stress research literature. These measures can be selected and tailored to the research objectives and experimental design as needed. This stress assessment and monitoring system uses a standardized methodology that has been validated using both military and civilian populations.

General Information Questionnaire: This questionnaire includes general demographic information (age, education, job title, etc.) and questions regarding the participant's health status.

Psychological Trait Measures: The following trait measure questionnaires are used to assess individual characteristics, and were administered on a non-test day.

Multiple Affect Adjective Check List - Revised (MAACL-R; Zuckerman & Lubin, 1985). The General form of the MAACL-R has five primary subscales (Anxiety, Depression, Hostility, Positive Affect, and Sensation Seeking) derived from a one-page list of 132 adjectives. The participants check all the words that describe how they "generally" feel. An overall distress score, Dysphoria or Negative Affect is calculated using the Anxiety, Depression, and Hostility scores. Positive Affect measures a sense of well being and scores vary independently from Negative Affect scores.

Psychological State Measures. A five-minute battery of stress perception measures were administered at strategic time points before, during, and after the different conditions being measured. The following state measures are included:

Specific Rating of Events Scale (SRE; Fatkin, King, & Hudgens, 1990). The SRE allows the participants to rate (on a scale of 0-100) how stressed they felt during a specified time period.

Subjective Stress Scale (SUBJ; Kerle & Bialek, 1958). This scale detects significant affective changes in stressful conditions. Participants are instructed to select one word from a list of 15 adjectives that best describes how they felt during a specified time.

Multiple Affect Adjective Check List - Revised, Today form (MAACL-R; Zuckerman & Lubin, 1985). The MAACL-R Today form is used to examine changes in specific affects in response to stressful situations. This measure is identical to the General form, except the participants are instructed to answer according to how they felt during a specified time period.

Self-Efficacy Scale. The Self-Efficacy Scale (SES; Bandura, 1977; Hudgens, Malto, Geddie, & Fatkin, 1991; Sherer et al., 1982) asks respondents to rate their level of confidence in their ability to do well with reference to anticipation of their mission in detecting UXO. Positive correlations have been obtained between self-efficacy and vocational, educational and military success. This questionnaire was given once with the baseline assessment.

Workload Assessment: National Aeronautics and Space Administration-Task Load Index (NASA-TLX). The NASA TLX is a subjective measure of workload developed by the Human Performance group at NASA Ames Research Center. Scores include a total overall workload score based on the weighted average of ratings on six subscales: mental demand, physical demand, temporal demand, own performance, effort level, and frustration level.

Physiological Assessment: Amylase is an enzyme that hydrolyzes starch to oligosaccharides and then slowly changes to maltose and glucose. Salivary amylase concentrations are predictive of plasma catecholamine levels and can be used as a measure of stress (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996). Measurement of amylase concentration in saliva includes the observation of chemical color changes according to standard photometric procedures developed by Northwestern University (Chatterton et al., 1996). Salivary cortisol was assayed using radioimmunoassay. Amylase and salivary cortisol were assayed at Northwestern University.

Procedure

Trait measures, baseline state measures, and baseline amylase and salivary cortisol data were collected on a non-test day prior to the study. Trait and baseline data collection required approximately one hour. State data collection sessions required approximately five minutes. Pre measures for the state stress questionnaire data and salivary amylase and cortisol were collected in the morning prior to testing. Three during measures were collected at given points. Table 1 identifies the UXO detection lanes each participant completed for each during condition. Post measures for the stress questionnaire data and saliva were collected at the end of each test day. For during and post sessions participants' were instructed to complete during and post surveys according to 'how they felt during the UXO task since the last time they completed the questionnaires.'

The stability of the saliva sample requires it be kept cold. Saliva samples were stored in coolers containing ice packs immediately following collection. At the end of the day saliva samples were placed in a freezer and stored until they were shipped to Northwestern for assay. Saliva was packed in coolers with dry ice and shipped via overnight delivery.

Experimental Design

This research used 2 groups (Experts vs. Novices) x 2 conditions (Schonstedt with TMS instrumentation vs. Schonstedt without TMS instrumentation) x 6 sessions (baseline, pre, during1, during 2, during 3, post) design with groups as a between-subjects variable and conditions and sessions as within-subjects variables. Dependent measures were the scores from the stress assessments, NASA TLX workload assessments, and saliva assays for cortisol and amylase.

Results and Discussion

Data analysis is limited to descriptive techniques due to the small group size. Stress assessment graphs are presented in Appendix B. Results from the post MAACL-R are plotted against comparison data from other studies. Comparison charts are in Appendix C.

Psychological Trait and State Measures

Self Efficacy Scale (SSE)

The SSE asks participants to rate how confident they are in their ability to accomplish the upcoming tasks on a scale of 1-10. This measure is collected once during administration of baseline measures. Two novices did not complete this form. All participants that responded had a high level of confidence on this measure. Three experts responded with a 10, one with 9.5 and one with 9.0. The three novices responded with a 10, 9, and 8.

Specific Rating of Events

The SRE asks participants to rate how much stress they feel on a scale of 1-100. It represents an overall measure of stress. Experts did not experience much variation from baseline. Novices reported higher SRE when compared to experts. Trait and baseline SRE scores were higher for novices and measures taken during testing did not vary above novices' trait measure.

Subjective Stress

This scale detects significant affective changes in stressful conditions. Participants are instructed to select one word from a list of 15 adjectives that best describes how they felt during a specified time. Like the SRE this measure represents an overall measure of stress. Experts' scores increased slightly above baseline during UXO test sessions with the added instrumentation. Their scores did not increase during testing without the added instrumentation. Novices' scores were generally higher then experts.

Their scores increased above baseline during UXO test sessions with added instrumentation. Their scores increased for the without instrumentation condition during the third session and post session.

MAACL-R

Five subscale scores for the MAACL-R, anxiety, depression, hostility, positive affect, and dysphoria (a composite measure that combines anxiety, depression, and hostility scores and represents negative affect) are used in the stress assessments. MAACL-R scores are used as an indication of a person's affect or response to an event, not as clinical indicators. These scores represent subcomponents of stress and further refine the stress assessments by giving an indication of what may be causing the psychological stress to occur.

The MAACL-R anxiety scale is associated with anticipation or uncertainty associated with an event. Experts' anxiety levels remained at baseline levels throughout test sessions. Novices' levels of anxiety increased for the during sessions. They had a larger increase when wearing the additional TMS instrumentation. It appears adding the unfamiliar TMS instrumentation increased the uncertainty for novices. Experts were more comfortable with the added equipment. It may be that inexperienced users had difficulty adjusting to the changes associated with additional new equipment.

The MAACL-R depression scale is a measure of the individual's sense of failure or ceaseless striving. It often correlates with measures of morale and cohesion. Experts' depression measures remained around baseline throughout test sessions. Novices' showed a slight increase in depression during testing with the added TMS instrumentation. They had a large increase for the pre and the first during session without instrumentation. This may indicate some sense of concern or dissatisfaction associated with their performance during testing.

The MAACL-R hostility scale represents frustration with the task, equipment, or performance. Experts' hostility scores remained around baseline. Novices' scores increased with the added TMS instrumentation during testing. They showed large increases for the pre and first during session for the no instrument condition. This may indicate novices were frustrated with the equipment or their performance using the equipment.

The MAACL-R dysphoria is a composite score of anxiety, depression, and hostility. It is used as a measure of overall negative affect. It followed the trends already discussed for the anxiety, depression, and hostility measures. Experts' dysphoria scores remained around baseline. Novices' scores increased during testing with the added TMS equipment and for the pre and first test session without added instrumentation.

The MAACL-R positive affect score measures an overall sense of well being. While positive affect is generally expected to vary in an opposite direction from negative affect the two subscale measures represent different dimensions and may vary independently during sessions. For positive affect experts and novices showed slight variations from baseline throughout testing.

Physiological Measures of Stress: Amylase and Salivary Cortisol

Participants provided saliva samples when they completed questionnaires for baseline, pre, during1, during 2, during 3, and post sessions. Saliva samples collected during testing were shipped on dry ice to Northwestern University and assayed for amylase and salivary cortisol.

Amylase and cortisol represent overall measures of stress. Environmental, physical, or psychological stressors may cause elevated levels of amylase or cortisol.

Salivary amylase is an enzyme secreted in response to sympathetic nervous system activity. It is used as a non-invasive measure representative of the individual's catecholamine response. Amylase activity of 400U/ml or greater represent moderate to high levels of stress response (Chatterton et al., 1996). Average amylase scores over all sessions and conditions ranged from 135.6 U/ml (SD=79.6) through 262.7 U/ml (SD=176.3). This represents low levels of stress. Experts' amylase levels remained around baseline for the no instrument condition, with slight elevations for the third during session and post session. Their amylase levels increased during the UXO task with the additional TMS instrumentation. This indicates the additional instrumentation caused some minor problems for the experts. Experts' scores on the MAACL-R remained around baseline. SRE and SUBJ increased slightly during UXO tasks. The lack of change in experts' MAACL-R scores indicates this slight elevation in stress may be due to physical factors rather then psychological factors.

With the exception of baseline and the second during test session with instrumentation, novices had higher amylase levels then experts. For both conditions amylase levels for novices were above baseline across all sessions. Novices' MAACL-R scores generally increased above baseline during the UXO tasks. Psychological and physical stressors most likely contribute to increased amylase activity for novices.

Cortisol is an adrenal hormone often associated with stress. Salivary amylase increases more rapidly then cortisol during a stressful event. Salivary cortisol was assayed at Northwestern University using radioimmunoassay without extraction. Salivary cortisol increased slightly above baseline for the experts' pre measure without instrumentation. Novices' cortisol increased slightly for the first during and post session with instrumentation. Salivary cortisol measures were low to moderate for both groups.

Stress Assessments and UXO Detection Performance

Correlations were computed between stress measures and the operator performance measures, probability of detection (PD), and background alarm rate (BAR). PD equals the number of declared targets divided by the number of actual targets. Each target had an imaginary 1 meter safe-halo. BAR refers to the number of false declarations per square meter and is a measure of effectiveness or efficiency.

Due to the small group size correlations were computed by combining the experts and novices.

Correlations were computed between PD with the MAACL-R subscales for anxiety, depression, and hostility, and subjective stress, specific rating of events, amylase and salivary cortisol (Table2). There was a significant correlation between positive affect and performance in the post Schonstedt with no instrument condition.

Correlations were computed between the BAR and the MAACL-R subscales for anxiety, depression, and hostility, subjective stress, specific rating of events, amylase and salivary cortisol (Table3). There was a significant correlation between subjective stress and during 2 session Schonstedt with no instrument condition.

Correlations were computed with PD and BAR between amylase and cortisol (Table 4). There were two significant negative correlations between salivary cortisol for the Schonstedt with no instrument condition (D1 PD and D3 BAR).

There are a few significant correlations between performance and stress measures, but these are spurious and not always in the direction expected. Over all there is not a strong relationship between stress and performance in this analysis. This is probably because the operator stress levels are low to moderate. Operators are not experiencing high levels of stress that would impact performance.

Comparative Stress Data

The stress battery used by the U. S. Army Research Laboratory has been tested and validated in numerous studies. In Appendix C mean scores and the standard error of the mean (SEM) for the state MAACL-R subscale profiles after UXO detection are compared with profiles obtained in relevant military studies. All comparative measures are stress perception measures taken on the day of the stressor following the stress event except for the independent control (INDEP CNTRL). Independent control data were collected from seventeen non-stressed individuals at Northwestern University. Weapons competition (WPN COMP) data were collected from twenty infantrymen engaged in a competitive weapons event (Torre, Wansack, Hudgens, King, Fatkin, Mazurczak, & Breitenbach, 1991). Chemical Defense Test Center (CDTF) data were collected following exposure to active chemical agents at that facility (Fatkin & Hudgens, 1994). Sustained operations data were collected from twenty-four soldiers following 48 hours of sleep deprivation (Fatkin, Knapik, Patton, Mullins, Treadwell, & Swann, 1997). Fire Fighting data were collected from soldiers fighting the fires at Yellowstone National Park in 1989 (Fatkin, King, & Hudgens, 1990). Recruiter data were collected from 287 Army recruiters in urban, suburban, and rural locations around the country (Mullins & Fatkin, 2000). Data collected from 40 UXO clearance personnel working on the Kaho'olawe Island UXO Clearance Project (KAHO) represent experienced UXO workers (Morgan & Mullins, 2002). Patient decontamination (patient decon) data represent Soldiers performing patient litter decontamination, participants wore Mission Oriented Protective Posture (MOPP4) (Blewett, Redmond, Fatkin, Popp, & Rice, 1995). The last four bars of the comparative charts represent data collected for this project: experts wearing the Schonstedt and TMS instrumentation (exp Schon), experts with Schonstedt only (exp no ins), novices with Schonstedt and TMS instrumentation (novice Schon), and novices with Schonstedt and no TMS instrumentation (novice no ins). With the exception of novices without the TMS instrumentation for MAACL-R hostility the means for all UXO detection data was lower then the independent control. Overall participants experience low to moderately low levels of psychological stress. This corresponds with data collected at the Kaho'olawe Island UXO Clearance Project. This data combined with the Kaho'olawe findings indicate trained individuals generally do not experience high levels of stress during UXO detection tasks.

NASA TLX

The NASA TLX is a subjective measure of workload. The overall measure of workload is based on the weighted average of ratings on the six subscales of mental demand, physical demand, temporal demand, performance, effort, and frustration. Means and standard deviations for total workload and the six subscales are presented in Table 2.

Novices reported a higher level of overall workload while wearing the TMS instrumentation (Figure 1) and without the TMS instrumentation (Figure 2). Novices tended to give higher ratings for the subscales mental demand and effort.

Conclusions

Overall stress perception data and the physiological data indicate that these groups of UXO clearance workers did not experience high levels of stress. Novices did have introductory level training in UXO detection. Novices generally experienced slightly higher stress levels then experts. The low stress levels experienced by test participants are likely due to training. Experience appeared to reduce stress perceptions to near baseline levels. The low levels of stress found here are in agreement with other UXO detection results.

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Table 1. Data Collection by UXO Lanes

Participant	Schonstedt				No Instrument			
	During 1	During 2	During 3	Post	During 1	During 2	During 3	Post
E1	21-27	1-9	10-18	19-20	33-25	24-16	15-7	6-1
E2	1-9	10-18	21-27	28-33	33-25	24-16	15-7	6-1
E3	1-9	10-18	21-27	28-33	20-12	11-3	33-27	26-21
E4	1-9	10-18	21-27	28-33	33-25	24-16	15-7	6-1
E5	1-9	10-18	21-27	28-33	33-25	24-16	15-7	6-1
S1	1-7	8-25		26-33	33-25	24-16	15-7	6-1
S2	21-29	1-9	10-18	19-20	33-25	24-16	15-7	6-1
S3	1-9	10-18	21-29	30-33	33-25	24-16	15-7	6-1
S4	21-29	30-33	10-18	1-9	33-25	20-16	15-7	6-1
S5	21-29	1-9	10-18	19-20	33-25	24-16	15-7	6-1

Table 2. Stress measure correlations with corresponding UXO PD Detection Performance

	Sh D1	Sh D2	Sh D3	Sh Post	NI D1	NI D2	NI D3	NI Post
MAACL								
Anxiety	.27	.17	.14	.01	-.34	.07	.14	.19
Depression	-.08	-.02	-.15	-.24	-.04	-.30	-.11	.20
Hostility	.03	.16	.13	.05	-.05	-.32	.13	-.10
Dysphoria	.17	.18	.10	.01	-.11	-.02	.16	.14
Positive Affect	.22	.24	.48	.19	.46	.38	.10	.67*
Subjective Stress	-.11	.17	.10	.13	-.04	.14	.40	-.12
Subjective Rating of Events	.14	.38	-.04	.11	-.07	-.12	-.006	-.42

*; $p \leq 0.05$

Table 3. Stress measure correlations with corresponding UXO BAR Detection Performance

	Sh D1	Sh D2	Sh D3	Sh Post	NI D1	NI D2	NI D3	NI Post
MAACL								
Anxiety	-.21	-.10	.40	.00	.37	.05	.07	.26
Depression	-.41	-.39	-.39	.01	.58	.15	.39	.25
Hostility	-.33	-.27	.40	.05	.60	.18	.12	.04
Dysphoria	-.35	-.16	.29	.04	.56	.10	.13	.23
Positive Affect	.30	.12	.35	-.14	.05	-.12	-.3	.19
Subjective Stress	-.26	-.35	.37	-.06	.54	.67*	.06	-.12
Subjective Rating of Events	-.05	.09	.35	-.27	.55	.49	-.11	-.42

*; p<=0.05

Table 4. UXO Detection Performance with Salivary Amylase and Cortisol

	AMY D1	AMY D2	AMY D3	AMY Post	CORT D1	CORT D2	CORT D3	CORT Post
PD Schon with TMS	-.34	-.13	-.02	-.13	.52	.14	-.18	.23
BAR Schon with TMS	-.11	.07	.52	-.22	-.42	.20	-.53	-.06
PD No inst.	.38	.24	-.28	.30	-.73*	.12	.06	.18
BAR No inst.	.07	.16	.03	.19	-.01	-.14	-.75*	-.41

*; p<=0.05

Table 5. NASA TLX Means and Standard Deviations *

	Schonstedt				No Instrument			
	During 1	During 2	During 3	Post	During 1	During 2	During 3	Post
Experts								
Total	17.5 (19.1)	27.4 (19.0)	35.6 (3.9)	38.7 (7.4)	32.5 (17.0)	35.3 (9.4)	33.7 (9.2)	36.8 (7.7)
Mental	1.2 (1.2)	1.1 (1.4)	2.1 (2.2)	2.3 (2.2)	1.8 (1.4)	3.2 (3.0)	1.2 (0.6)	2.1 (1.5)
Physical	1.3 (1.7)	1.4 (1.4)	1.9 (1.4)	1.5 (1.3)	2.1 (2.2)	1.4 (0.9)	1.9 (1.6)	2.7 (2.1)
Temporal	1.4 (1.8)	1.2 (2.1)	2.5 (2.9)	1.7 (2.3)	2.0 (1.8)	1.8 (1.8)	2.4 (2.2)	1.5 (1.1)
Performance	10.3 (13.4)	19.7 (13.5)	22.9 (12.2)	27.1 (6.0)	20.3 (12.1)	25.1 (8.9)	24.3 (8.6)	25.3 (10.4)
Effort	3.3 (5.0)	4.1 (6.1)	6.3 (8.5)	6.0 (7.1)	6.3 (7.2)	3.7 (4.8)	3.9 (4.4)	5.1 (5.4)
Frustration	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Novices								
Total	62.4 (20.6)	34.8 (41.4)	44.6 (38.3)	37.5 (40.4)	59.1 (15.5)	50.8 (16.5)	60.3 (21.1)	42.4 (33.3)

Mental	15.5 (12.6)	5.6 (10.3)	10.4 (14.0)	8.7 (12.9)	13.9 (11.1)	12.2 (10.4)	12.3 (12.7)	5.7 (9.1)
Physical	5.4 (4.5)	2.3 (3.1)	4.0 (5.1)	2.4 (3.1)	2.3 (2.8)	3.5 (2.0)	5.4 (3.1)	6.7 (6.0)
Temporal	5.9 (1.8)	3.6 (4.7)	3.5 (2.1)	2.4 (4.7)	9.1 (5.0)	3.3 (4.0)	5.3 (2.7)	4.3 (3.3)
Performance	17.3 (7.8)	10.5 (14.0)	10.9 (13.7)	11.9 (10.9)	20.2 (5.7)	18.6 (4.7)	20.1 (10.6)	14.7 (13.0)
Effort	17.8 (7.1)	12.8 (16.0)	15.9 (14.1)	12.1 (14.0)	12.5 (5.7)	13.3 (6.6)	15.9 (5.3)	10.5 (9.8)
Frustration	0.5 (1.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (2.4)	0.0 (0.0)	1.3 (3.0)	.53 (1.2)

* Standard deviation in parentheses

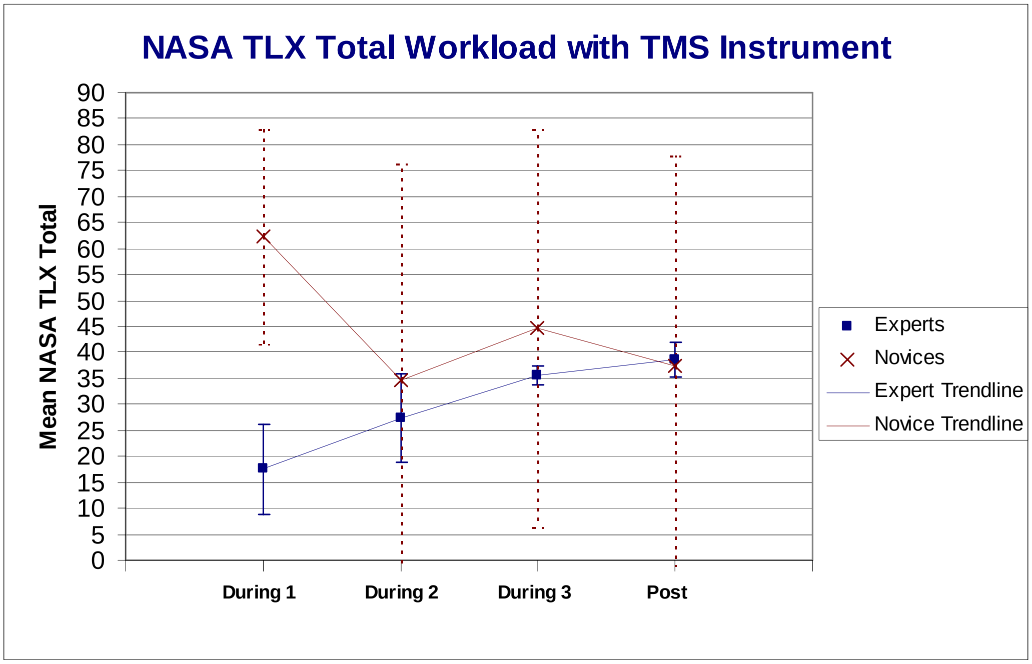


Figure 1. Mean total workload for experts and novices using Schonstedt with TMS instrumentation.

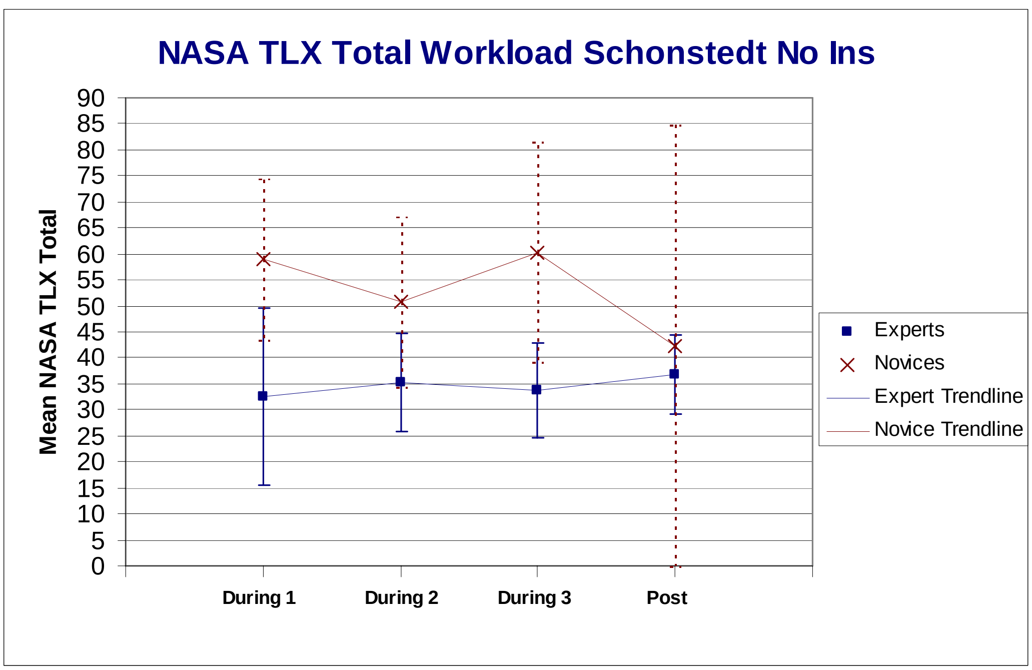


Figure 2. Mean total workload for experts and novices using Schonstedt without TMS instrumentation.

APPENDIX A

SAMPLE DATA COLLECTION QUESTIONNAIRES

General Information Questionnaire

Subjective Stress

Subjective Rating of Events

GENERAL INFORMATION QUESTIONNAIRE

Please answer all questions by filling in the blanks as completely as possible. All information will be kept **strictly confidential**.

ID # __________

BACKGROUND

1. Age: _________

2. Ethnicity (check one)
______African American
______Native American
______Caucasian
______Hispanic
______Asian
______Pacific Islander
______Other

3. Gender: Female ____ Male _____
(check one)

4. Height ______ Weight _______

5. Are you: ___Married ___Single ___Divorced (or in the process)
___Widow

6. Are you a smoker? (circle one) Yes No
If yes,
How many packs a day?
0 – 1 ______
1 – 2 ______
2 – 3 ______
More than 3 ______

7. Education completed:
High School _______ (years)
GED _______ (yes or no)
College _______ (years)
Grad School _______ (years)

8. Do you have EOD experience? (circle one) Yes No

If yes, how many years experience ___________

9. Do you have combat engineer experience? (circle one) Yes No

If yes, how many years experience ___________

10. Do you have field experience in UXO detection? (circle one) Yes No

If yes, how many years experience ___________

11. Do you have experience with the Schonstedt magnetic locator? (circle one) Yes No

If yes, how many years experience ___________

12. Do you have experience with the EM61 hand held system? (circle one) Yes No

If yes, how many years experience ___________

13. Have you had any prior military service? (circle one) Yes No

If yes:

What service? ______________

MOS Primary ________ Time in MOS ________ (years) ________ (months)

MOS Secondary ________ Time in MOS ________ (years) ________ (months)

CURRENT STATUS

14. Current Job Title ___________________________

15. Time in Current Position ______ (years) ______ (months)

Brief Job Description ____

____

____

16. Present overall health: (check one)

(1) _____ excellent

(2) _____ good

(3) _____ fair

(4) _____ poor

17. How many hours of sleep do you normally get on week nights? _______
on weekends? _______

18. Do you find you are overtired: (check one)

(1) _____ never

(2) _____ occasionally

(3) _____ frequently

Please feel free to add any other comments you feel are important or that we may have left out.

Thank You For Your Participation!

<u>SUBJECTIVE SCALE</u>

Circle **<u>ONE</u>** word that best describes how you felt <u>since you last completed this questionnaire</u>.

Wonderful

Fine

Comfortable

Steady

Not Bothered

Indifferent

Timid

Unsteady

Nervous

Worried

Unsafe

Frightened

Terrible

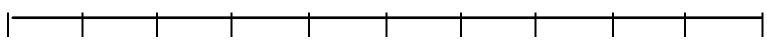
In Agony

Scared Stiff

RATING OF EVENTS - SPECIFIC

1. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (4) to rate how much stress you were experiencing while you were scanning for unexploded ordnance during this session.

Not at All Stressful **Most Stress Possible**



0 10 20 30 40 50 60 70 80 90 100

2. At what number value does the check mark touch the line?

____

APPENDIX B

Psychological and Psychological

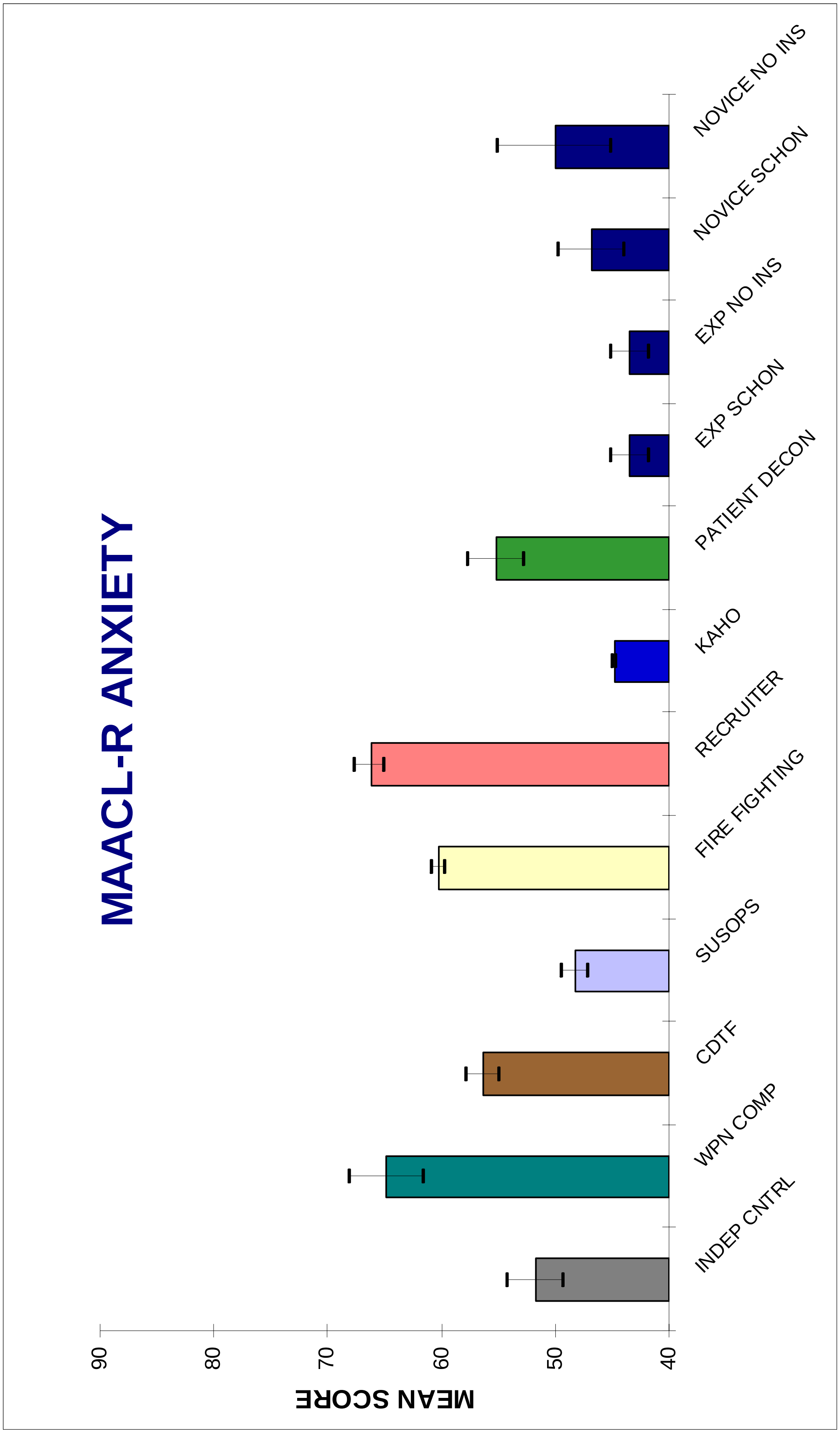
Stress Assessment Graphs

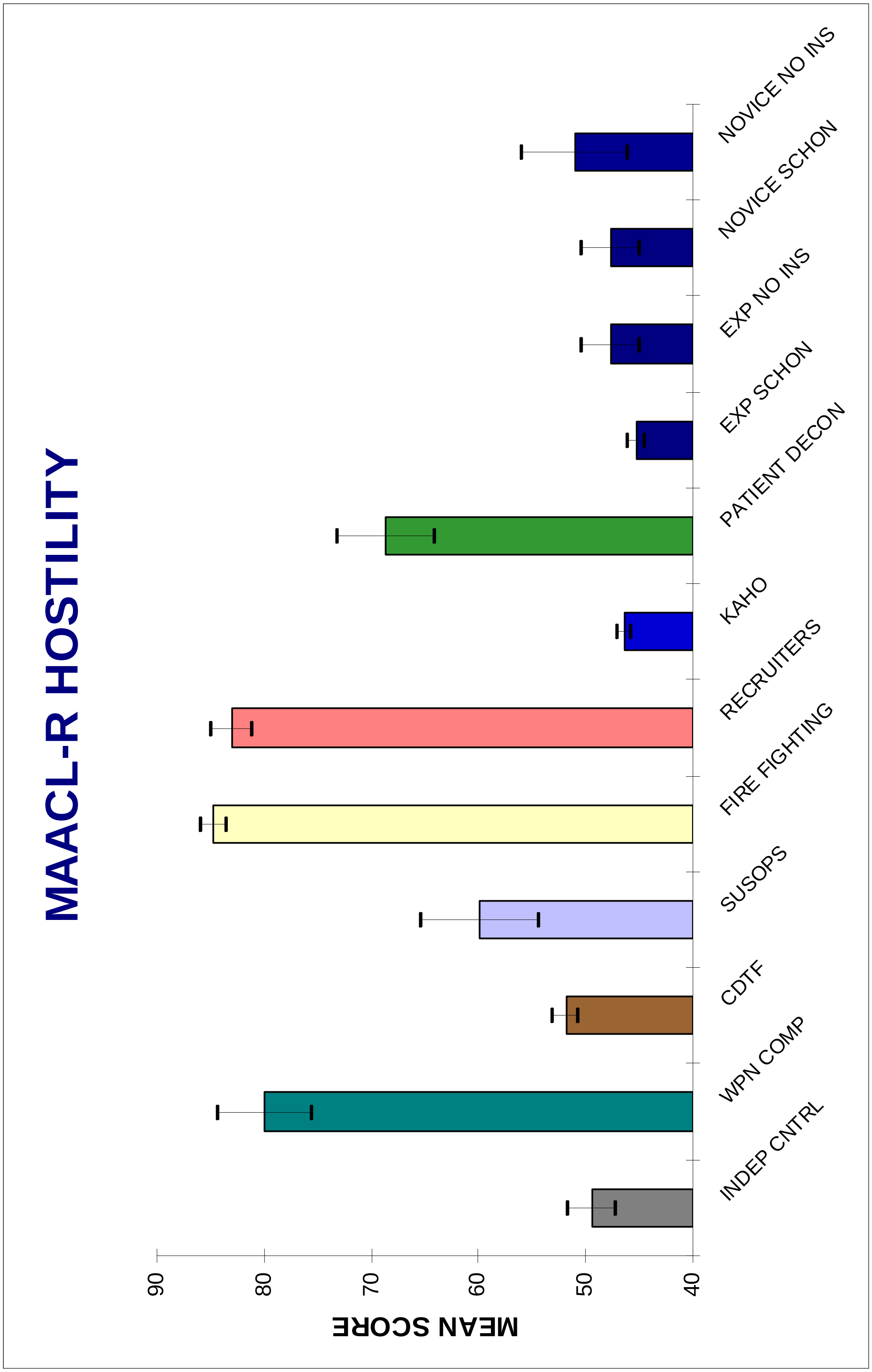
Comparison of Experts vs. Novices

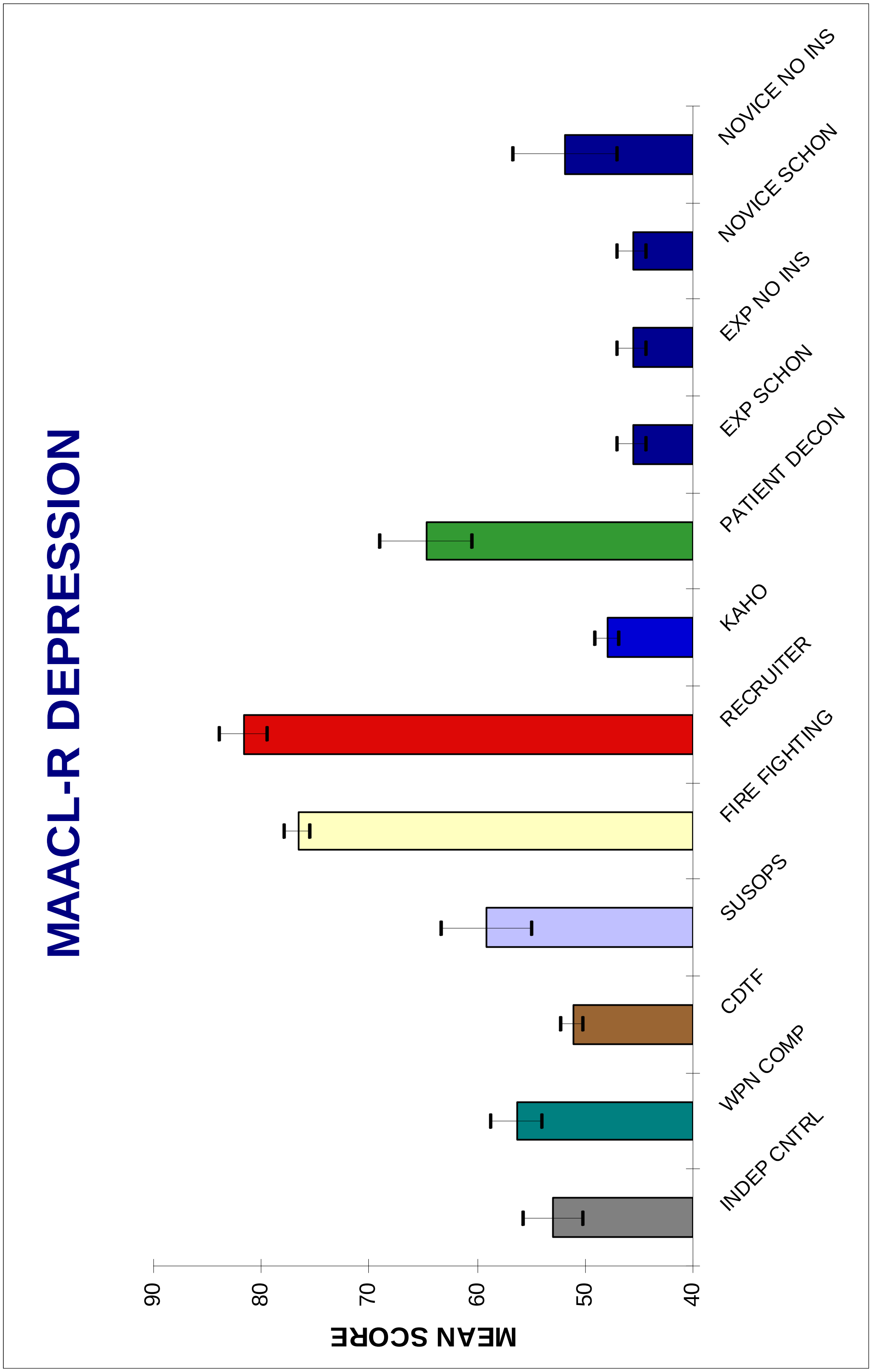
In Power Point file Report Appendix B Graphs

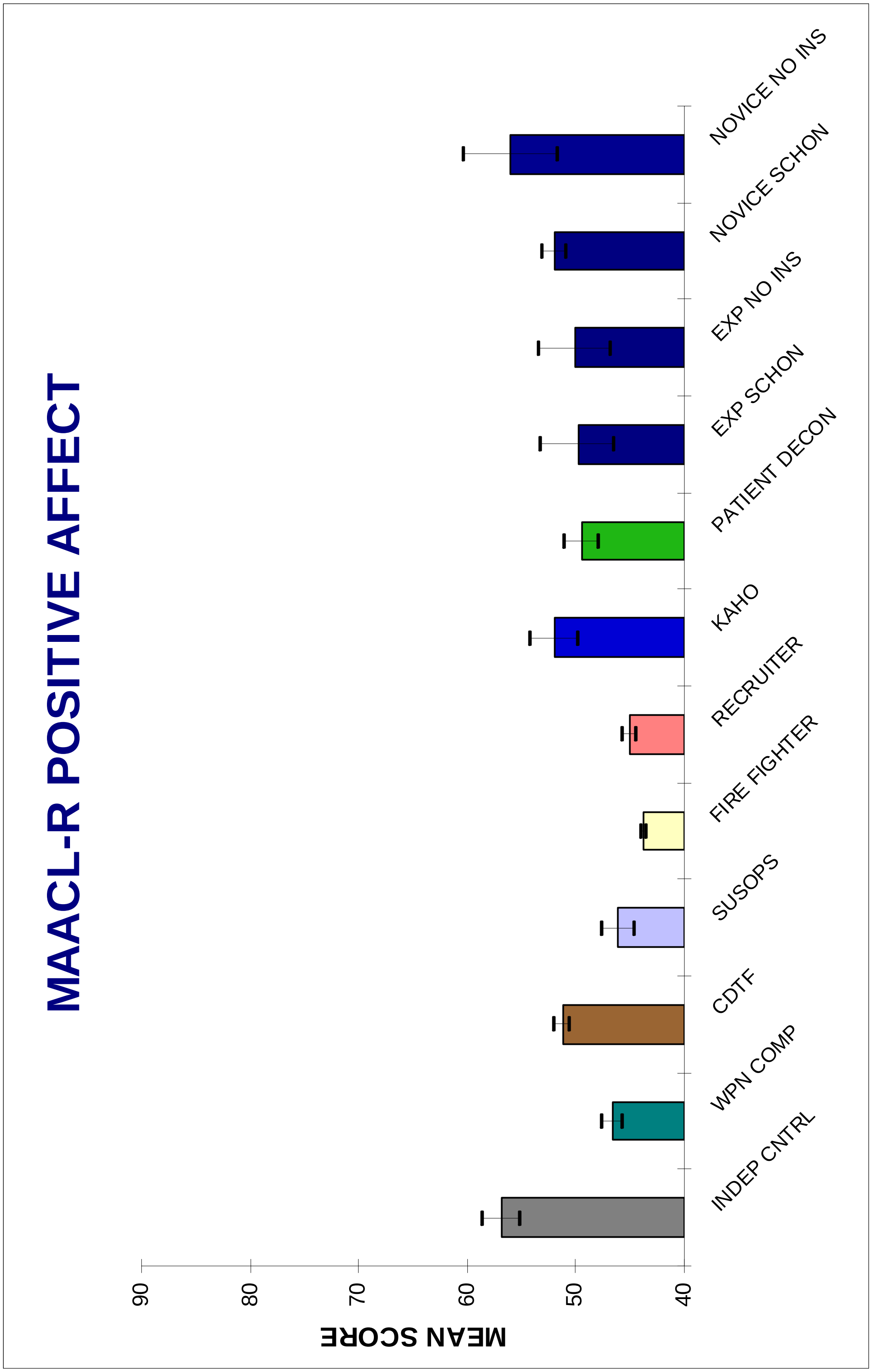
APPENDIX C

MAACL-R Comparison Graphs


MAACL-R ANXIETY
MEAN SCORE
90
80
70
60
50
40
INDEP CNTRL
WPN COMP
CDTF
SUSOPS
FIRE FIGHTING
RECRUITER
KAHO
PATIENT DECON
EXP SCHON
EXP NO INS
NOVICE SCHON
NOVICE NO INS


MAACL-R HOSTILITY
MEAN SCORE
90
80
70
60
50
40
NOVICE NO INS
NOVICE SCHON
EXP NO INS
EXP SCHON
PATIENT DECON
KAHO
RECRUITERS
FIRE FIGHTING
SUSOPS
CDTF
WPN COMP
INDEP CNTRL


MAACL-R DEPRESSION
MEAN SCORE
90
80
70
60
50
40
INDEP CNTRL
WPN COMP
CDTF
SUSOPS
FIRE FIGHTING
RECRUITER
KAHO
PATIENT DECON
EXP SCHON
EXP NO INS
NOVICE SCHON
NOVICE NO INS


MAACL-R POSITIVE AFFECT
MEAN SCORE
90
80
70
60
50
40
INDEP CNTRL
WPN COMP
CDTF
SUSOPS
FIRE FIGHTER
RECRUITER
KAHO
PATIENT DECON
EXP SCHON
EXP NO INS
NOVICE SCHON
NOVICE NO INS

APPENDIX N. HEARING TEST PROCEDURES AND RESULTS

MEMORANDUM

TO: Chris Appelt, Aberdeen Test Center

FROM: Paula Henry, Ph.D., Research Audiologist and Timothy Mermagen, Electrical Engineer, US Army Research Laboratory, AMSRD-ARL-HR-SD, Building 520, Aberdeen Proving Ground, MD 21005-5425

RE: Hearing tests performed on study participants, predicted effects of hearing loss on mine detection performance, and comparison on mine detection devices

---

Hearing test methods:

A certified audiologist performed audiologic testing on all participants. Testing began with an otoscopic examination to determine the status of the pinnae and external auditory canals. Participants then completed pure tone air conduction testing. The testing took place in a sound treated booth through the use of a clinical diagnostic audiometer (Interacoustics AC40). Pure tones at octave frequencies 250 – 8000 Hz and interoctaves 3000 and 6000 Hz were presented through TDH-39 superaural headphones. Middle ear status was determined through tympanometry using a Grason-Stadler 37 Auto Tympanometer.

Hearing test results:

Results of audiologic testing, as shown in Figure 1, revealed that on average the participants had normal hearing sensitivity (defined as air conduction thresholds of 20 dB HL or better) in both ears and all participants showed normal bilateral middle ear function. After examination of individual hearing tests, one participant, E1, was found to have mild-to-moderate high frequency hearing loss (3000-8000 Hz) in both ears. Two additional participants, S2 and S4, had moderate hearing loss in the high frequencies, but only in one ear. For participant S2, the hearing loss was in the left ear and for S4, the loss was is the right ear.

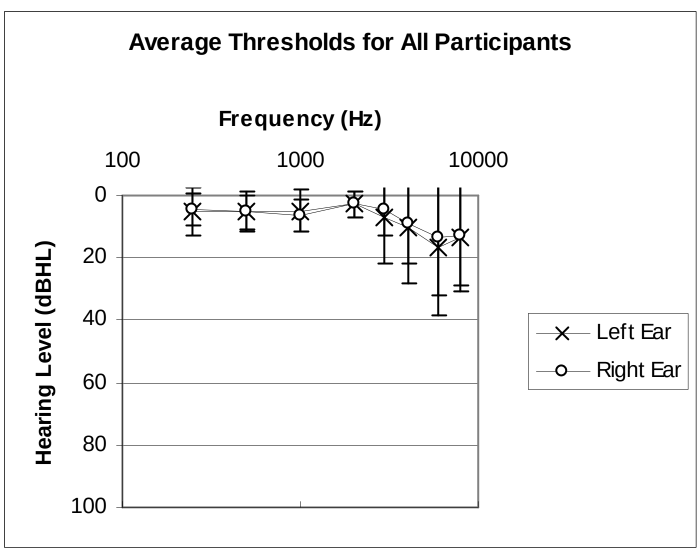


Figure 1. Average hearing thresholds for all participants. Error bars indicate +/- 1 standard deviation.

Measurements from magnetic locator devices:

Recordings from the two Schonstadt magnetic locators used in the study, were made in the following manner. A Knowles Electronics Manikin for Acoustic Research (KEMAR) was used with Etymotic E-11 microphones mounted in the ear canals. The acoustic output from the Schonstadt was routed through a Bogen Communications, Inc. 10 Watt attenuator to the Audio-Technica ATH M-30 headphones which were placed over the manikin's ears. The particular Schonstadt device that the participant used was held in their preferred calibration position, set to their selected instrument sensitivity and volume control setting. The output of the headphones was recorded through the E-11 microphones into a Vaio notebook computer using a 01dB sound analysis system.The frequency responses of the stimuli were measured in 1/3 octave bands. The hearing thresholds measured on the participants were converted from dB HL (as measured for the hearing tests) to dB SPL in order to equate the signals. Figures 2 through 13 show the frequency responses of the acoustic stimuli recorded from the Schonstadt magnetic locator along with the participant's hearing thresholds for comparison. The difference between the stimuli response and the participants' thresholds is the amount of the stimulus that was audible to the user.

For all participants, hearing status was not expected to have a significant impact on performance in the study for three reasons. First, the signals from the magnetic locators presented to the listeners were provided through headphones to both ears. Therefore, hearing loss in only one ear (participants S2 and S4) should not impact overall performance as the better ear would be able to compensate for the loss in the poorer ear. Second, the signals provided to the listeners were of a level high enough to be above their hearing thresholds as shown in the graphs. Third, the signals emitted from the magnetic locators were broad in their frequency spectrum, so that an individual with a bilateral high frequency hearing loss (E1) should have been able to utilize the lower frequency information in the signal. Indeed, in the case of participant E1, the frequency range of the signal from 500 to 3000 Hz was between 10 and 70 dB above threshold.

Comparisons of Schonstadt devices:

Concern was raised as to the equality of the stimuli provided by the two Schonstadt devices. In order to compare the two, recordings were made of the signal emitted from each of the devices under the same conditions. A shot, used in shot put, was placed under a bucket of a particular height. The, the sensitivity control and the volume control on the two devices were set to the same levels. Recordings of the signal from the two Schonstadts are shown in Figure 14. As can be seen in the figure, very little difference is seen between the stimuli recorded from the two instruments. Based on this figure, it is reasonable to state that the two Schonstadts are sufficiently equivalent.

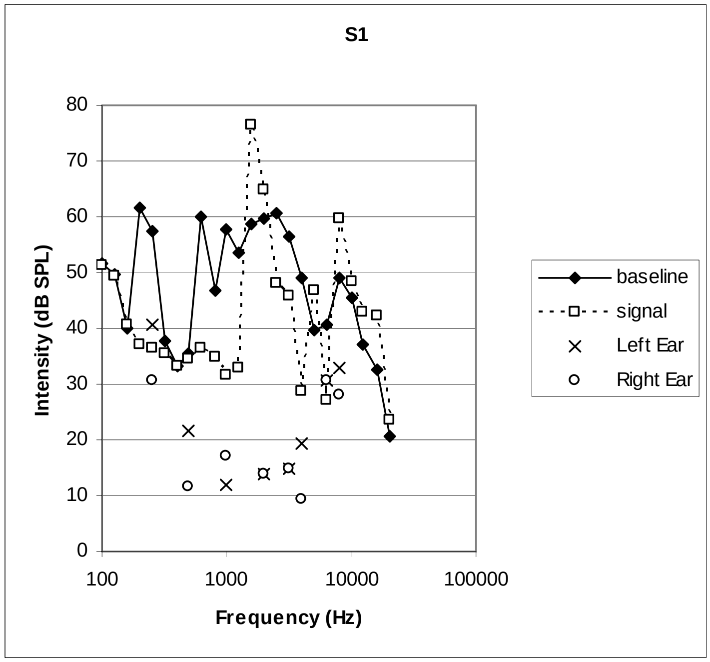


Figure 2. Plot of frequency response of baseline and signals measured from the Schonstadt mine detector along with hearing thresholds from participant S1.

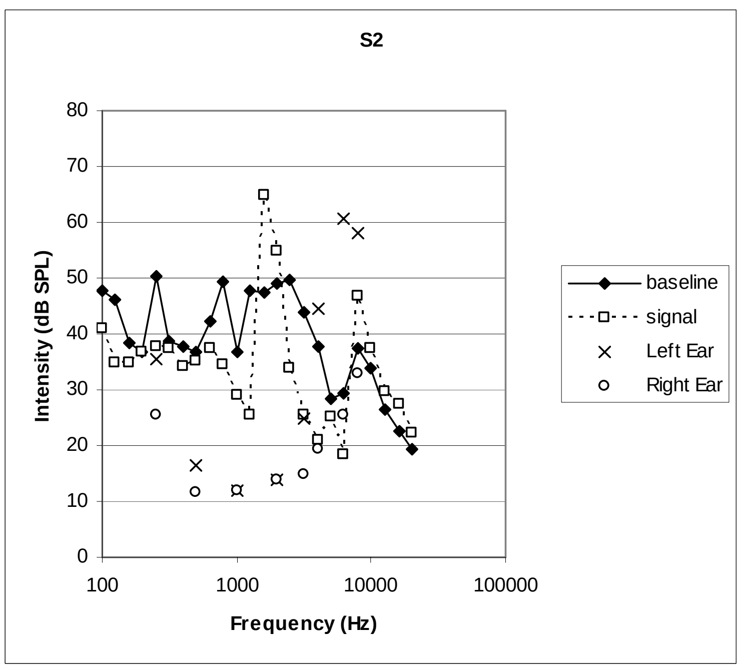


Figure 3. Same as Figure 2, for participant S2. Note that this participant has a hearing loss in the high frequencies in his left ear shown by the x symbols.

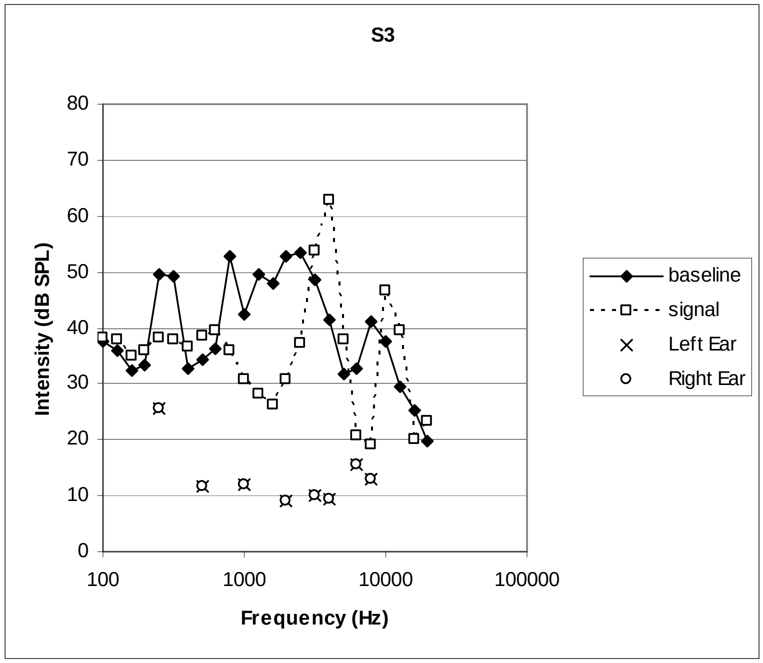


Figure 4. Same as Figure 2, for participant S3.

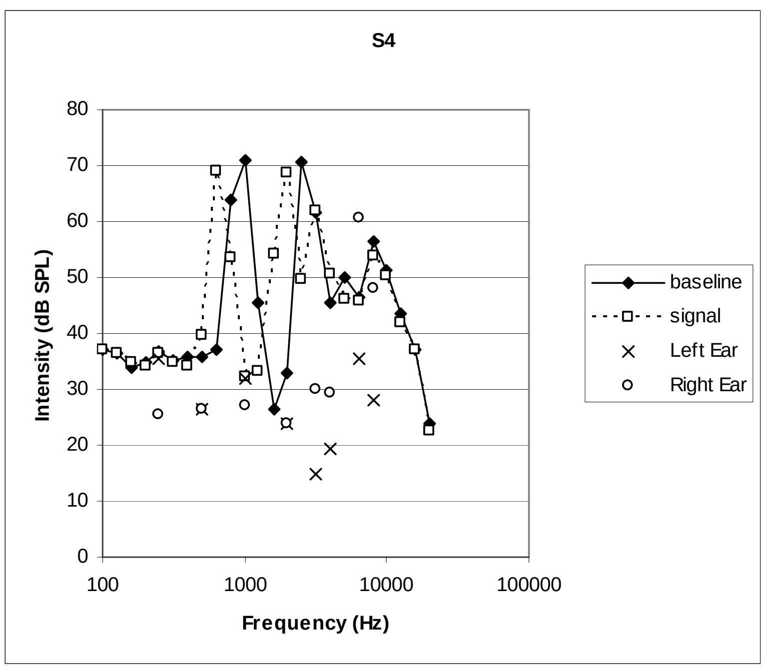


Figure 5. Same as Figure 2, for participant S4. Note that this participant has a high frequency hearing loss in his right ear, shown by the o symbols.

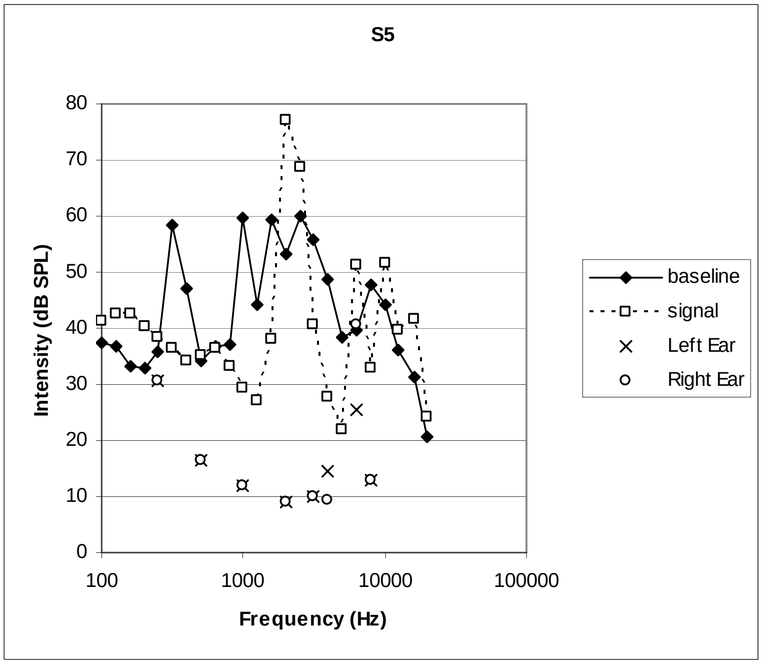


Figure 6. Same as Figure 2, for participant S5.

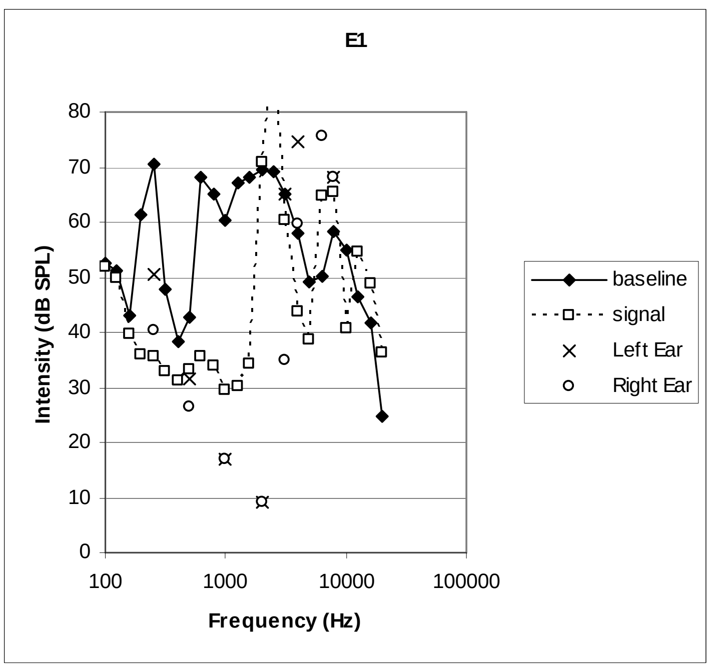


Figure 7. Same as Figure 2, for participant E1. Note that participant has hearing loss above 3000 Hz, but would have audibility of the signal between 500 and 3000 Hz.

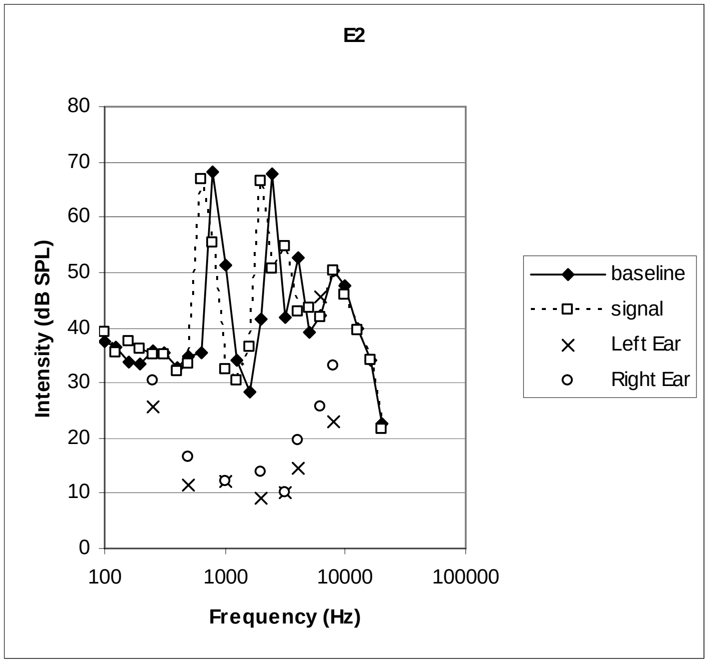


Figure 8. Same as Figure 2, for participant E2.

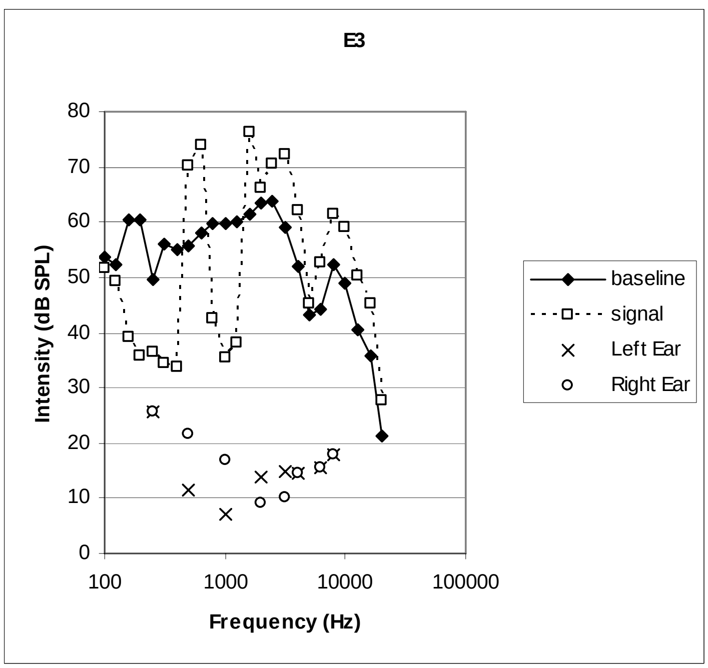


Figure 9. Same as Figure 2, for participant E3.

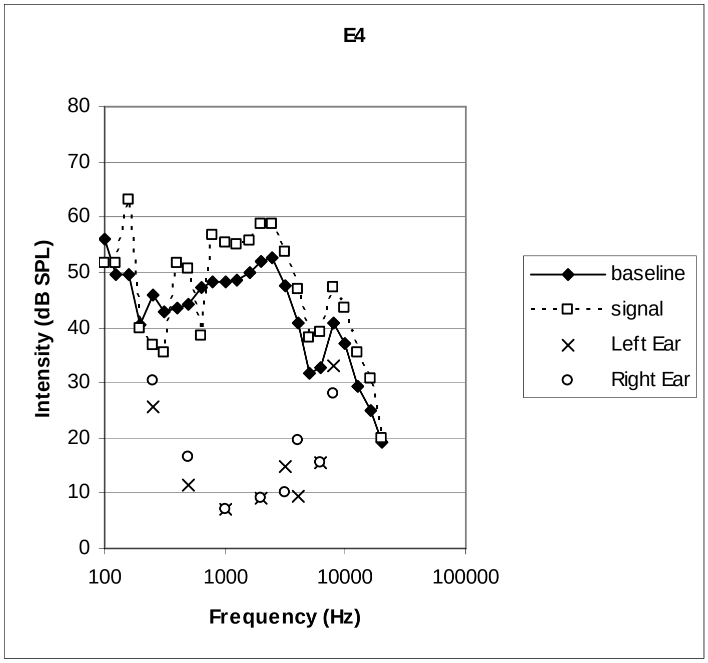


Figure 10. Same as Figure 2, for participant E4.

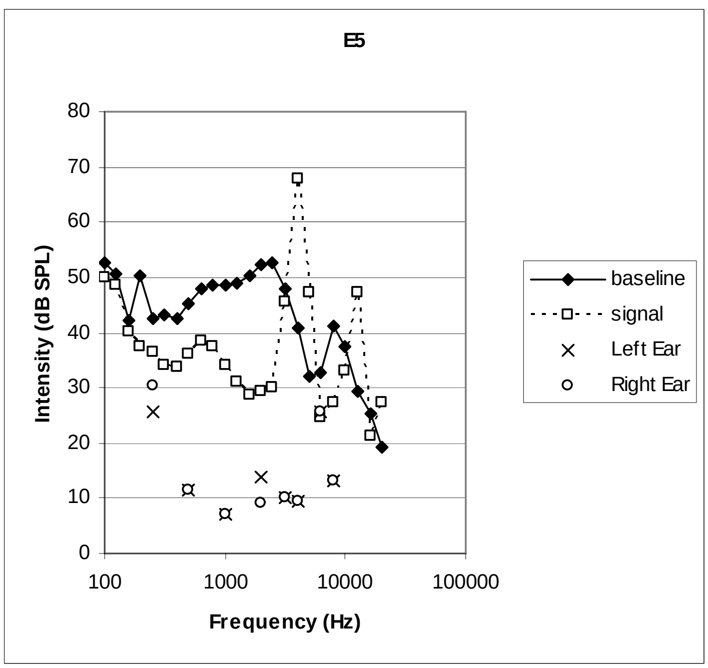


Figure 11. Same as Figure 2, for participant E5.

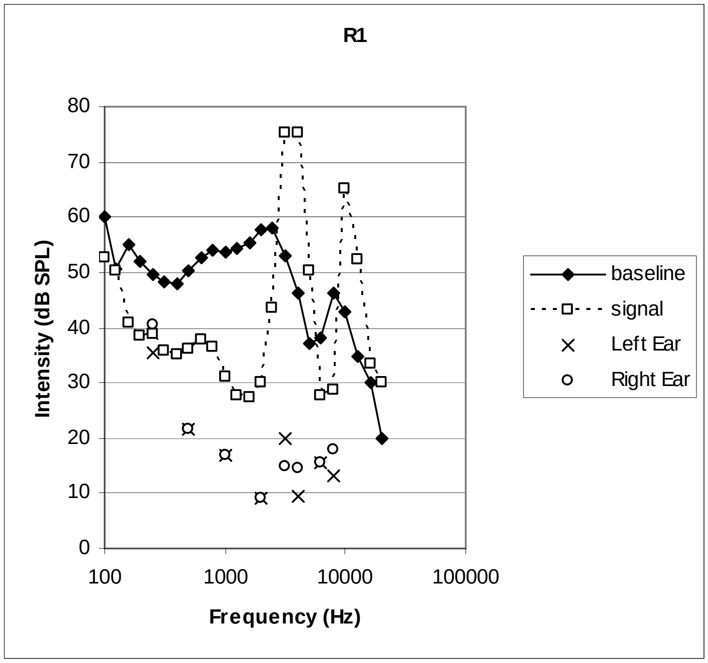


Figure 12. Same as Figure 2, for participant R1.

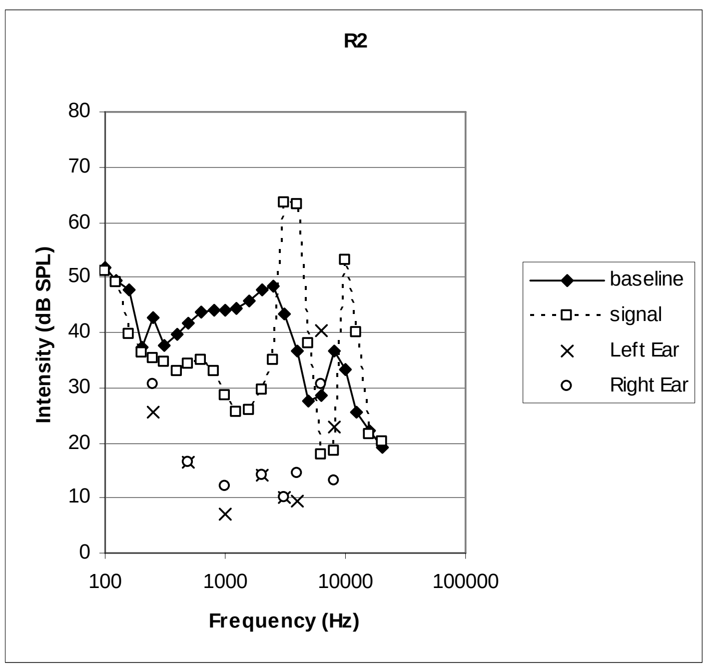


Figure 13. Same as Figure 2, for participant R2.

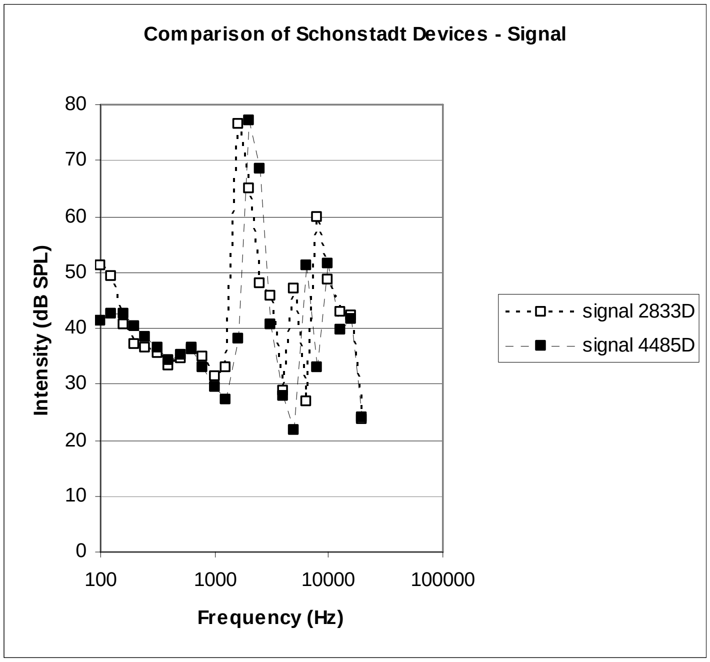


Figure 14. Comparison of the signals emitted from the two Schonstadt devices recorded under the same condition. The devices were held directly over the bucket with the shotput beneath it and the instrument sensitivity set at 4.

APPENDIX O. PERFORMANCE AND MEASUREMENTS OF OPERATOR WITHOUT TMS

CSTE-DTC-AT-AD-R 19 May 2006

MEMORANDUM FOR CHIEF, Military Environmental Technology Demonstration Center Team, ATTN: Chris Appelt
SUBJECT: Performance Characteristics and Measurements of Operators without TMS Instrumentation

1. Background

a. Ten operators were chosen to conduct this test. Five were considered novices with little to no experience with UXO searching, while the remaining five were considered experts with twelve months or more UXO experience. Thirty-three lanes were scattered with 60 UXO, consisting of 40mm, 60mm, 81mm, 105mm, and 155mm rounds. The burial depths of these items were 6 inches, 12 inches, 18 inches, 24 inches, and 30 inches, respectively. The UXO were randomly placed throughout the lanes and were arbitrarily orientated horizontally or vertically. Table 1 presents the number and orientation of each ordnance type used for this test.

Table 1. Summary of Ordnance Type and Orientation

40mm		60mm		81mm		105mm		155mm		Total
H	V	H	V	H	V	H	V	H	V	
4	5	5	7	6	7	5	8	6	7	60
9		12		13		13		13		

b. Each operator used the Schonstadt magnetometer to traverse all thirty-three lanes twice, once with just the Schonstadt and again with the Schonstadt equipped with two sensors allowing the TMS system to track and record the coordinates of the sensors at a rate of ten Hertz. The data in this memorandum are of the operators using the Schonstadt without the TMS instrumentation, except where comparisons are made between with and without instrumentation.

c. In addition to the ten operators, two quality control operators traversed through the 33 lane grid without instrumentation with the EM-61. Also, two rookies with no UXO experience or training went through the first seven lanes with the Schonstadt magnetometer.

2. Scoring Methodology

a. The actual coordinates of emplaced UXO are called ground truth. Each operator's data was scored against the ground truth. The findings made by an operator are called anomalies. If an anomaly was within a one-meter radius halo of the ground truth, it was considered a hit. Anomalies outside this radius were considered false alarms. If there were multiple anomalies within a halo, only one was counted as a hit, while the others were not considered false alarms.

b. Three performance measurements were calculated for each operator – Probability of Detection (P_d), False Alarm Rate (FAR), and a numerical combination of P_d and FAR, Distance from Optimal Point (DOP). It is assumed that the number of correct hits is a binomially distributed random variable. FAR was calculated by the number of false alarms divided by the area traversed by the operator. On the graph of P_d versus FAR, the closer an operator is to (0,1), (zero FAR and 100% P_d, or the optimal point), the better the operator did. The DOP was calculated as the distance from (0,1) to an operator's point (FAR, P_d). The smaller DOP number, the better the operator did.

c. Two performance characteristics, lane velocity and total time, were obtained for each operator without instrumentation. Lane velocity is defined by the lane length divided by the time each operator took to complete each lane. This performance characteristic is the average lane velocity over all thirty-three lanes.

d. The objective of this phase of testing was to observe and record UXO Technicians while executing a "mag and flag" operation on the pre-seeded test grid.

3. Test Findings

a. The DOP parameter is a combination of Pd and FAR and is therefore an overall performance measurement. Figure 1 depicts the relationship between DOP and UXO Experience. The expected outcome of this plot would be a linear correlation with negative slope of low experience receiving high DOP and high experience receiving low DOP. To assess the linear correlation, the R^2 term is used. R^2 is a descriptive measure between zero and one that measures how well the linear line approximates real data points. The closer R^2 is to one, the better the sample is at predicting the true population. From Figure 1 it can be concluded that there seems to be no correlation between experience level and optimal performance.

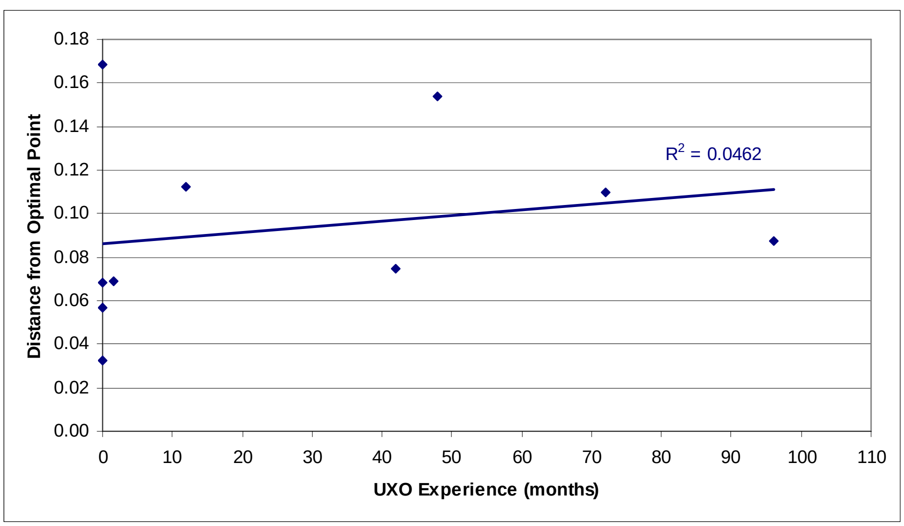


Figure 1. Distance from Optimal Point versus UXO Experience of All Operators without Instrumentation.

b. Table 2 displays the average Pd for each ordnance type/depth and orientation for all the operators without instrumentation. All operators achieved 100% detection rates on the 40mm both when horizontally and vertically oriented. Operators had the lowest detection rates on the 81mm both horizontally and vertically oriented. Overall, vertically oriented ordnance had higher Pd than horizontally oriented ordnance. Note also from Table 2 that ordnance type and depth are codependent; that is, since each ordnance type was buried at a certain depth, no information can be deduced about ordnance type or depth separately.

Table 2. Average Pd of All Operators without Instrumentation by Ordnance Type/Depth and Orientation.

Type	Depth, in	Horizontal	Vertical	Total
40mm	6	100.0%	100.0%	100.0%
60mm	12	94.0%	98.6%	96.7%
81mm	18	80.0%	92.9%	88.5%
105mm	24	100.0%	97.5%	98.5%
155mm	30	100.0%	98.6%	99.2%
Total		**94.2%**	**97.9%**	**96.3%**

4. Technical Assessment

The ten operators were compared in three different groupings: five experts versus five novices, top five performers versus bottom five performers, and three highest performers versus four middle performers versus three lowest performers. The latter two comparisons are for informational purposes and are presented in Appendix A. The Chi-Square Test for differences in proportions and the Mann-Whitney test were used to statistically compare the performance data of each of these breakdowns. The Mann-Whitney test is a nonparametric technique that uses the ranked order of the data to see if two samples are identical when nothing about the underlying distributions are known. {reference: Conover W. J. Practical Nonparametric Statistics. 2nd Edition. New York: John Wiley and Sons, 1980.}

a. Experts versus Novices

1) Table 3 presents a summary of the performance data of each expert and novice without instrumentation. Figure 2 illustrates the Pd versus FAR of experts and novices.

Table 3. Summary of Performance Data of Experts and Novices without Instrumentation.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	100.0%	0.154	0.154	0.095	8238
	E-2	91.7%	0.072	0.110	0.088	9086
	E-3	100.0%	0.087	0.087	0.100	8279
	E-4	93.3%	0.034	0.075	0.092	8608
	E-5	93.3%	0.090	0.112	0.096	8199
	Mean	**95.7%**	**0.087**	**0.108**	**0.094**	**8482**
	Std. Dev.	**0.0401**	**0.0435**	**0.0302**	**0.0044**	**374.7**
Novices	N-1	100.0%	0.057	0.057	0.104	7612
	N-2	98.3%	0.028	0.033	0.112	6810
	N-3	95.0%	0.047	0.069	0.124	6661
	N-4	98.3%	0.168	0.169	0.050	17073
	N-5	93.3%	0.017	0.069	0.094	8733
	Mean	**97.0%**	**0.063**	**0.079**	**0.097**	**9378**
	Std. Dev.	**0.0274**	**0.0605**	**0.0522**	**0.0284**	**4379.6**

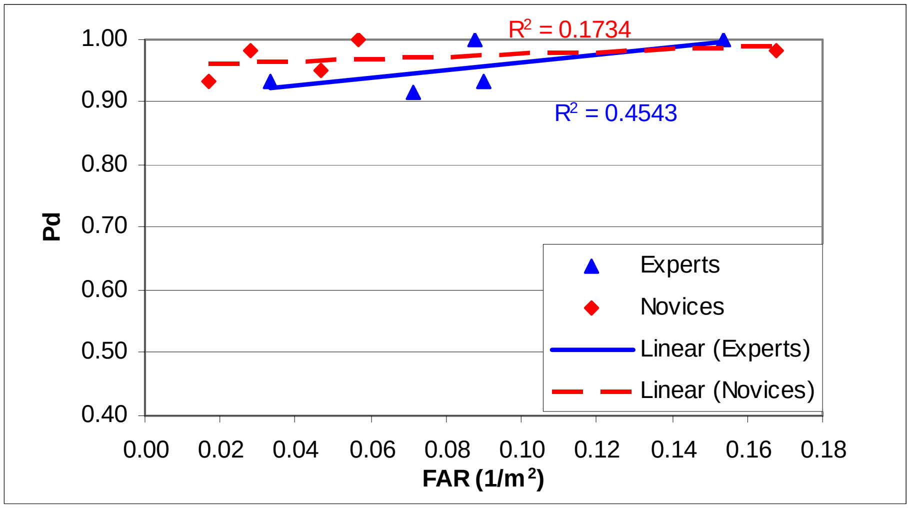


Figure 2. Pd versus FAR of Experts and Novices without Instrumentation.

2) Using the Chi-Square Distribution at 0.05 significance level, Pd between experts and novices without instrumentation was found not to be significantly different. Using the Mann-Whitney Test at the 0.05 significance level, no significant differences were found between the number of false alarms, DOP, and time between the novices and experts.

3) Table 4 presents the Pd by ordnance orientation and type for both novices and experts. Novices had 100% Pd both horizontally and vertically with three different types of ordnance: 40mm, 105mm, and 155mm. They also did equal to or better than the Experts in every category except two, the 60mm horizontally and vertically. Overall, the Novices averaged 1.1% higher Pd's than the Experts.

Table 4. Experts vs. Novices without Instrumentation – Pd by Ordnance Orientation and Type.

	Type	Novices	Experts	Total	Pd Differences
Horizontal	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	92.0%	96.0%	94.0%	-4.0%
	81mm	83.3%	76.7%	80.0%	6.7%
	105mm	100.0%	100.0%	100.0%	0.0%
	155mm	100.0%	100.0%	100.0%	0.0%
	Total	**94.6%**	**93.8%**	**94.2%**	
Vertical	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	97.1%	100.0%	98.6%	-2.9%
	81mm	94.3%	91.4%	92.9%	2.9%
	105mm	100.0%	95.0%	97.5%	5.0%
	155mm	100.0%	97.1%	98.6%	2.9%
	Total	**98.8%**	**97.1%**	**97.9%**	
Overall Total		**97.0%**	**95.7%**	**96.3%**	

4) Figures 3-5 show the comparison of average lane velocity to the three performance measurements, Pd, FAR, and DOP respectively. Two trends can be seen from these plots as the quicker the novices traverse the lanes: the fewer false alarms they indicate and they also have a better overall performance (low DOP). Also, the experts had little variation among themselves for lane velocity (standard deviation equal to .0044). The novices, on the other hand, did have high variation for lane velocity (standard deviation equal to .0284).

5) Figures 6-8 show the comparison of total time to the three performance measurements. Consistent with average lane velocity, the experts had less variation among themselves then the novices for total time. Also, the more time the novices took, the more false alarms they indicated.

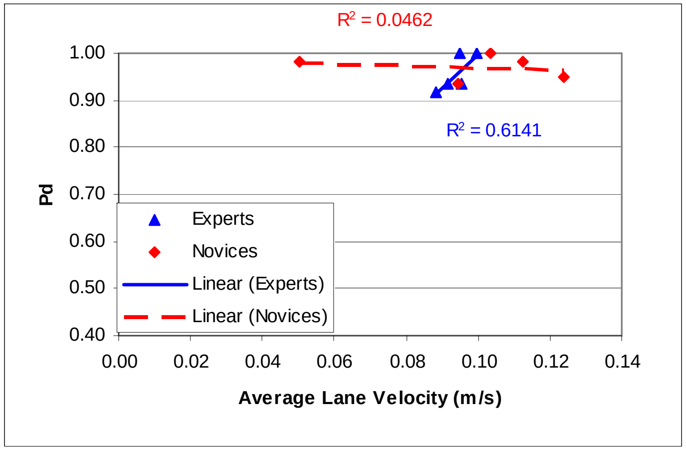


Figure 3. Experts and Novices – Pd vs. Average Lane Velocity.

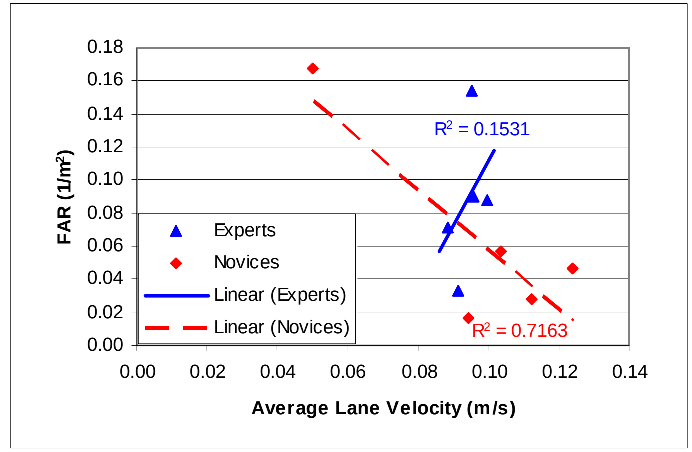


Figure 4. Experts and Novices – FAR vs. Average Lane Velocity

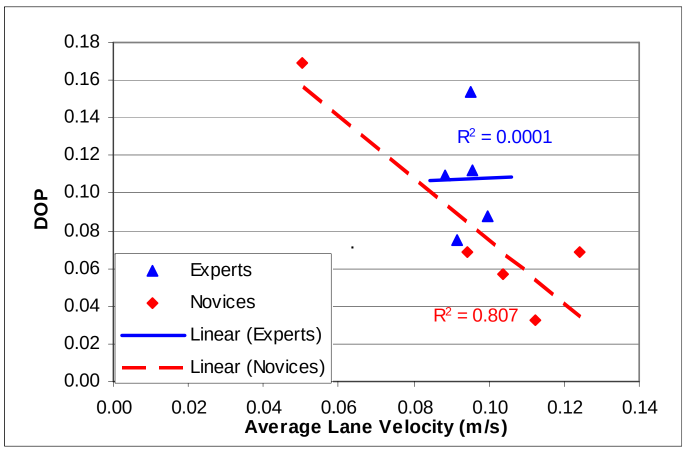


Figure 5. Experts and Novices – DOP vs. Average Lane Velocity.

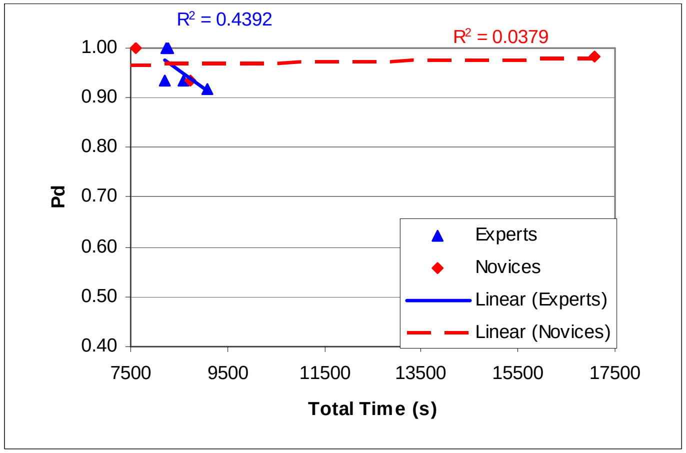


Figure 6. Experts and Novices – Pd vs. Total Time.

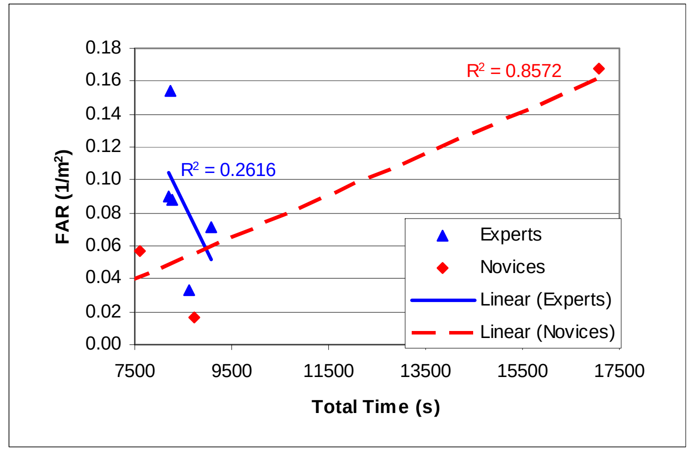


Figure 7. Experts and Novices – FAR vs. Total Time.

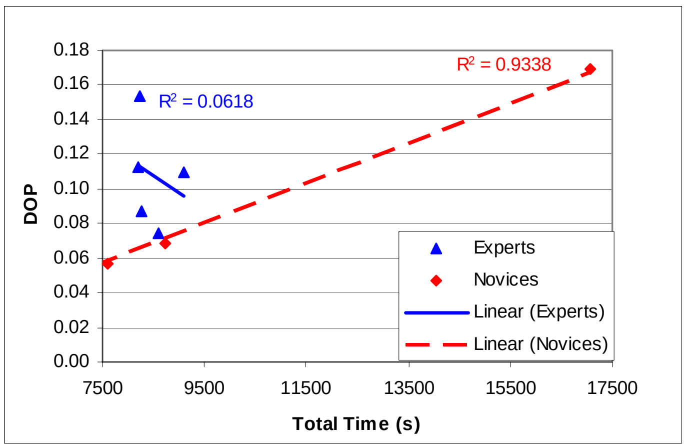


Figure 8. Experts and Novices – DOP vs. Total Time.

b. Operators with Instrumentation

1) For comparison purposes, a summary of the performance data of the experts and novices with instrumentation for all 33 lanes is presented in Table 5. Figure 9 illustrates the Pd versus FAR of experts and novices.

Table 5. Summary of Performance Data of Experts vs. Novices with Instrumentation.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	98.3%	0.048	0.051	0.089	9304
	E-2	83.3%	0.061	0.177	0.075	10602
	E-3	100.0%	0.087	0.087	0.074	10661
	E-4	61.7%	0.012	0.384	0.105	7574
	E-5	95.0%	0.096	0.109	0.069	11626
	Mean	**87.7%**	**0.061**	**0.161**	**0.082**	**9953**
	Std. Dev.	**0.1593**	**0.0333**	**0.1325**	**0.0147**	**1565.4**
Novices	N-1	98.3%	0.020	0.026	0.088	8848
	N-2	98.3%	0.013	0.021	0.110	7074
	N-3	95.0%	0.016	0.052	0.097	9097
	N-4	100.0%	0.042	0.042	0.035	23347
	N-5	100.0%	0.015	0.015	0.106	7562
	Mean	**98.3%**	**0.021**	**0.032**	**0.087**	**11186**
	Std. Dev.	**0.0204**	**0.0120**	**0.0155**	**0.0302**	**6851.3**

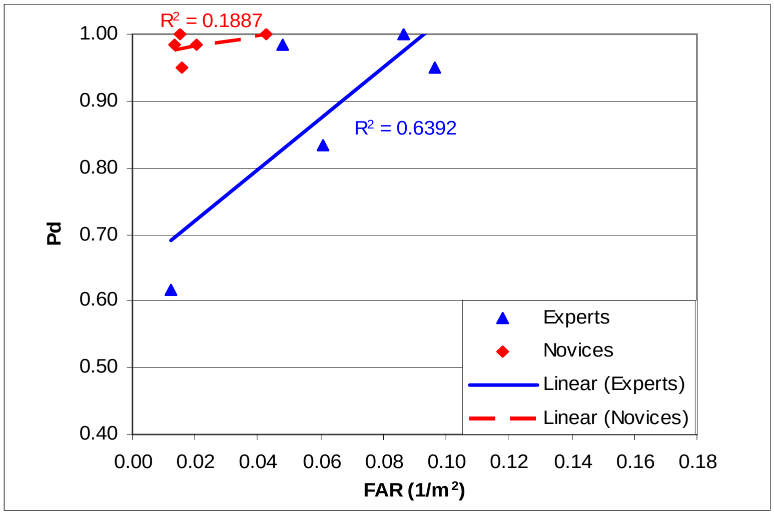


Figure 5. Pd versus FAR of Experts and Novices with Instrumentation

2) Using the Chi-Square Distribution at 0.05 significance level, the novice Pd with instrumentation was found to be significantly greater than the expert Pd with instrumentation. Using the Mann-Whitney Test at the 0.05 significance level, no significant differences were found between the number of false alarms and time, but the DOP of the novices was significantly less than the experts.

c. Quality Control Operators

Two quality control operators (W-1 and W-2) went through the 33 lane grid without instrumentation with the EM-61. They performed slightly below the overall Pd average and around the same as the FAR average. Table 6 is a summary of their performance, and Figures 10 and 11 are plots of all operators Pd and FAR.

Table 6. Summary of Quality Control Operators without Instrumentation for Lanes 1-33.

Operator	#Targets	#Hits	#Misses	Probability of detection (P_d)	# False Alarms	FA Rate, cnts/m^2	#Mult Hits
W-1	60	57	3	0.950	83	0.073	14
W-2	60	55	5	0.917	72	0.064	14

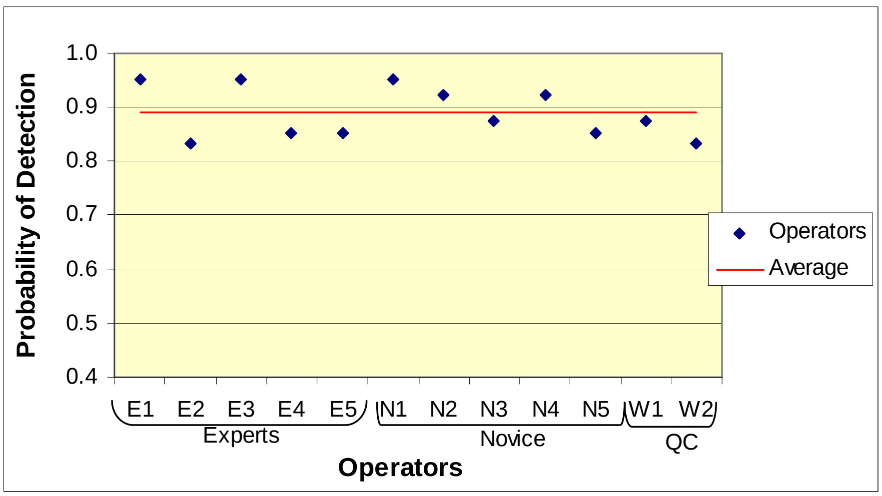


Figure 10. Probability of Detection of All Operators Without Instrumentation for Lanes 1-33.

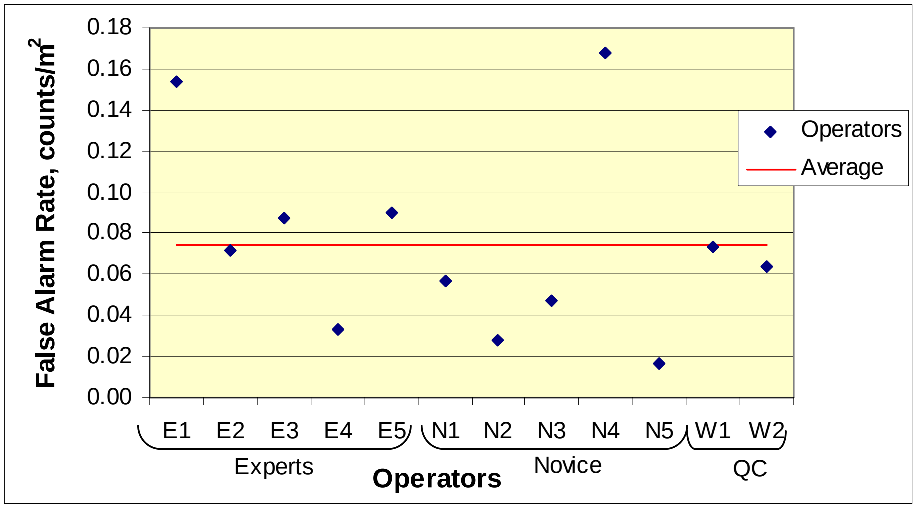


Figure 11. False Alarm Rate of All Operators Without Instrumentation for Lanes 1-33.

d. Lanes 1 – 20

Lanes 1 – 20 were situated north to south, and were 23.703 meters by 1.5 meters (35.6 m^2). There were 28 ordnance scattered throughout these twenty lanes. Tables 7 and 8 present the performance data of all the operators with and without instrumentation of only lanes 1–20.

Table 7. Summary Table of All Operators with Instrumentation for Lanes 1-20.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	100.0%	0.052	0.052	0.101	4904
	E-2	82.1%	0.082	0.196	0.068	7259
	E-3	100.0%	0.107	0.107	0.070	7030
	E-4	60.7%	0.020	0.393	0.094	5247
	E-5	92.9%	0.136	0.154	0.062	7907
	Mean	**87.1%**	**0.079**	**0.181**	**0.079**	**6469**
	Std. Dev.	**0.1648**	**0.0456**	**0.1306**	**0.0172**	**1318.1**
Novices	N-1	96.4%	0.024	0.043	0.084	5806
	N-2	96.4%	0.014	0.038	0.120	4049
	N-3	96.4%	0.018	0.040	0.087	6489
	N-4	100.0%	0.051	0.051	0.038	13696
	N-5	100.0%	0.017	0.017	0.118	4243
	Mean	**97.9%**	**0.025**	**0.038**	**0.090**	**6857**
	Std. Dev.	**0.0196**	**0.0149**	**0.0126**	**0.0331**	**3960.1**

Table 8. Summary Table of All Operators without Instrumentation for Lanes 1-20.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	100.0%	0.198	0.198	0.091	5371
	E-2	85.7%	0.093	0.170	0.095	5304
	E-3	100.0%	0.124	0.124	0.092	5634
	E-4	89.3%	0.048	0.117	0.095	5223
	E-5	96.4%	0.120	0.125	0.091	5419
	Mean	**94.3%**	**0.116**	**0.147**	**0.093**	**5390**
	Std. Dev.	**0.0649**	**0.0548**	**0.0357**	**0.0020**	**154.9**
Novices	N-1	100.0%	0.083	0.083	0.101	4916
	N-2	100.0%	0.042	0.042	0.109	4400
	N-3	96.4%	0.055	0.065	0.141	3685
	N-4	100.0%	0.167	0.167	0.060	8498
	N-5	92.9%	0.023	0.075	0.112	4475
	Mean	**97.9%**	**0.074**	**0.087**	**0.105**	**5195**
	Std. Dev.	**0.0319**	**0.0566**	**0.0477**	**0.0292**	**1898.6**
QC	W-1	92.9%	0.097	0.120		
	W-2	100.0%	0.089	0.089		
	Mean	**96.4%**	**0.093**	**0.105**		

e. Lanes 21 – 33

Lanes 21 – 33 were positioned east to west. Lanes 21 - 26 were 17.55 meters by 1.5 meters (26.325 m^2), and lanes 27 – 33 were 25.00 meters by 1.5 meters (37.5 m^2). There were 32 ordnance placed throughout these thirteen lanes. Tables 9 and 10 present the performance data of all the operators with and without instrumentation of only lanes 21-33.

Table 9. Summary Table of All Operators with Instrumentation for Lanes 21-33.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	96.9%	0.040	0.051	0.070	4400
	E-2	84.4%	0.026	0.158	0.085	3343
	E-3	100.0%	0.052	0.052	0.081	3631
	E-4	62.5%	0.000	0.375	0.121	2327
	E-5	96.9%	0.029	0.042	0.079	3719
	Mean	**88.1%**	**0.029**	**0.136**	**0.087**	**3484**
	Std. Dev.	**0.1553**	**0.0195**	**0.1420**	**0.0198**	**754.1**
Novices	N-1	100.0%	0.014	0.014	0.093	3042
	N-2	100.0%	0.012	0.012	0.094	3025
	N-3	93.8%	0.012	0.064	0.112	2608
	N-4	100.0%	0.029	0.029	0.030	9651
	N-5	100.0%	0.012	0.012	0.087	3319
	Mean	**98.8%**	**0.016**	**0.026**	**0.083**	**4329**
	Std. Dev.	**0.0280**	**0.0073**	**0.0221**	**0.0310**	**2985.9**

Table 10. Summary Table of All Operators without Instrumentation for Lanes 21-33.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	DOP	Lane Velocity (m/s)	Total Time (s)
Experts	E-1	100.0%	0.078	0.078	0.101	2867
	E-2	96.9%	0.036	0.047	0.078	3782
	E-3	100.0%	0.026	0.026	0.111	2645
	E-4	96.9%	0.010	0.033	0.086	3385
	E-5	90.6%	0.040	0.102	0.103	2780
	Mean	**96.9%**	**0.038**	**0.057**	**0.096**	**3092**
	Std. Dev.	**0.0383**	**0.0255**	**0.0321**	**0.0133**	**476.9**
Novices	N-1	100.0%	0.012	0.012	0.108	2696
	N-2	96.9%	0.005	0.032	0.117	2410
	N-3	93.8%	0.033	0.071	0.098	2976
	N-4	96.9%	0.169	0.172	0.035	8575
	N-5	93.8%	0.007	0.063	0.068	4258
	Mean	**96.3%**	**0.045**	**0.070**	**0.085**	**4183**
	Std. Dev.	**0.0261**	**0.0701**	**0.0617**	**0.0338**	**2554.7**
QC	W-1	96.9%	0.033	0.046		
	W-2	84.4%	0.021	0.158		
	Mean	**90.6%**	**0.027**	**0.102**		

f. Lanes 1-20 vs. Lanes 21-33

A statistical analysis was done to compare performance data from lanes 1-20 (north-south lanes) to lanes 21-33 (east-west lanes). Pd was tested using the Chi-Square Test at 0.05 significance level, while the number of false alarms, distance measurement, and total time were tested using the Mann-Whitney Test at the 0.05 significance level. Table 11 shows the performance measurements that were significantly different between experts and novices. With instrumentation for all lanes, the novices had significantly better Pd and significantly shorter DOP. Without instrumentation for all lanes, the novices and experts performed similarly. Table 12 presents the significant difference between lanes 1-20 and lanes 21-33 data. (Total time was not addressed in these comparisons because the area covered was not the same.) For experts and novices both with and without instrumentation, there were significantly more false alarms found for lanes 1-20 than lanes 21-33. Common False Alarms (CFA) are false alarms in which four or more operators detected a FA within a .25 meter radius circle. For the operators without instrumentation (78 CFA), 86% occurred in lanes 1-20. For the operators with instrumentation (38 CFA), 89% occurred in lanes 1-20.

Table 11. Summary of Significance Testing of Experts vs. Novices.

		Pd[a]	**# FA**[b]	**DOP**[b]	**Total Time**[b]
with Inst	Lanes 1-33	SIG	--	SIG	--
	Lanes 1-20	SIG	SIG	SIG	--
	Lanes 21-33	SIG	--	SIG	--
without Inst	Lanes 1-33	--	--	--	--
	Lanes 1-20	--	--	SIG	--
	Lanes 21-33	--	--	--	--

[a]Chi-Square Distribution, one-sided test, at 0.05 significance level
[b]Mann-Whitney Test, one-sided test, at 0.05 significance level

Table 12. Summary of Significance Testing of Data from Lanes 1-20 vs. Lanes 21-33.

		Pd[a]	**# FA**[b]	**DOP**[b]
with Inst	Experts	--	SIG	--
	Novices	--	SIG	--
without Inst	Experts	--	SIG	SIG
	Novices	--	SIG	--

[a]Chi-Square Distribution, one-sided test, at 0.05 significance level
[b]Mann-Whitney Test, one-sided test, at 0.05 significance level

g. Operator data with Instrumentation versus without Instrumentation

A statistical analysis was done to compare performance data with instrumentation and without instrumentation. Pd was tested using the Chi-Square Distribution at 0.05 significance level, while the number of false alarms, distance measurement, and total time were tested using the Mann-Whitney Test at the 0.05 significance level. Table 13 shows the performance measurements that were significantly different between the operators with and without instrumentation. For all lanes, the experts had significantly higher Pd without instrumentation, and the novices had significantly greater number of false alarms and greater DOP without instrumentation. Figures 12-15 graphically depict the difference between the operators with vs. without instrumentation for probability of detection, false alarm rate, distance from optimal point, and time, respectively.

Table 13. Summary of Significance Testing of Operators with Instrumentation and without Instrumentation.

		Pd[a]	# FA[b]	DOP[b]	Total Time[b]
Lanes 1-33	Experts	SIG	--	--	--
	Novices	--	SIG	SIG	--
Lanes 1-20	Experts	SIG	--	--	--
	Novices	--	SIG	SIG	--
Lanes 21-33	Experts	SIG	--	--	--
	Novices	--	--	--	--

[a]Chi-Square Distribution, one-sided test, at 0.05 significance level
[b]Mann-Whitney Test, one-sided test, at 0.05 significance level

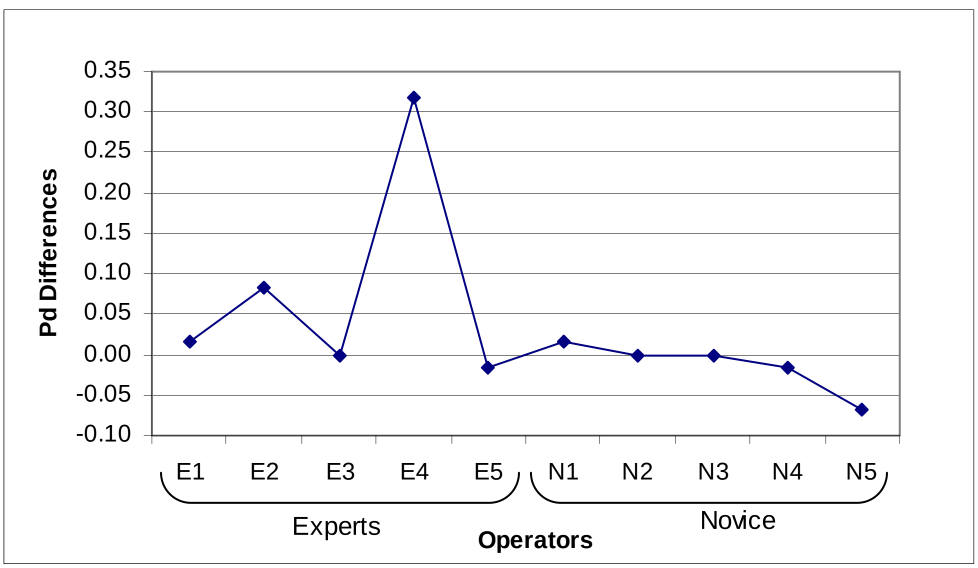


Figure 12. Difference in Probability of Detection between Operators without Instrumentation and with Instrumentation.

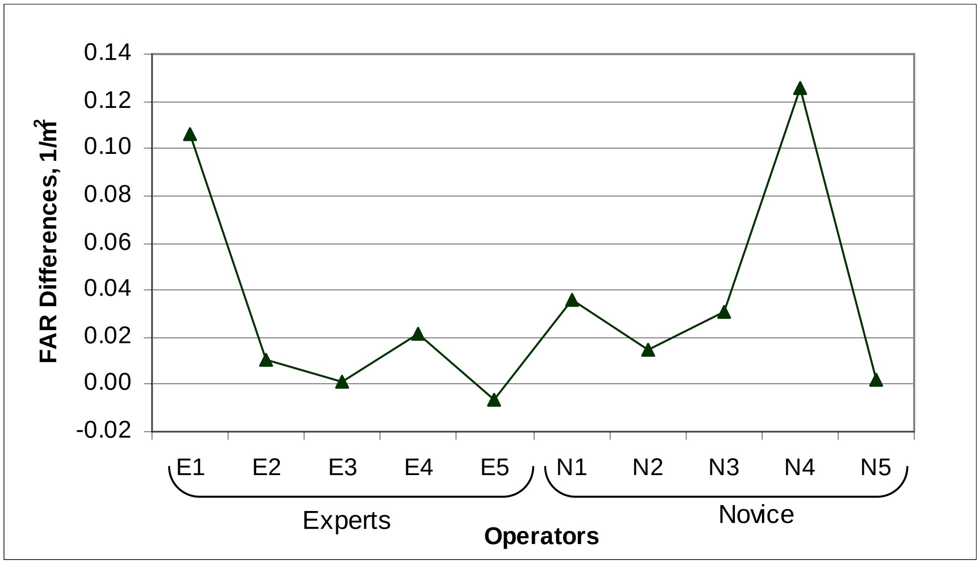


Figure 13. Difference in False Alarm Rate between Operators without Instrumentation and with Instrumentation.

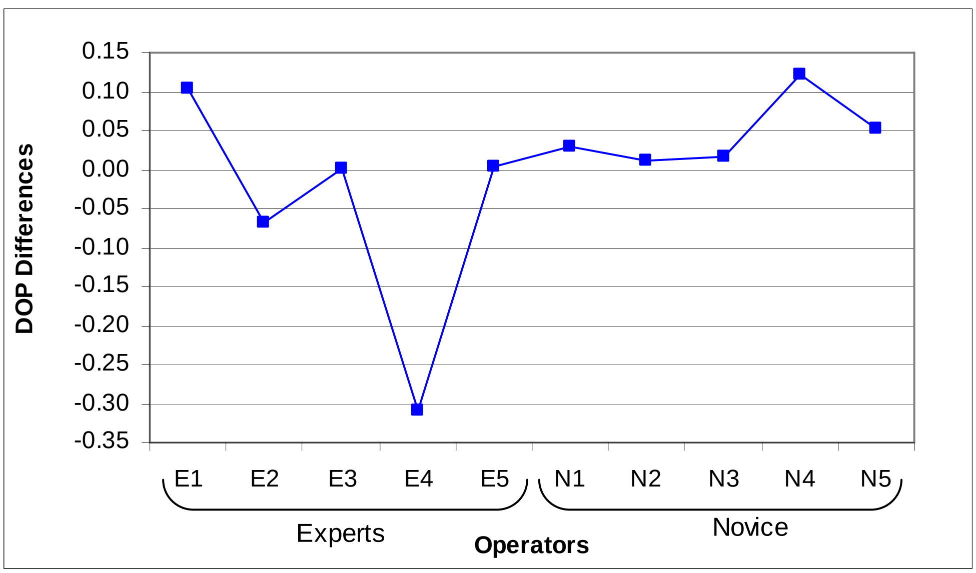


Figure 14. Difference in Distance from Optimal Point between Operators without Instrumentation and with Instrumentation.

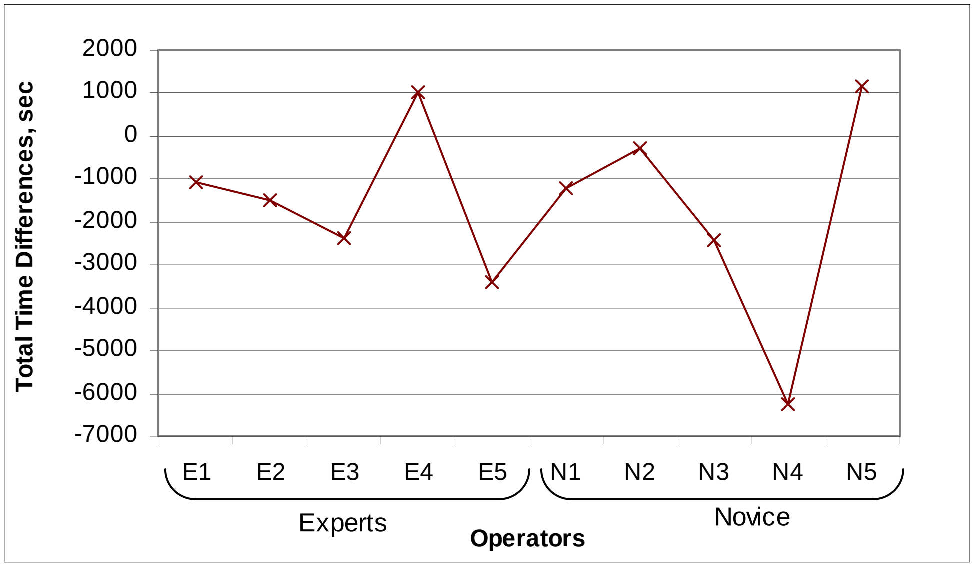


Figure 15. Difference in Total Time between Operators without Instrumentation and with Instrumentation.

h. Rookie Data

Two rookies with no UXO experience or training were asked to traverse the first seven lanes with the Schonstadt. Table 14 presents the results of rookies along with the other ten operators without instrumentation and two quality control operators. One rookie, R-2, had as good a Pd as the expert average (.917). The other rookie, R-1, had a poor performance, with the lowest Pd of all the operators and high FAR. Figure 16 is Pd versus FAR plot of all fourteen operators without instrumentation for only lanes 1-7.

Table 14. Summary Table of Test Operators, Quality Control Operators, and Rookies without Instrumentation Lanes 1-7.

Operator	Rating	#Targets	#Hits	#Misses	Probability of detection (P_d)	# False Alarms	FA Rate, cnts/m^2	#Mult Hits
E-1	Expert	12	12	0	1.000	31	0.125	3
E-2	"	12	10	2	0.833	18	0.072	1
E-3	"	12	12	0	1.000	18	0.072	1
E-4	"	12	10	2	0.833	8	0.032	1
E-5	"	12	11	1	0.917	19	0.076	2
		MEAN	**11.0**	**1.0**	**0.917**	**18.8**	**0.076**	**1.6**
N-1	Novice	12	12	0	1.000	22	0.088	3
N-2	"	12	12	0	1.000	8	0.032	1
N-3	"	12	11	1	0.917	7	0.028	3
N-4	"	12	12	0	1.000	27	0.108	1
N-5	"	12	11	1	0.917	4	0.016	1
		MEAN	**11.6**	**0.4**	**0.967**	**13.6**	**0.055**	**1.8**
W-1	QC	12	11	1	0.917	21	0.084	4
W-1	"	12	12	0	1.000	25	0.100	7
		MEAN	**11.5**	**0.5**	**0.958**	**23.0**	**0.092**	**5.5**
R-1	Rookie	12	8	4	0.667	25	0.100	0
R-2	"	12	11	1	0.917	46	0.185	46
		MEAN	**9.5**	**2.5**	**0.792**	**35.5**	**0.143**	**23.0**

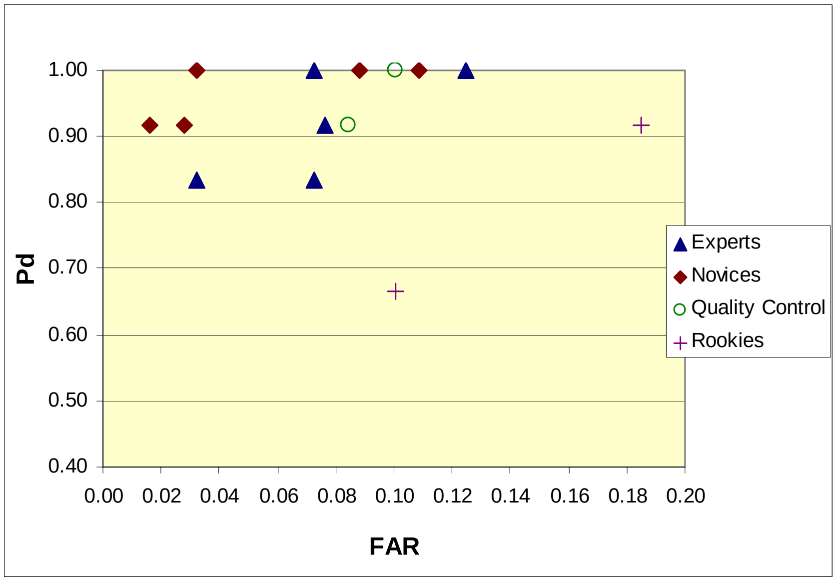


Figure 16. All Operators without Instrumentation for Lanes 1-7.

i. Demographic Data

1) Table 15 presents the demographic information about the ten operators. For analysis, the age, education, and years of UXO experience were broken into three groups. Table 16 displays these groups and the operators that fall into each group.

Table 15. Summary Table of Operator Demographics

	Operator	Age	Gender	Years of Education	Months of EOD Experience	Months of UXO Experience	Months of Schonstadt Experience	Prior Military Experience
Experts	E-1	34	Male	12	120	48	48	Yes
	E-2	37	Male	12	156	72	72	Yes
	E-3	28	Male	13	102	96	84	Yes
	E-4	43	Male	12	252	42	42	Yes
	E-5	25	Female	14	78	12	12	Yes
Novices	N-1	31	Male	16	0	0	0.25	No
	N-2	53	Male	16	0	0	0	No
	N-3	22	Male	12	0	0	0	No
	N-4	40	Male	12	0	0	0	Yes
	N-5	24	Male	16	0	1.5	1.5	No

Table 16. Breakdown of Expert and Novice Demographic Data.

	Experts					Novices				
	A	G	H	I	J	B	C	D	E	F
Age										
≤ 29 years old			X		X			X		X
30-39	X	X				X				
≥ 40 years old				X			X		X	
Education										
high school	X	X		X				X	X	
some college/assoc. degree			X		X					
bachelor degree						X	X			X
UXO Experience										
≤ 6 months						X	X	X	X	X
6 - 24 months					X					
24 - 60 months	X			X						
≥ 60 months		X	X							

2) Some interesting points to notice from the above tables are that all the experts had prior military experience compared to only one novice. Also, only three people had college degrees, and they were all novices.

3) Using the above tables, the operators' performance measurements, Pd and FAR, with and without instrumentation were plotted against age and education. Figures 17-20 display the average Pd and FAR of all operators over age and education.

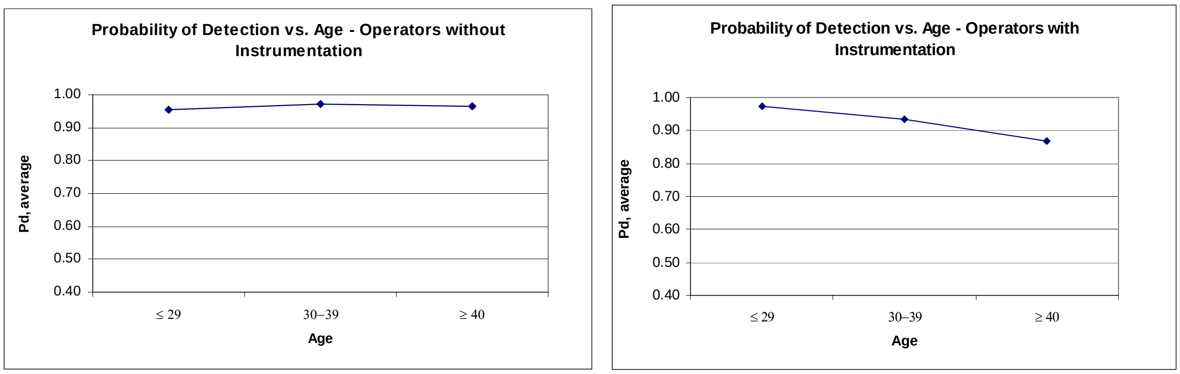


Figure 17. Average Probability of Detection over Age for All Operators.

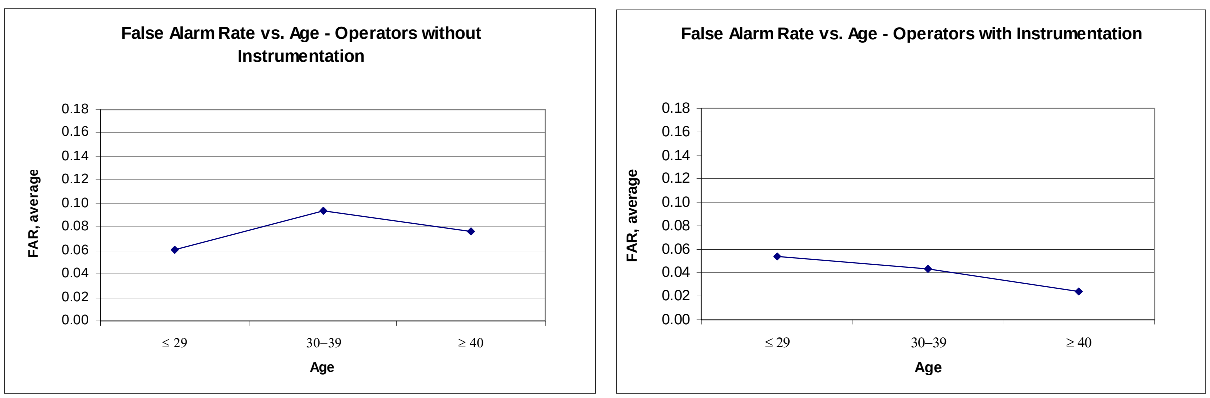
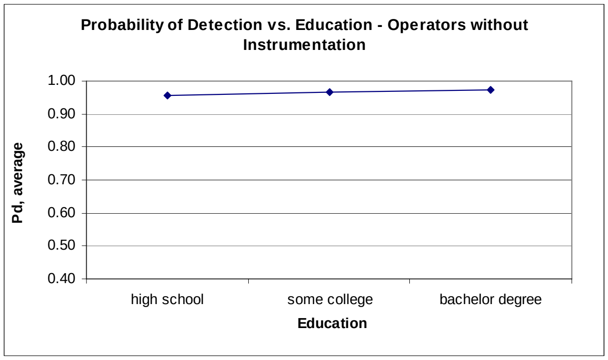


Figure 18. Average False Alarm Rate over Age for All Operators.



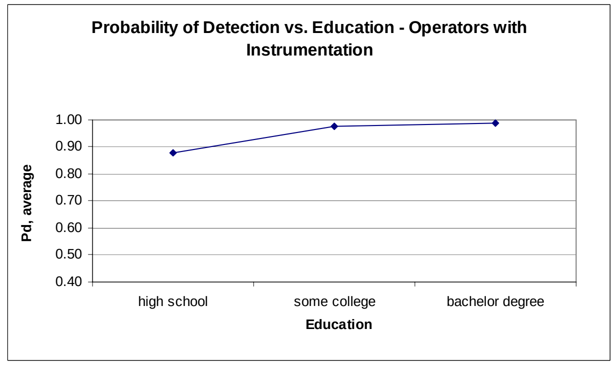
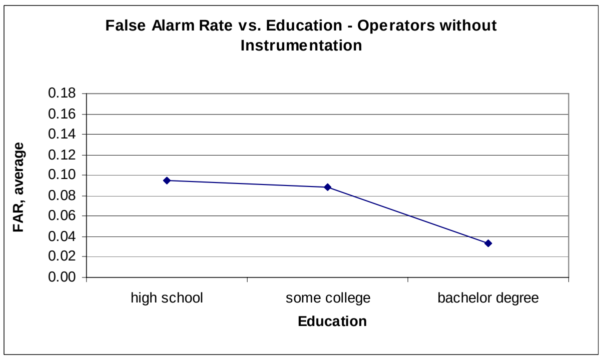


Figure 19. Average Probability of Detection over Education for All Operators.



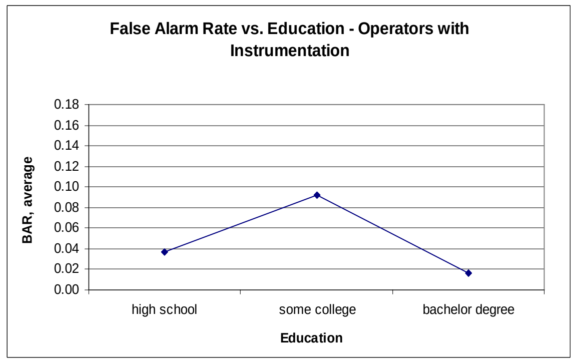
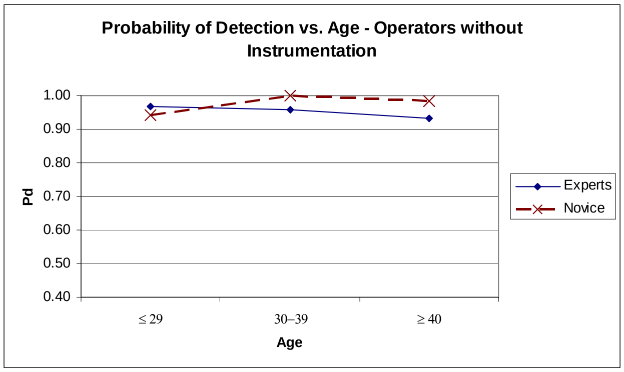


Figure 20. Average False Alarm Rate over Education for All Operators.

4) Figures 21-24 present the average Pd and FAR of experts versus novices over age and education. Figures 21 and 22 indicate there is a significant interaction effect of age between experts and novices.



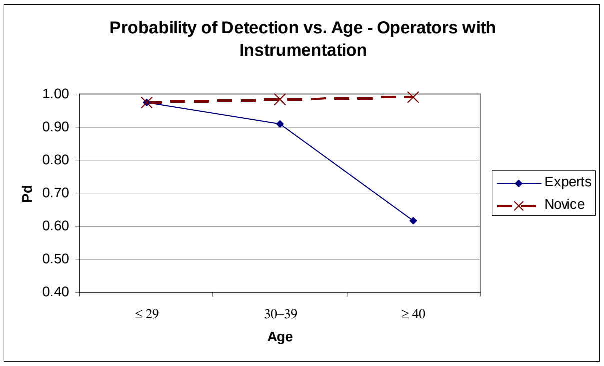
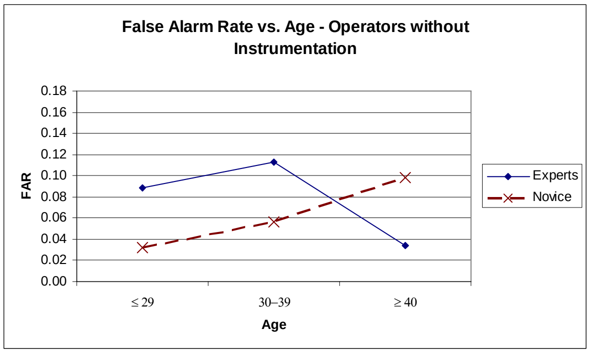


Figure 21. Probability of Detection over Age for Experts vs. Novices.



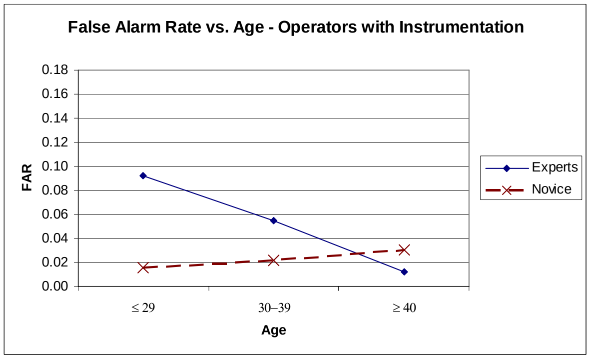


Figure 22. False Alarm Rate over Age for Experts vs. Novices.

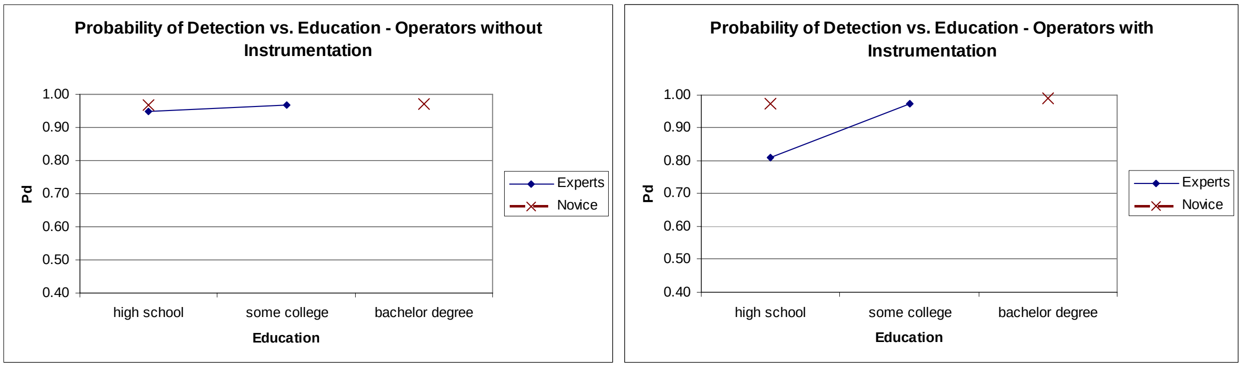


Figure 23. Probability of Detection over Education for Experts vs. Novices.

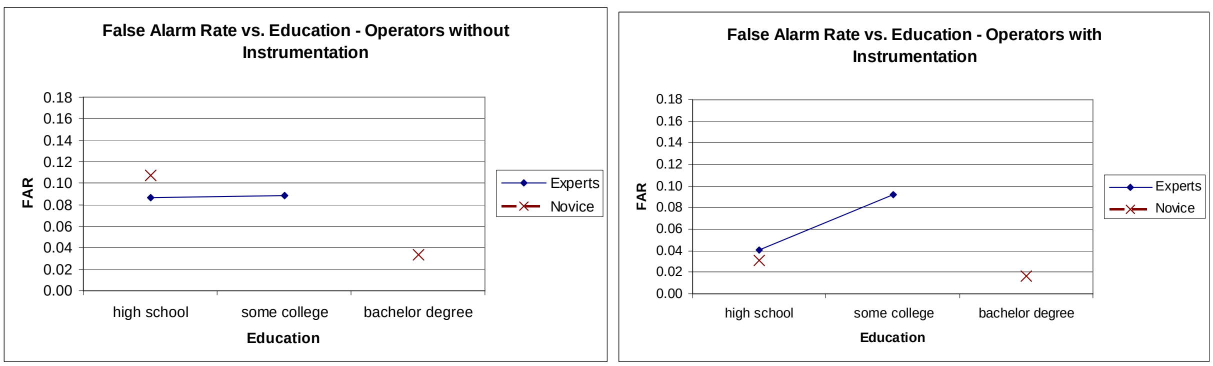


Figure 24. False Alarm Rate over Education for Experts vs. Novices.

5. This memorandum is referenced as 06-ADA-026. The point of contact for this memorandum is Selena Bednarz, 3-4528.

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Appendix A

1. Additional Group Breakdowns

a. Group 1 (High Performers) versus Group 2 (Low Performers)

Since comparing Experts and Novices resulted in most of the novices performing better, the consideration of rearranging the groups to find the high and low performers and then discovering what performance characteristics make them stand out as "better" than the rest was evolved. Using both the operators instrumented and uninstrumented performance data (Pd and FAR), each operator was ranked in order of best to worse performance with and without instrumentation. Then those two ranks were averaged, and a final ranking was made. The top five operators are called Group 1 and the bottom five operators are called Group 2. Group 1 consists of one expert and four novices, and Group 2 consists of four experts and one novice. Table A-1 presents a summary of the performance data of the two groups without instrumentation.

Table A-1. Summary of Performance Data of Group 1 and Group 2 without Instrumentation.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance	Lane Velocity (m/s)
Group 1	E-1	100.0%	0.154	0.154	0.095
	N-1	100.0%	0.057	0.057	0.104
	N-2	98.3%	0.028	0.033	0.112
	N-4	98.3%	0.168	0.169	0.050
	N-5	93.3%	0.017	0.069	0.094
	Mean	**98.0%**	**0.085**	**0.096**	**0.091**
	Std. Dev.	**0.0274**	**0.0712**	**0.0611**	**0.0240**
Group 2	E-2	91.7%	0.072	0.110	0.088
	E-3	100.0%	0.087	0.087	0.100
	E-4	93.3%	0.034	0.075	0.092
	E-5	93.3%	0.090	0.112	0.096
	N-3	95.0%	0.047	0.069	0.124
	Mean	**94.7%**	**0.066**	**0.091**	**0.100**
	Std. Dev.	**0.0321**	**0.0250**	**0.0199**	**0.0142**

Breaking the operators into the high performer group and low performer group resulted in a larger the gap in the mean Pd measurement than the expert/novice breakdown. However, Group 1 has higher FAR and ROC Distance. This occurred because the breakdown of groups was not solely based on this data, but a combination of this data and the data with instrumentation. Using the Chi-Square Distribution at 0.05 significance level, the Pd of Group 1 was found to be significantly greater than the Pd of Group 2. Figure A-1 illustrates the Pd versus FAR of Group 1 and Group 2. Using the Mann-Whitney Test at 0.05 significance level, no significant differences were found between the number of false alarms and distance measurement of Group 1 and Group 2.

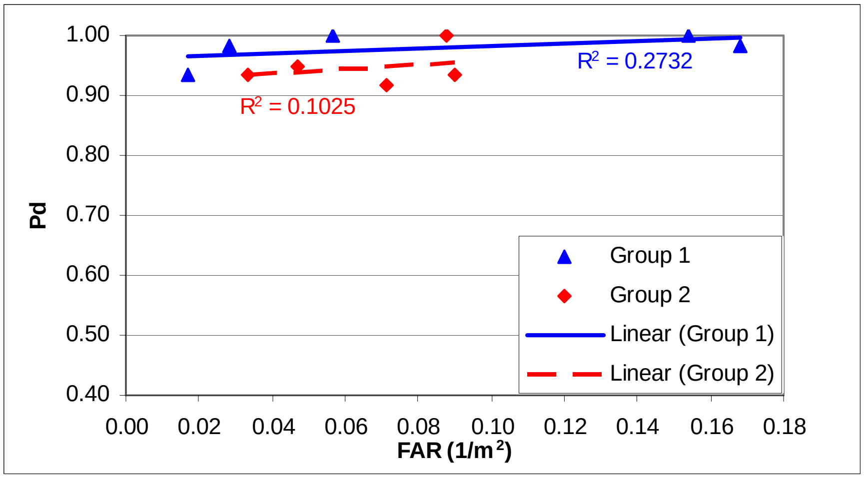

Figure A-1. Pd versus FAR of Group 1 and Group 2 without Instrumentation.

Table A-2 presents the ordnance Pd of Group 1 (High Performers) vs. Group 2 (Low Performers). Group 1 had 100% Pd both horizontally and vertically with three different types of ordnance: 40mm, 105mm, and 155mm. They also did equal to or better than the Group 2 in every category except the 60mm vertical. Overall, Group 1 averaged 3.1% higher Pd's than the Group 2.

Table A-2. Group 1 (High Performers). vs. Group 2 (Low Performers) without Instrumentation – Pd by Ordnance Orientation and Type.

	Type	Group 1	Group 2	Total	Pd Difference
Horizontal	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	96.0%	92.0%	94.0%	4.0%
	81mm	86.7%	73.3%	80.0%	13.3%
	105mm	100.0%	100.0%	100.0%	0.0%
	155mm	100.0%	100.0%	100.0%	0.0%
	Total	**96.2%**	**92.3%**	**94.2%**	
Vertical	40mm	100.0%	100.0%	100.0%	0.0%
	60mm	97.1%	100.0%	98.6%	-2.9%
	81mm	97.1%	88.6%	92.9%	8.6%
	105mm	100.0%	95.0%	97.5%	5.0%
	155mm	100.0%	97.1%	98.6%	2.9%
	Total	**99.4%**	**96.5%**	**97.9%**	
Overall Total		**98.0%**	**94.7%**	**96.3%**	

Figures A-2 – A-4 show the comparison of lane velocity to the three performance measurements, Pd, FAR, and Dist ROC, respectively. No trends are evident through these figures.

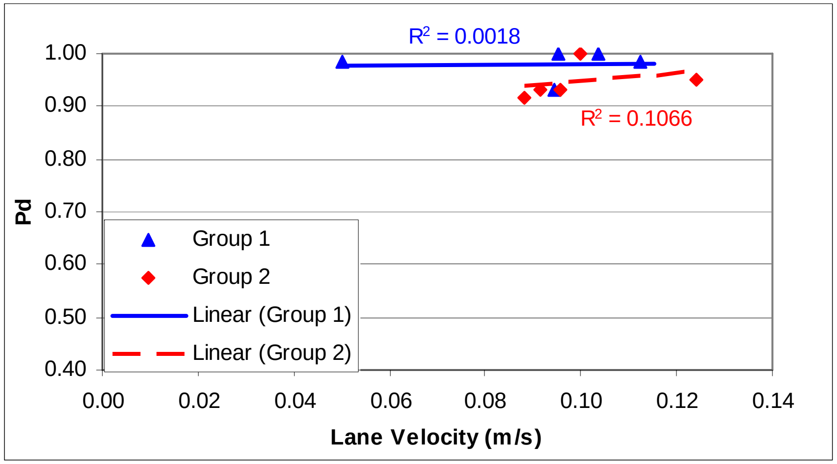

Figure A-2. Group 1 and Group 2 – Pd vs. Lane Velocity.

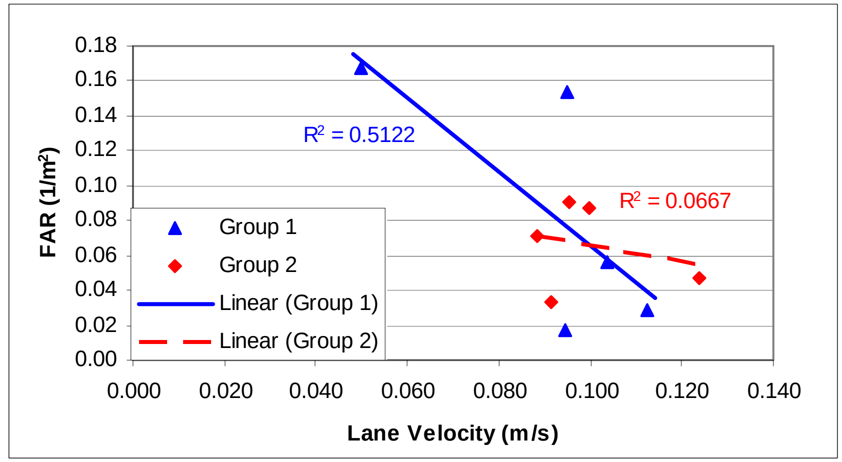

Figure A-3. Group 1 and Group 2 – FAR vs. Lane Velocity

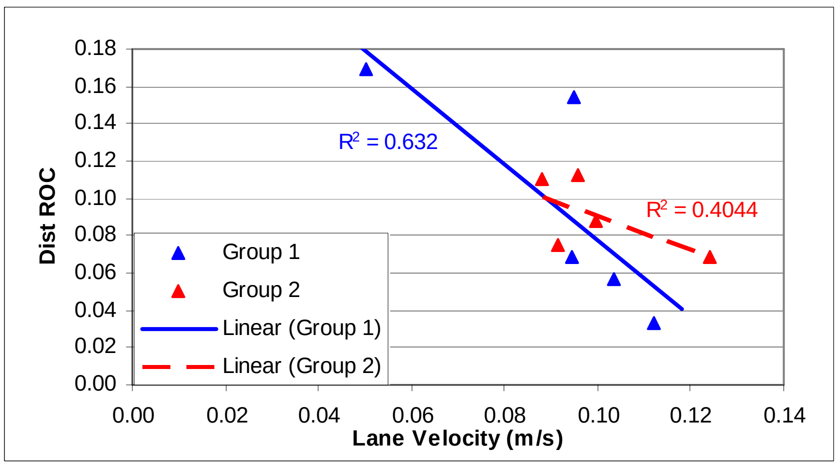

Figure A-4. Group 1 and Group 2 – Dist ROC vs. Lane Velocity.

b. Group 1 (High Performers), Group 2 (Middle Performers), and Group 3 (Low Performers)

Further exploring the idea of best and worst performers, it seemed that there was a clear distinction between the top three and bottom three performers. Three groups were then formed based on the previously discussed rank to determine what characteristics make the high performers better than the rest and the low performers worse than the rest. Group 1 consists of three novices, Group 2 contains two experts and two novices, and Group 3 has the remaining three experts. Table A-3 presents a summary of the performance data of the three groups without instrumentation.

Table A-3. Summary of Performance Data of Group 1, Group 2, and Group 3 without Instrumentation.

	Operator	Probability of Detection (Pd)	False Alarm Rate (1/m^2)	ROC Distance	Avg Lane Velocity (m/s)
Group 1	N-5	93.3%	0.017	0.069	0.094
	N-2	98.3%	0.028	0.033	0.112
	N-1	100.0%	0.057	0.057	0.104
	Mean	**97.2%**	**0.034**	**0.053**	**0.103**
	Std. Dev.	**0.028**	**0.017**	**0.015**	**0.007**
Group 2	N-4	98.3%	0.168	0.169	0.050
	E-1	100.0%	0.154	0.154	0.095
	N-3	95.0%	0.047	0.069	0.124
	E-3	100.0%	0.087	0.087	0.100
	Mean	**98.3%**	**0.114**	**0.120**	**0.092**
	Std. Dev.	**0.020**	**0.049**	**0.042**	**0.027**
Group 3	E-5	93.3%	0.090	0.112	0.096
	E-2	91.7%	0.072	0.110	0.088
	E-4	93.3%	0.034	0.075	0.092
	Mean	**92.8%**	**0.065**	**0.099**	**0.092**
	Std. Dev.	**0.008**	**0.024**	**0.017**	**0.003**

Breaking the operators into three groups resulted in a larger the gap in the mean Pd and mean FAR measurement between groups 1 and 3 than the expert/novice breakdown. To statistically analyze Pd, the Chi-Square Distribution at 0.05 significance level was used. To analyze the number of false alarms and distance measurement, the Mann-Whitney Test at the 0.05 significance level was used. For both tests, only two groups can be compared at a time. Testing of Group 1 versus Group 2 indicated no significant differences were found. Testing of Group 1 versus Group 3 resulted in Group 1 having significantly higher Pd than Group 3 and also significantly shorter ROC distance. Testing of Group 2 versus Group 3 indicated Group 2 had significantly higher Pd than Group 3. Despite several significant conclusions, these results are only for informational purposes because the groups were purposely grouped by performance. Figure A-5 illustrates the Pd versus FAR of Group 1, Group 2, and Group 3.

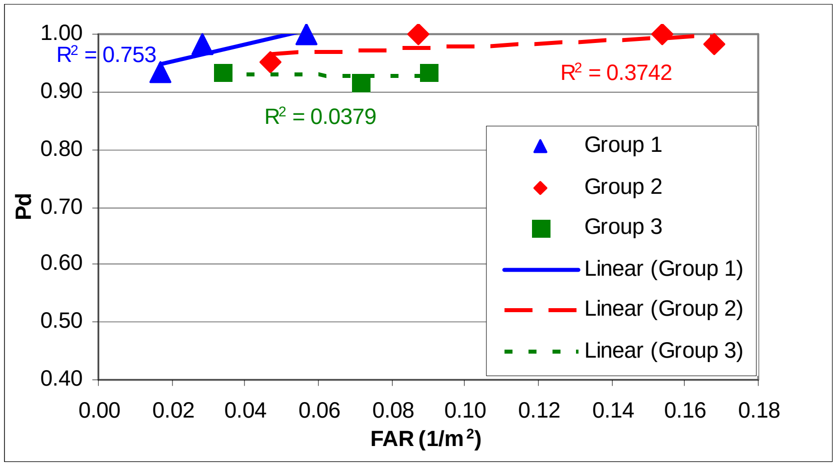

Figure A-5. ROC Plot of Group 1 (high performers), Group 2 (middle performers), and Group 3 (low performers) without Instrumentation.

Table A-4 presents the ordnance Pd of Group 1 (High Performers) vs. Group 2 (Middle Performers) vs. Group 3 (Low Performers). Groups 1 and 2 had 100% Pd both horizontally and vertically with three different types of ordnance, 40mm, 105mm, and 155mm. Group 1 had greater or equal Pd to Group 3 except for the 60mm vertical. Group 1 had trouble detecting 60mm horizontal and vertical and 81mm horizontal. Group 3 had particular difficulty with 81mm horizontal. Overall, Group 1 averaged 4.5% higher Pd's than the Group 3.

Table A-4. Group 1 (High Performers). vs. Group 2 (Middle Performers) vs. Group 3 (Low Performers) without Instrumentation – Pd by Ordnance Type and Orientation.

	Type	Group 1	Group 2	Group 3	Total	Pd Difference - Group 1 vs. Group 3
Horizontal	40mm	100.0%	100.0%	100.0%	100.0%	0.0%
	60mm	93.3%	95.0%	93.3%	94.0%	0.0%
	81mm	83.3%	91.7%	61.1%	80.0%	22.2%
	105mm	100.0%	100.0%	100.0%	100.0%	0.0%
	155mm	100.0%	100.0%	100.0%	100.0%	0.0%
	Total	**94.9%**	**97.1%**	**89.7%**	**94.2%**	
Vertical	40mm	100.0%	100.0%	100.0%	100.0%	0.0%
	60mm	95.2%	100.0%	100.0%	98.6%	-4.8%
	81mm	100.0%	92.9%	85.7%	92.9%	14.3%
	105mm	100.0%	100.0%	91.7%	97.5%	8.3%
	155mm	100.0%	100.0%	95.2%	98.6%	4.8%
	Total	**99.0%**	**99.3%**	**95.1%**	**97.9%**	
Overall Total		**97.2%**	**98.3%**	**92.8%**	**96.3%**	

Figures A-5 – A-7 show the comparison of lane velocity to the three performance measurements, Pd, FAR, and Dist ROC, respectively. The trend that stands out the most from these plots is in Figure 13, both Group 1 and Group 2 have lower Dist ROC as their Lane Velocities increase.

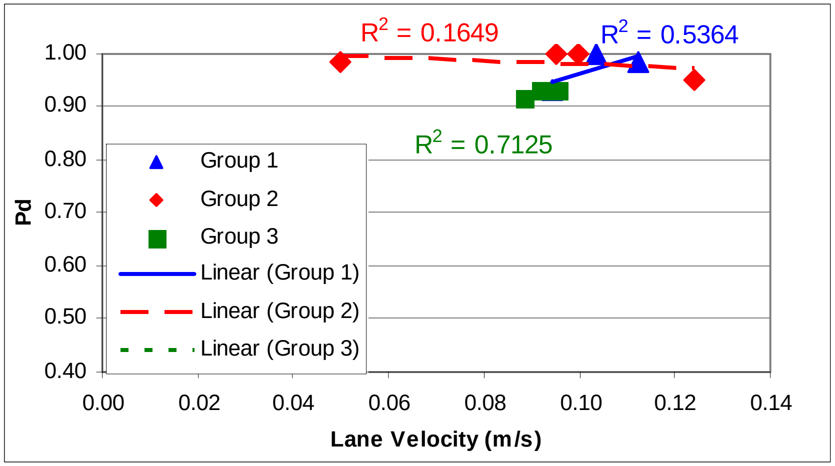

Figure A-5. Group 1, Group 2, and Group 3 – Pd vs. Lane Velocity.

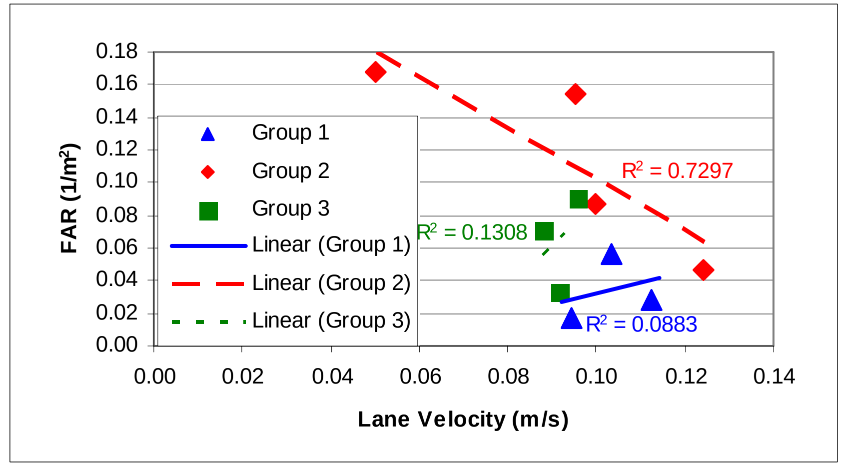

Figure A-6. Group 1, Group 2, and Group 3 – FAR vs. Lane Velocity

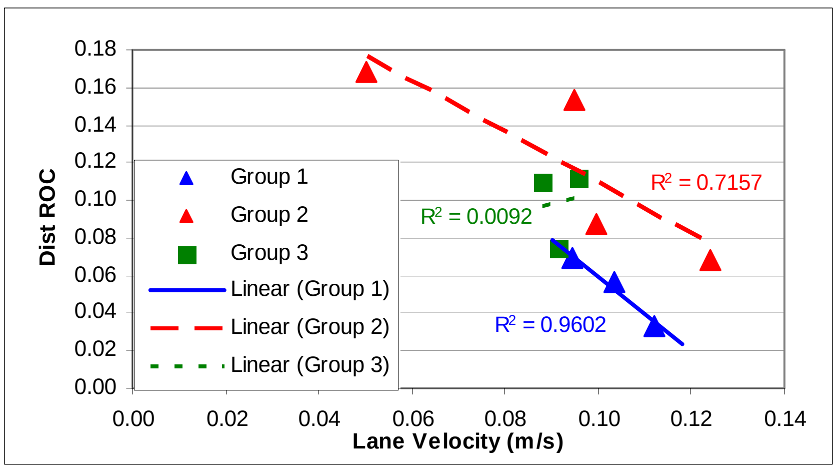

Figure A-7. Group 1, Group 2, and Group 3 – Dist ROC vs. Lane Velocity.

2. Ordnance Type, Depth, and Orientation

The greatest Pd differences between the groups occurred for the 81mm horizontal and vertical and 105mm vertical. The worse groups had trouble with this ordnance, while the better groups excelled. Table A-5 provides the difference between the Pd of the best and worst group for the three classifications.

Table A-5. Greatest Pd Differences per Group Breakdowns.

Group Breakdown	81mm Horizontal	81mm Vertical	105mm Vertical
Novices vs. Experts	6.7%	2.9%	5.0%
Group 1 vs. Group 2	13.3%	8.6%	5.0%
Group 1 vs. Group 3	22.2%	14.3%	8.3%

APPENDIX P. TRACKING SYSTEM

TRACKING SYSTEM

Objective

The objective of this phase of testing was to select and utilize a tracking system capable of recording human motion during the UXO survey, as well as use geophysical data acquired on the site prior to testing as input to a tracking system. This data input enabled the system to display site boundaries and test item locations.

Requirements

A system capable of tracking human motion during a UXO survey was required for this test. The system must allow for evaluators to review data from each test participant on a lane-specific basis. Additionally, a real-time playback of participant's motion was required. A target coverage or ground truth Geographic Information System (GIS) map with site boundary points was also required for use as input to this tracking system.

Test Procedures

a. Identify human tracking system capable of meeting test requirements:

   1) Complete Commercial technology study.

   2) Communicate with Subject Matter Experts within current government mission areas.

   3) Define and refine test requirements based on a and b.

   4) Evaluate technologies based on test requirements.

   5) Select best system that meets criteria.

b. Obtain system.

   1) Evaluate current operational status.

   2) Hardware prove-out.

   3) Software prove-out.

   4) Operational prove-out.

c. Repair, modify or upgrade based on evaluations.

d. Train operators for test scenario.

e. Re-evaluate the system for pre-testing.

f. Determine if system will meet test specifications.

Data Required

The system must provide evaluators with detector sweep height and sweep rate. Additionally, it must record and verify the dynamic motion of test participant as they traverse the test grid. In general, data required must fulfill test requirements described in the Operator Influence on Sensor Technologies Detailed Test Plan.

All emplaced items and boundary points within the test bed were recorded in the form of NAD83 Northing/Easting coordinate locations.

Outcomes

System Identification

The first step in the process was to locate and identify a system that satisfied test criteria. A complete commercial market research study was initiated for a previous test effort by members of the ATC Geodetics team. Factors such as usability, maintainability, technology maturity, and adaptability to various testing scenarios were reviewed during this process. The results of this study determined that the Threat Management System (TMS) was a suitable and rugged platform for human motion tracking in an urban environment. Although, designed for minefield training scenarios, it was assumed that this system would be suitable for the purposes of this test based on clear similarities in de-mining and UXO sweep operations. The system provided a comprehensive platform that would allow most test requirements to be met.

Threat Management System Introduction

a. The TMS system consisted of a laser based motion tracking system linked directly to a telemetry data acquisition system. A PC-based Field Instrumentation Unit (FIU) translated three dimensional coordinates to a secondary PC-based system that recorded real time positioning. The two systems communicated via wireless gateway based on IEEE 802.11b interface requirements. A TMS operator monitored the telemetry link to ensure that data was flowing from the laser sensors through the communication's link. A detailed overview of this system can be found in the TMS Systems User manual in appendix L.

b. The TMS platform was originally engineered for the Program Office for Simulations, Training and Instrumentation (PEO STRI). The US Army Threat Systems Management Office (TSMO) program was the main authority upon the platform's inception during FY2001. The TMS system facilitates de-mining testing and training in either real or virtual environments. The system provides virtual mines for inclusion into exercises (TMS Systems Manual).

Obtaining the System

a. After contacting members of PEO STRI, ATC Geodetics team members found that the technology required for tracking human motion was available, however the TMS hardware and associated components were mothballed due to budget constraints. PEO STRI authorized ATC to utilize the system for testing requirements. ATC Geodetics personnel acquired the TMS hardware, trained on associated software and attempted to set-up the complete system onsite at Aberdeen Test Center.

b. The complete TMS was then tested for operational utility at ATC's Standardized UXO Site. This process entailed three main procedures; hardware configuration, software configuration, and operational prove-out. Hardware configuration was defined as obtaining all necessary components and computer interfaces required to obtain operational status. Software configuration included obtaining necessary software, troubleshooting interfaces between hardware, and verifying data reporting in required formats. Operational prove-out involved pre-testing onsite, tracking operators traverse a scale plot of land similar to those found on the Standardized UXO Test Site.

c. Geophysical referencing data was collected on-site using a Trimble GPS. The locations of all targets and boundaries were recorded and mapped. Target properties known to influence detection (type, ferrous/nonferrous, depth, and orientation) were annotated for each. The compiled data was used as input to the TMS, prior to test commencement, in the form of the test bed map. The data input allowed the TMS to provide an accurate and visual readout of operator location with respect to the test items. Input of the site boundary points made available clear delineation of the test bed borders. Geodetics personnel documented the data, on-site, when emplacement was completed.

System prove-out

a. The TMS platform provided a fundamental design that contained high potential to satisfy test requirements. The TMS project effort had been stopped one year prior to ATC contacting PEO - SRI to inquire on utilizing the system for the Operator Influence on UXO Sensor testing. Thus, the hardware was in a warehouse-containerized state when ATC personnel received the complete unit. After piecing the system together and performing system checks, a preliminary prove-out test was completed.

b. On the basis of mobility, the TMS system was placed in an ATC data van and powered from an external power source. If a regulated hard line electrical source was available, the system was powered by a standard shore power 120V AC connection. When deployed in field conditions, the system was powered by a model 806A 60kW Tactically Quiet Generator. The generator was fueled with DF2 diesel fuel. Daily Inspections were made to the power generation system, to include connections and wiring to the data van.

c. The Hardware Configuration process yielded many noticeable issues with the TMS. Of the two operator stations both experienced intermittent operational status during the course of prove out. It was determined that this was caused by fluctuations from the 60kW TCQ set coupled with low battery back-up systems. Additionally, loose wiring and connections were observed throughout the setup during short movements of the data van. Ancillary cards contained onboard both operator stations (PC motherboards) were damaged and required replacement. These consisted of video and network communications cards.

d. The TMS utilized four rotating laser light energy sources that were positioned on the perimeter of the test grid. The radial effectiveness of each transmitter was found to be approximately 250 degrees with a maximum linear range of 130 meters. Ranges were observed to be highly dependent on environmental conditions such as ambient light, wind-speed and temperature. The four individual laser emitters were powered by eight Lithium Ion D Cell rechargeable batteries. Operating times between charges ranged from 30 minutes to 3 hours. It was determined that because of the time that batteries were in storage prior to set-up and the tendency for Li ion batteries to deteriorate in such conditions, the majority of the batteries supplied with the TMS were deemed unusable for the test. It was observed, however, that batteries that were cycled on a regular basis provided greater time between charges.

e. The laser tracking would self-calibrate, however a notable signal drift was observed over an extended time domain. It was noted that the first two hours of continuous tracking indicated under 2 cm signal drift, however time periods of over two hours yielded exponentially higher signal drift. Accuracy low, however results location error was consistent and repeatable.

f. Laser receivers located on each participant's foot as well as the shaft of the UXO sensor provided absolute coordinates to a data acquisition system via wireless telemetry link. It was observed that the wiring and connections of the foot and shaft mounted sensors were very sensitive to shock and vibration.

g. The laser sensors were hardwired to the PC based Field Instrumentation Unit (FIU), which was a self-contained communication link and position calculation device powered by a SINGARS style rechargeable lithium ion 30V 5.5 amp-hour battery. The FIU was linked to the Operator stations, which recorded the conditioned signals from the laser sensors. The FIU was designed to be worn around the waist of the operator, allowing easy connectivity to the laser sensors and geophysical detection device.

h. It was observed that the complete FIU with battery was cumbersome and induced stressors on individuals while traversing the test plot. Alternative strategies consisted of allowing a second individual to carry the FIU with battery and towing the FIU behind the participant in a hand-cart. The first alternative proved to be difficult as the connecting wires between the laser sensors and the FIU were designed for very short lengths, thus the second individual was required to walk in close proximity to the test participant. Due to the sometimes erratic motions of the test participants, the second individual would make contact and distract the test participant. This would not provide an ideal situation required for test requirements. The second method, which involved towing the FIU behind the test participant was successful, however, required an extension of the cabling connecting the laser sensors and FIU. The cabling proved difficult to modify, as unique connectors to the FIU were used in the original design.

i. A video feed channel was available; however no camera or video feed path was installed on initial set-up. A USB thumb-style camera was plugged directly into the operator unit and video feed was found to be operational, however the feed's reliability was intermittent. Troubleshooting revealed that this was caused by either poor connection within the FIU, or insufficient bandwidth between the FIU and the Operator stations. Thus, the IEEE 802.11b interface seemed to inadequate for the video feed and position calculations to be sent simultaneously between the FIU and operator station. The video feed was unreliable in operation.

j. The operational prove-out of the system provided a rapid fielding situation that was intended to allow data collected during prove-out to be utilized in addition to data collected during full scale test work. The system tracked human movement 32% of the time that was required. Additionally, signal dropout various hardware failures and system power requirements were concerns that required attention.

Upgrading the TMS

a. The integrated test team determined that upgrades to the existing TMS would be required in order to meet test schedule requirements based on the results of the operational prove-out.

b. Members contacted the developer of the TMS; Scientific Research Corporation, Inc. The results of the TMS system prove-out were relayed to the developers at SRC. Discussion was initiated concerning possible improvements to the existing TMS for use under the Operator Influence Test plan. SRC provided an overview of options that would allow for improvement of the existing system. The requirements from the prove-out and SRC's recommendations can be found in appendix M. A Firm fixed cost contract was initiated with SRC and funded with project funds.

c. The complete system, consisting of all hardware and software, was delivered to SRC via data van from ATC. At this time, developers were able to first-hand troubleshoot, diagnose, repair and modify as necessary using a systems engineering strategy.

d. The two operator stations within the data van were removed, inspected and made functional by replacing hardware components within the computers. Loose cables were identified and replacement components were replaced or procured. The 802.11b wireless card was upgraded to an 802.11g protocol. This was tested and increased reliability, but also communication speed to accommodate a new USB camera.

e. The individual FIU's were observed to be creating large amounts of heat from the CPU contained in the airtight container. Temperatures were estimated to be above 45 degrees centigrade. There was concern that the high temperatures might damage the FIU circuitry within the airtight container. A heat sink was designed and fabricated to attach directly to the large surface area of the FIU. Additionally, two small fans were placed on opposing sides of the FIU container to allow for cooling of internal components.

f. The ArcSecond laser transmitters were functional, however the batteries that provided power were observed to have low endurance limits. New batteries and complete battery trays were ordered.

g. These improvements were made onsite at the SRC facilities in Huntsville, AL.

h. The system was then packaged for shipment and sent to Aberdeen Test Center. The complete system was setup at the Standardized UXO test site to simulate testing conditions. Members of the SRC test staff were on-hand to complete on-site diagnosis and repairs of any travel-related complications found.

i. At this time, it was determined that the network interface (NIC) cards on each operator station were damaged and inoperable as well as the battery back-up system. Both were replaced onsite by SRC technicians.

j. Upon completion of set-up at ATC, the system was fully functional with improved reliability, endurance and range.

k. The data collected as a result of the geophysical survey was downloaded using computer-assisted design (CAD) and GIS software platforms. The UTM coordinates were maintained by the ATC test director and ATC geodetics staff.

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APPENDIX R. ABBREVIATIONS

A&M	=	Agricultural and Mechanical
ACE	=	U.S. Army Corps of Engineers
ADST	=	Aberdeen Data Services Team
APG	=	Aberdeen Proving Ground
ARL	=	U.S. Army Research Laboratory
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test and Support Services
BAR	=	background alarm rate
BAR^{res}	=	response stage background alarm rate
CAD	=	computer-assisted design
CFA	=	common false alarms
CTC	=	Concurrent Technologies Corporation
DOD	=	Department of Defense
DTC	=	U.S. Army Developmental Test Command
DTP	=	Detailed Test Plan
EEE	=	explosives and explosive effects
EOD	=	Explosive Ordnance Disposal
EPA	=	Environmental Protection Agency
EQT	=	Environmental Quality Technology
FA	=	false alarm
FAR	=	false alarm rate
fp^{res}	=	response stage false positive
GIS	=	Geographic Information System
GPS	=	Global Positioning System
IUTP	=	International Unexploded Ordnance Training Program
LED	=	light emitting diode
Log.Sec	=	Logistics Engineering and Information Technology Company
METDC	=	Military Environmental Technology Demonstration Center
P_d	=	probability of detection
P_{fa}	=	probability of false alarm rates
P_{fp}^{res}	=	response stage probability of false positive
P_d^{res}	=	response stage probability of detection
PTA	=	pure tonal average
R&D	=	research and development
RTK	=	real-time kinematic
TAMUS	=	Texas Agricultural and Mechanical University System
TEEX	=	Texas Engineering Extension Service
TMS	=	Threat Management System
USAEC	=	U.S. Army Environmental Command
UTM	=	Universal Transverse Mercator
UXO	=	unexploded ordnance

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