20 December 99

MINE DETECTION EQUIPMENT FOR DEMINING (HAND-HELD OR VEHICLE MOUNTED)

1. SCOPE.

1.1 Objectives and Purpose.

1.1.1 The principal objective of this document is to aid in defining the acceptability of mine detection systems (hand-held human platforms) or ground vehicle-mounted (vehicle platforms) and to determine if the systems:

a. Can effectively detect surface laid or buried individual mines minefields, or unmanned target activated weapons (UTAW) arrays;

b. Are affected by minefield background, time of day, weather, or other common battlefield conditions;

c. And are better than existing fielded systems or improve team concepts involving multiple items.

1.1.2 Secondary objectives and benefits of this document are as follows:

a. It provides the basis for comparing present techniques and instrumentation and also for improving and optimizing existing technologies (in terms of sensor efficiency and effectiveness, reduction of false alarm rate, time required for operations, …). However, this document is seen as a crucial aspect also for the development of new technologies and it is recognized that this document will positively contribute to increase the credibility when a new prototype is introduced on the market.

b. This document can be used to help users to find the key technique or the key combination of techniques most adapted to given mine detection and identification operations whether the operations are applied to demining, or unexploded ordnance (UXO) remediation.

1.1.3 In general, this procedure provides the structure necessary to determine whether an item is suitable for standard use (ready for production) and does not dictate how an item is to proceed through early developmental testing. General guidance for testing non-performance aspects such as environments during operation, transport and storage is covered within this document primarily by reference to document "General test requirements for demining testing", and its references.

1.2 References.

Refer to documents "Target Standardization for Demining Testing", and "General test requirements for demining testing""General Test Requirements for Demining testing". The former is a critical test control element that influences the validity of all demining testing. The latter provides a general, convenient framework to examine all categories of demining equipment and other potential test data topics governing different design considerations. It also provides a convenient matrix of test procedure references that may be used for non-performance oriented testing (Human Factors, Integrated Logistics Supportability, Reliability, Transportability, et al). These two documents should be read and consulted prior to proceeding further to understand their complementary nature.

Where appropriate, material has been applied based upon investigations by other panels or groups, to ensure greater applicability of use and broader acceptance. This includes incorporation of key elements of papers prepared for the European Union Humanitarian Demining Activities by the Advanced Techniques Unit, "Workshop on Identification of Standard Methodologies in the Context of Anti-Personnel Landmines Localization and Identification"[3]; the Swiss Federal Institute of Technology, Demining Technology Center "Building a Sandbox with a Cartesian Gantry for Sensor Testing"[4]; and the U.S. Naval Postgraduate School, "Sensors for the Detection of Land-Based Munitions."[5] Additionally, other useful papers are referenced in Appendix D where methodologies or background are relevant to or influenced this document.

1.3 Terms and Conditions.

This document specifically applies to Mine Detection Equipment either hand-held or vehicle mounted. It is intended that this document be used for appraisal of mine detection equipment used for demining. While mine detection equipment may vary from probes to highly sophisticated devices featuring sensor fusion, it is intended that this document be used for appraising the adequacy of mine detection equipment featuring electronic sensors and associated processing equipment. Additionally, detection equipment may include integrated displays to ease not only detection, but also identification and electronic or physical marking. Detection equipment has to function in a diverse array of world-wide climates, terrain, soils, and vegetation. Mines that must be detected vary in shape, size, metallic content, emplacement pattern and density, burial depth, sensor/fuse type, kill mechanism, explosive type, and explosive quantity. It is within this framework of variables that the detection equipment must function and perform. Detection equipment may feature multiple active or passive sensors working singly or in combination. These sensors may be magnetic (induction), infrared, vapor, radar, neutron absorption, and/or hyperspectral. Definitions of and methods of analysis of sensor performance are provided in Appendix C.

1.4 Limitations.

The inclusion of specific test data topics in this document does not mandate that each included topic be addressed specifically through testing. It is the intent of this document to serve a logical structure, with the specific need to test determined based upon a careful review of the design; prior history of similar design components or subsystems; test strategy; and the complementary consideration of modeling and simulation. This is especially true when examining the relevance of certain test data topics to demining purposes where climatic suitability, tempo, or other factors may not be as important in determining overall utility.

2. FACILITIES AND INSTRUMENTATION.

All instrumentation used for test must be calibrated in accordance with national standards. Since many nations have unique capabilities and instrumentation for testing mine detection equipment, types of facilities and instrumentation are discussed in general form. Due to the large variety of sensor technologies currently in development and those emerging technologies, highly specialized facilities are beyond the scope of this document. Facilities for judging performance of mine detection equipment falls into three general categories: Sensor Experimentation Facility; Sensor Verification Area; and minefield test areas.

2.1 Sensor Experimentation Facility.

This type of facility is designed to provide for performance characterization under highly controlled conditions of soil, soil moisture content, light conditions, and/or temperature conditions. Soils are normally homogeneous, pristine soils (sand, clay, loam, etc). Guidance has been suggested in reference 7, Appendix D that different types of soils be used for experimentation proceeding from homogeneous to heterogeneous samples. That is,

a. Homogeneous soil samples, chemically and physically well characterized, in particular having well defined electromagnetic (EM) properties (electrical permittivity and conductivity, magnetic permeability, …);

b. Soils made of layers of types above, each layer having distinct EM properties;

c. Mixtures of soils above (paragraph 2.1.1).

d. Real soil samples; that is soils in regions or minefields of interest.

Moisture content may be controlled through various means. To effect this type of control, soils are normally contained within a deliberately constructed soil bin. Lighting may be artificially induced if covered. This type of facility is normally used to screen multiple candidates under a very narrow set of conditions. It is suggested that this be used prior to Sensor Verification Trials or system performance trials discussed in paragraph 4.2. This type of facility is of most utility when applied to multiple candidates, to characterize limits of or to benchmark performance. This type of facility may have means to move detector heads at controlled velocities, directions, tilt, and heights to evaluate the effects of these conditions independent of platform (human or vehicle) for each set of environment conditions examined. Cartesian gantries (x, y, z) may be used to provide a controlled method of maintaining these vector and scalar parameters.

Care should be taken to ensure that the sizing of and construction of this type of facility does not compromise test results. That is, certain types of sensors may be very sensitive to either facility (soil bin), size (height, width, and depth), or construction materials. Depending upon the type of sensors, edge effects may occur at the sides of the soil bin, limiting the useful scan area. Additionally, for certain types of sensors, inadequate depth may induce unwanted or spurious reflects. If devices such as Cartesian gantries are used, nonmetallic or other suitable materials should be used for the carriage, to ensure results are not compromised.

2.2 Sensor Verification Area.

As a test control, and as an aid in diagnostics, it is recommended that a special minefield test area be dedicated to calibrating, training, and/or verifying operation of the detection equipment sensors.

2.3 Minefield Test Areas.

Minefield test areas should be representative of the environmental categories and conditions that the detection equipment is intended to be used in. document "Target standardization for demining testing" provides guidelines for test target selection and emplacement within the minefield test area. Two basic approaches are suggested for selection of minefield test areas: a global classification approach and a simplified approach. In the global approach, a list of typical soils found in mine affected countries or threat countries should be developed from existing databases (such as the UNESCO database). These soils should be prioritized by independent experts in terms of probability of encounter or percentage of occurrence. The soils should then be grouped by similar physical properties using a soil classification method. Once accomplished, minefield test areas should be selected that represent the highest probability of encounter (nominal) with possible off-nominal conditions selected, if time permits. In the simplified approach, a narrow set of soils (suggested by reference 3, Appendix D) should be selected that represent the expected boundary conditions of performance for a specific sensor from worst to best. Appendix A1 shows an example of the selection process for soils. Other methods of selecting soils are presented in reference 7, Appendix D.

3. REQUIRED TEST CONDITIONS.

3.1 Test Item Configuration.

In general, the item should be tested at system level unless it can be shown that system integrity does not contribute to the specific results.

Specially instrumented subsystems may be included to provide a real-time record of detection trials. As an example, an Electronic Detection Reporting System (EDRS) can be embedded by design or installed as special test instrumentation to provide integrated reporting of detection alerts or marks as a function of geodetic position. Instrumented systems or subsystems should be used to enhance quality assurance, in-test inspections, failure analysis or diagnostics, and data acquisition, where it can be shown that results are not compromised or that results are better quantified. Care should be taken to ensure that integral instrumentation is sufficiently rugged to withstand and operate following natural and induced environments. Additionally, care should be taken to ensure that the presence of instrumentation does not interfere with the man-machine interface regardless of platform (human or vehicle) or bias human factors appraisals.

3.2 Test Planning.

The general approach to test planning is described in document "General test requirements for demining testing".[1]

3.3 Factors and Conditions for Performance Trials.

a. Trials shall be designed to collect system performance data over a variety of minefield types, backgrounds, and time-of-day conditions. To the extent possible, the trials will be controlled and executed such that the systems' performances are directly comparable to existing systems to be replaced or competing systems. Since climate cannot be fully controlled in outdoor test conditions consider how data between test samples at different sites, locations or times can be compared effectively. The trials will be conducted with conditions tabulated in Table 1.

b. A matrix of conditions should be established with a finite number of mine encounters planned considering each condition. The total number of trials will drive the duration of test. Therefore, it is incumbent upon the test planner to limit the test conditions to a period in which all conditions can be practically addressed. The test planner should ensure that for each human participant/system combination, a corresponding minimum number of repetitions of background, system type/vehicle combination, Mine Test Area, etc., occur to provide a statistically relevant set of system performance trials. See Appendix A1 and A2 for useful examples to aid in outlining trials to enable assessment of a broad range of factors and conditions; specific sensor detector types of a narrow range; or a specific performance characteristic of interest.

Table 1. Matrix of Trial Factors, Controls, and Conditions.

Factor	Control	Condition
Minefield Type	Systematic, Doctrinally Driven or Current Intelligence	Replicate threat or friendly pattern and density; burial depth; scattering method; surface preparation and emplacement techniques
Mine Type	Systematic, Doctrinally Driven or Current Intelligence See document "Target standardization for demining testing". Ensure that Sensors/Processors are appropriately challenged.	See document "Target standardization for demining testing".
Background	Systematic, Select Backgrounds that appropriately characterize range of performance	Grass; plowed; surface water; scattered trees/brush; bare ground with multiple soil conditions; battlefield detritus; and include weathering factors. Weathering factors will be determined by whether detection equipment is HD, or UXO.
Time-of-day	Systematic; Ensure diurnal cycle spans all conditions of solar radiation and thermal input	Break up the diurnal cycle into defined intervals. i.e. Daytime (1000-1800); Evening (1800-2200); Night (2200-0600); and Morning (0600-1000)
Climate and Obscurants	Ensure that test sites provide full synergy's of or range of climates. Test in those conditions required in requirements document.	Use host nations standards to characterize envelope of climatic conditions. Select test sites based upon range of conditions. Ensure that

Factor	Control	Condition
Climate and Obscurants (cont'd)	Smoke and obscurants should be included by test design at planned intervals.	human participants are dressed in standard field-issue clothing and equipment appropriate to the environment and mission. This should also include NBC equipment on a separate trials basis
Human Participants	Systematic. Ensure that route reconnaissance and area search methods of detection are addressed.	Select test participants with the correct or associated military skill codes or civilian skill descriptors. Select participants that span anthropometric extremes, genders, and other demographic considerations where feasible.
System	Systematic	Compare to existing system to be replaced or competitor(s) to provide baseline reference (i.e. better than, etc). Ensure that sufficient sample size is available to be a production representative sample or a statistically relevant population. Have sufficient spares to preclude test delays. If vehicle-mounted, ensure that platforms are selected that are configured properly and that sufficient platforms are available to address compatibility as well as test requirements.

c. Special test controls. Special test controls may be added to ensure that operators use detection equipment under operationally realistic conditions. Since it may not be practical or exceedingly costly to build numerous minefields for tests, it may be necessary to design the test so that operators do not “learn or game” the minefields while being exposed to the minefields from multiple aspects. Test controls should include: training; pilot tests or trials in the Sensor Verification Area; rotation of test teams; changes in directions, times of day (see Table 1), deliberate false sets of targets, varying “weathering in” of targets, and varied vegetation and soil conditions.

d. Training must always be the lead-in activity. Following training, a pilot test or “learning trial” should be performed to ensure familiarity with the system as well as the doctrinally correct approach to detection which may include a number of individual soldiers or test technicians working as a team, with responsibilities corresponding to those practiced doctrinally. Pilot tests will also serve to familiarize trials teams and test observers (data collectors) with the data collection and reporting procedures to be employed during system performance trials. System performance trials are those trials where data will be used towards assessing the effectiveness of integrated system detection performance, or for other evaluation purposes relative to the suitability of detection system. System performance trials should not begin until each team member has demonstrated competence. Test team rotation is intended to ensure that lower or higher performing individuals do not bias performance results where one or more individuals are required to work as a team mimicking actual demining detection teams. Deliberate false sets of targets should be introduced to include empty holes, surface disturbances, or battlefield detritus. Weathering in of targets should reflect the intent of the detection equipment. For example, demining equipment may have to perform after the targets have been weathered in place for 1 month or much greater. Vegetation may be added or minimally disturbed for those tests involving HD equipment. For HD equipment it may be necessary to continue test under actual field conditions ranges or in theater after system performance trials to verify ability to function where extensive weathering or re-vegetation has occurred or to examine the effects of controlled burns if vegetation has been removed through burns.

4. TEST PROCEDURES.

Test procedures in Section 4 should result in all data required in Section 5, as a minimum.

4.1 Inspections.

Inspections will be used as test controls to assure readiness for test and to reduce decision risk where sample sizes are limited.

4.2 Performance.

4.2.1 General.

a. Regardless of whether the test item is hand-held or vehicle mounted test procedures will be similar for appraising performance. To that end, only where exceptions apply, will any attempt be made to differentiate between human platforms and vehicle platforms. All procedures for the minefield test area apply to system performance trials. System performance trials are designed to demonstrate the detection equipment performance and the participants' (individually or as a team) respective capabilities to detect mines in operationally realistic conditions. The objectives of this document are stated in paragraph 1.1.1 and 1.1.2. To those ends, most of the testing activities are designed to be integrated with the system performance trials. Performance and reliability parameters will be developed from the system performance trials for the purposes of determining final acceptance. Other procedures (sensor experimentation testing or sensor verification testing) may support source selection, performance benchmarking or investigation, diagnostics, training, or pilot tests and are considered experimental trials. While these trials may yield useful parameters for the referenced purposes of paragraph 1.1.2, data should not be aggregated with the system performance trials. Ensure that trials include the baseline fielded system in addition to the detection equipment candidate(s). Ensure that the fielded system is new or like-new condition.

b. Performance benchmarking implies establishing a reference performance level for ideal, controlled conditions so that a range of expected performance levels and expected degradations can be established for sets of ideal, controlled conditions. Additionally, the benchmarking can be accomplished using the system to be replaced as a special reference standard for a set of ideal, controlled conditions. While not mandatory, benchmarking can provide useful information for subsequent diagnostics, as well as enabling side-by-side comparisons with existing or competing systems in controlled conditions (especially when standard targets are used (see document "Target standardization for demining testing"for standard reference targets)).

c. Detection system testing should progress logically and systematically from the experimental through the system performance trials. Experimental and system performance trials phases need to be planned together to be synergistic and support each other. Progression through the test program should provide increasing confidence that the capabilities and limitations of the equipment under test are defined and understood.

4.2.2 Sensor Experimentation Testing (Source Selection, Benchmarking, or Investigative Experimental Trials).

a. Establish a position location database for each mine placed in each soil plot in the facility. Prior to the start of all testing of each candidate or fielded system, ensure that no mines have been inadvertently disturbed. Record the plot of mine positions and burial depths/orientations relative to each soil bin.

b. Mount the candidate or fielded detection system on a maneuverable platform above the soil plot or maneuver using a human participant. Either through cabling, telemetry, or other conventional manual means record the output history as the candidate or fielded detection system advances over the soil plot. Ensure that advance rate and sensor height replicate the expected heights and advance rates of the platform regardless of whether it is a human or vehicle platform. If automated means are used, record the output history as a function of soil type, mine type/location, path, advance rate, height, and candidate or fielded detection system. Other variables of importance may be added. For systems that do not automatically "mark" detections, special techniques will need to be used to ensure that the detection is recorded. This may be done through inter-range instrumentation group (IRIG) global positioning system (GPS) tracking, IRIG video, and other simpler means. If none of these are feasible, it may be necessary to ignore advance rates and stop for marking at each detection event.

c. Depending upon sensor outputs and signal processing/display methods, the start and stop times and the rate of advance for each "trial" or "mission" should be recorded to establish a time history for the trial.

d. During and/or following each trial, the location data for each detection mark should be recorded and compared to each mine location to determine if the mark would have been a false alarm or detection event.. In this facility, for most candidate or fielded detection systems, false target sets or disguised target sets are optional.

e. A description of the Sensor Experimentation Testing Facility should be included with the following documented: soil types, soil moisture/density, soil bin size/depth, covered or uncovered, natural or artificial light, ambient or artificial climate control, and other descriptors. Other soil properties may be of value for specific sensor types. If artificial light or artificial climate control is used, the range of values occurring during test should be recorded.

4.2.3 Sensor Verification Testing (Experimental or Learning Trials). Sensor verification testing should be done initially by special test technicians upon receipt of candidate or fielded detection system(s). This testing will be performed to determine if the test items are ready for test or have been damaged as a result of shipment. After initial verification the Sensor Verification Area will be used for training, pilot tests (learning trials), and diagnostics.

a. The sensor verification area will be set up with geodetically surveyed mines of all types to be used during the system performance trials in the minefield test areas. Establish a position location database for each mine placed in the Sensor Verification Area. Prior to the start of all inspections, training, or pilot test of each candidate or fielded system, ensure that no mines have been inadvertently disturbed. Record the geodetic surveyed plot of mine positions and burial depths/orientations relative to the surveyed area.

b. Document inspections, training, or pilot tests to assure test readiness. It will be advantageous to record system responses in a marking location database to provide a basis for diagnostics. These diagnostics may relate to hardware readiness, individual readiness, or minefield test readiness. Diagnostics should also be documented to provide an audit of readiness issues or factors that should be corrected prior to test or prior to fielding. Examples may include corrected field manuals, training packages, or amended test procedures.

c. Pilot tests (learning trials) in the Sensor Verification Area should parallel those that will be used during performance tests in the minefield test areas so that the entire team of test participants and test observers (data collectors) establish proficiency prior to system performance trials and means are confirmed to ensure that test observers (data collectors) are transparent to the test participants.

4.2.4 System Performance Trials in the Minefield Test Area. The procedures below are specified generically for either candidate or fielded detection system(s) whether the platform is human (hand-held) or vehicle.

a. Prior to start of test, ensure that all test readiness issues have been resolved satisfactorily. Each minefield test area will be set up with surveyed mines of all types to be used during the system performance trials in the minefield test areas. Establish a position location database for each mine placed in the minefield test area. Record the plot of mine positions and burial depths/orientations relative to the surveyed area to the required accuracy.

b. The minefield test area will be operationally realistic. Minefield test areas will be periodically added to, removed from, relocated from, and disturbed during the system performance trials to ensure a changing appearance. The position location database for each minefield test area will be recorded for each change to fully document baseline and subsequent changes to each minefield test area. Where disturbances are added (false target sets, vegetation, etc), these will be narratively described as well as surveyed. Each set of minefield description data for each minefield test area will be assigned a unique minefield identification (ID) number (minefield ID). Each planned path or lane through the minefield test area will be assigned a unique lane ID (route reconnaissance search method). Each planned trial or mission will have a unique trial ID. Each test player will have a unique test player ID to be retained throughout testing. If teams of test players are used for a search method, the team will have a unique ID.

c. A schedule must be developed for all system performance trials to ensure that all test conditions are addressed. The schedule must include time for periodic human factors interviews, questionnaires, and/or measurements. Care should be taken to ensure that the test participant duty day is representative of the mission profile.

d. Once preparatory activities above have been completed, system performance trials should commence.

e. System performance trial overview. System performance trials may be structured in two manners: route reconnaissance and area searches. Route reconnaissance consists of controlled paths or lanes through the minefield test area. Area searches are designed to test each systems ability to search for minefields within a controlled set of boundaries. Search pattern/strategy may be tailored to the technology of the test item or comparative fielded system. The basic difference between route reconnaissance and area search system performance trials is that, in route reconnaissance, search paths are controlled. In the area search, teams may develop a strategy that better exploits the characteristics of the new technology. Route reconnaissance system performance trials will enable direct performance comparison of systems. Area search system performance trials will enable identification of performance weak/strong points of competing systems.

f. System performance trial events. The basic trial event is the encounter of each minefield (Mine Test Area) with the system search swath under a specified set of test conditions (see Table 1). A route reconnaissance system performance trial will provide a finite number of planned encounters for each path/direction through the minefield. The area search system performance trial will provide a different number (multiple to near zero) of encounters depending upon the search strategy. Note: Depending upon the mine pattern and density (mines/sq. meter or mines/meter front), any random path will yield a probability of encounter. During pre-test activities, it may be necessary to construct a model to theoretically predict this probability to determine a reasonable expected bound of encounters given a specific search strategy.

g. System performance trials control concepts. Free force-on-force play is characteristic of the real battlefield upon which an infinite number of situations can occur. Control is imposed to limit the possibilities to a finite set of factors and to permit replication of trials to the desired sample size in order to collect objective data amenable to statistical analysis. Certain factors can be systematically controlled. Other factors such as the weather, vegetation, smoke and obscurants, etc. cannot be controlled in the real battlefield. However, during test these factors can be induced or introduced on a planned, controlled basis (such as smoke, obscurants, or RF energy).

h. System performance trials design control. Test duration should include a finite number of days. That is, duration should be time limited as opposed to being driven by an open ended test where performance and associated reliability has to be demonstrated at a specified probability and confidence, regardless of failure rate. Test design should assume a duration (specific number of system performance trials) based upon a pre-assumed numbers of failures for required probability and confidence. Therefore, based upon a predetermined number of trials and trial days, each system will have the same opportunities to search specified Minefield Test Areas and trial times will be staggered to ensure that all systems are exposed to complete diurnal cycles and other factors. This approach will provide for clear delineation between items that have problems with availability, reliability, or performance. The special test controls discussed in paragraph 3.3.1 will be employed to preclude gaming of the trials.

i. System performance trials minefield test area control. Position location of mines and minefields will be treated as sensitive information and will not be provided to system representatives or test team participants, or anyone else unless there is a valid need to know. A valid need to know will be determined by the test director, project manager, or independent evaluator. Minefield test areas will be emplaced by the demolition team or other special team independent of the test participants. The initial layout of each minefield test area and subsequent changes to each area will be controlled by the test director and documented by the test observers (data collectors). As stated under test conditions, all systems have human operators who will deliberately or unwittingly endeavor to locate and identify minefields in post-trial analysis. To prevent the test participants from being cued by prior knowledge, special test controls above should be adhered to and controlled by the test director. The test director must have direct control over test observers, system contractors, test participants, and range areas where minefield test areas are located.

j. System performance trials mine test area encounters. On a daily basis, minefield test areas will be inspected, clearing previous marking, and posting of controllers for subsequent trials will be performed to maximize the validity of system performance trials. For a given trial ID, the path of the search and rate of advance will be recorded (if a vehicle platform with GPS) or documented by video or other means (if human platform). The type of encounters planned for system performance trials (route reconnaissance or area clearance) will be determined by reference to the trials schedule. Test observers will record trial condition data to include Administrative Data such as trial ID, date, start trial time, end trial time, player ID, system ID, team ID, and test sequence identifier. Ground truth data (soil data and meteorological data) will be collected. Meteorological data will be collected during trials at weather stations located adjacent or near to minefield test areas. Soils data will be collected prior to test. Test observers will collect minefield truth data to fully describe the composition of the minefield test areas. This will include minefield ID, background type, minefield descriptors, and false set descriptors. Individual mines within a minefield as well as the surrounding terrain will be surveyed/characterized as necessary. Mine/minefield description data will be used in the mine location database and will be presented in spreadsheet or graphic form. Test observers will collect mission data for any given trial ID and minefield ID, to include start point (geodetically marked), geodetic path and swath path in lane, stop point (geodetically marked), alert number, time of alert, alert status (initial alert, continue, disappear), and detection point for alert (geodetically marked). If no EDRS instrumentation is available, minimum data acquired should include start, stop, and mark points and times. Following each trial, the location data for each detection mark should be compared to each mine location in the mine location database for that minefield ID to determine if the mark would have been a false alarm or detection event.

4.3 Reliability and Compatibility.

Any problems noted with incompatibility during test with either human or vehicle platforms will be noted. Problems of incompatibility for human or vehicle platforms will be collated from performance, human factors, safety, integrated logistics supportability, transportability, or climatic suitability observations or testing. If a standard vehicle platform is used, special attention should be devoted to addressing the potentially degrading effects of the detection system installation/removal on the operation, maintenance, and shipment of the integrated detection-vehicle platform system. See document "General test requirements for demining testing"[1] for guidance on reliability testing.

4.4 Safety and Human Health.

See document "General test requirements for demining testing"[1] for guidance on safety and human health testing.

4.5 Climatic Suitability.

For all system performance trials, meteorological conditions will be documented and recorded so that the conditions can be characterized in terms of climatic design types; performance or reliability degradations or failures can be quantified as a function of climatic design type or climatic factor; and other types of climatic suitability problems can be solved through changes to design, hardware, procedure, or training. Climatic factors should encompass temperature, solar radiation, precipitation, wind, salt fog, sand and dust, pressure-altitude, and immersion.

Testing in climatic chambers and facilities may be creatively exploited, desirably before system performance trials, if facilities can permit operation of detection equipment. Where desired, screening of climatic factors should be combined with the shock and vibration associated with transportation and handling to address storage and transport of packaged equipment prior to mounting on human or vehicle platform. document "General test requirements for demining testing",[1] contains those test standards that may be used if screening tests are desirable. This may not be necessary if multiple test sites are selected that provide a range of climatic conditions and system performance trials include the complete life cycle (issue, operational storage, mounting, use, transport, maintenance, etc) in accordance with the requirements document and associated operational mode summary/mission profile. See document "General test requirements for demining testing"[1] for additional guidance on climatic suitability testing.

4.6 Transportation and Handling.

document "General test requirements for demining testing", contains those test standards that may be used if screening tests are desirable. Screening tests, if required, will focus on intermodal transport, air delivery, and handling related shock and vibration effects on the item and will be coupled with climatic conditions as stated above.

Tactical vibration profiles should be developed and used for all items to be mounted on vehicle platforms to enable screening of item ruggedness to that specific environment to enable repeatable acceptance tests. These vibration tests will be in addition to logistics-related vibration tests such as secured cargo or loose cargo. Special tactical mockups may be fabricated to physically simulate the mounting platform (pod, rack, compartment, etc.). See document "General test requirements for demining testing" for additional guidance on transportation and handling testing.

4.7 Integrated Logistics Supportability.

See document "General test requirements for demining testing"[1] for guidance on integrated logistics supportability testing.

4.8 Human Factors or Ergonomics.

Checklists, interviews, and questionnaires will be administered to test team participants after system performance trials to aid in appraisal of training, hardware, doctrine, and equipment publications. For example, see Appendix A. See document "General test requirements for demining testing" for additional guidance on human factors or ergonomics testing.

4.9 Electromagnetic Environmental Effects (E3) and Vulnerability.Testing should be designed to reveal vulnerabilities of design or hardness of the design. Vulnerabilities could be false or improper detections or reversible/irreversible degradation following exposure to the phenomenon. Where possible, testing that reveals vulnerabilities should also examine whether hardening, proliferation, or dispersion would solve the specific vulnerability. See document "General test requirements for demining testing"for additional guidance on E3 and vulnerability testing.

4.10 Software.

Software testing techniques will vary dramatically and may not lend themselves to standardization. Software should be baselined prior to test start and should be maintained throughout each test session. See document "General test requirements for demining testing" for guidance on software testing.

5. Data Required.

Metric units will be used (not “soft” conversions).

5.1 Inspections.

5.1.1 Record of inspections prior to, during, and following trials.

5.1.2 Description of packaging, item nomenclature (serial number or identifying number), item type (if special variants are built), and quantity of each type of test item.

5.1.3 Record of packaging and detection system damage or discrepancies.

5.1.4 Completeness of the System Support Package (SSP) received for the test (manuals, repair parts, tools, etc).

5.2 Performance.

5.2.1 Common Data Requirements for All Trials.

5.2.1.1 Administrative Data.

a. Trial ID number.

b. Trial date.

c. Test player ID number.

d. Test player equipment and clothing (as appropriate, for collation to human factors appraisal).

e. System ID number.

f. Test player team ID number, if teams of individuals are used for search method.

g. Platform ID number, if vehicle platform.

5.2.1.2 Ground Truth Data.

a. Minefield description data.

(1) Tabulated composition of each individual minefield with a minefield ID number.

(2) Minefield ID number.

(3) Lane ID number within minefield ID (route reconnaissance).

b. Targets characterization, selection, and description (See document "Target standardization for demining testing" for detailed data requirements for targets to be used in detection trials).

c. Geodetic plots and x-y position spreadsheets of individual targets identified by type, each minefield ID number.

d. Overlay of lane ID numbers on respective minefield ID (route reconnaissance).

e. Updated plots and position spreadsheets if deliberate changes are made to a minefield ID, such as planned disturbance or addition of detritus (battlefield trash or other objects).

f. Meteorological data (regardless of whether natural conditions or artificially developed conditions) on IRIG basis collated with Trials ID number:

(1) Air temperature.

(2) Precipitation, duration, intensity, accumulation, and phase (rain, snow, etc).

(3) Wind speed/direction.

(4) Barometric pressure.

(5) Relative humidity.

(6) Ground temperature.

(7) Solar loading.

(8) Cloud cover, height.

(9) Light level.

g. Other target truth data unique to the environment or detector type or detector platform (such as, vehicle speed/position, radiometric temperatures of backgrounds and targets).

h. Soil data (All minefield ID numbers).

(1) Plot of soil survey measurement points and tabulation of classification by measurement points.

(2) Type of soil and soil classification/sampling system used to characterize type.

(3) Metal content.

(4) Soil composition.

(5) Soil texture.

(6) Rock distribution.

(7) Moisture content and method used to characterize moisture or control moisture.

(8) Vegetation type with both narrative description, photographs, and physical surveys.

NOTE: Other unique soil properties or soil features may be of interest for specific sensor types.

5.2.1.3 Mission Data for Each Trial or Mission ID.

a. Start Time.

b. Stop Time.

c. Start Point (geodetically marked).

d. Geodetic path and swath path in lane.

e. Stop Point(geodetically marked).

f. Alert number.

g. Time of alert.

h. Alert status.

i. Detection point for alert.

5.2.2 Sensor Experimentation Testing (Source Selection, Benchmarking, or Investigative Experimental Trials).

5.2.2.1 See 5.2.4 for system performance trials data and 5.2.1 for common trials data. Although not all may be applicable to experimental trials, these will provide a framework for collection.

5.2.2.2 Description of test setup to include construction materials of soil bins, special apparatus (if used) to control detector position (x, y, z), detector advance or sweep rates, and detector angular displacement.

5.2.3 Sensor Verification Testing (Experimental or Learning Trials). See 5.2.4 for system performance trials data and 5.2.1 for common trials data. Although not all may be applicable to experimental trials, these will provide a framework for collection.

5.2.4 System performance trials in the minefield test area.

a. Data collector ID.

b. Administrative data (see 5.2.1.1).

c. Ground truth data (see 5.2.1.2).

d. Mission data (see 5.2.1.3).

5.2.4.1 Accuracy of Alert. (Note that the following measures apply to both the electronic “mark” of an EDRS if used for a test or to a physical mark).

a. Distance from center of mine to center of mark. This measure will provide data for examining accuracy after the fact; i.e., if most detections are closer than the required distance, the “halo” can be decreased to determine the accuracy of the system.

b. Whether or not any portion of mark is within a “halo” about perimeter of mine (accurate to desired or specified level).

5.2.4.2 Individual Detection Encounter Score, as well as “Total Scores”. Mine detections may be scored for evaluation as shown in Appendix C, methods 1, 2 (pending), or 3. There may be other unique scoring methods that are appropriate to any given system.

5.2.4.3 System Performance Trials, Vehicle-Platform Unique Data Requirements (to include teleoperation, if applicable) (only if EDRS type instrumentation has been planned as part of trials).

a. Near real-time performance.

(1) Length of time from when each individual detector swath first fully contains the mine until the indicator is displayed on the operator's monitor.

(2) Length of time from when each individual detector swath first fully contains the mine until the physical mark is made.

b. Distance host vehicle travels between encounter of target by sensor and stopping of the vehicle, when vehicle is travelling at required speed.

(1) Vehicle speed.

(2) Description of terrain and weather/climatic conditions; i.e., grass, gravel road, sand, on-road, off-road, moisture content in soil.

(3) Time from operator receipt of mine detection indicator to application of brake.

(4) Time from application of brake to stopping of vehicle.

(5) For all mines, distance between tire or track of vehicle and mine.

c. Given a detection, the ability of host vehicle to avoid the mine, when vehicle is travelling at required speed.

(1) Vehicle speed.

(2) Point of closest approach (PCA) when attempting to avoid the mine.

(3) Description of terrain and weather/climatic conditions; i.e., grass, gravel road, sand, on-road, off-road, moisture content in soil.

(4) Time from operator receipt of mine detection indicator until steering-around attempt; i.e., until PCA is reached.

(5) Success rate; i.e., number avoided/number detected, in avoiding mines.

d. Advance rate during initial detection or "standoff alert" operation.

(1) Vehicle speed, without attempting to verify alerts.

(2) Probability of detection (Pd) and false alarm rate (FAR) during initial detection operation.

e. Advance rate during verification of alerts.

(1) Vehicle speed, while attempting to verify alerts.

(2) Pd and FAR during verification.

f. Standoff distance.

(1) Distance from mine edge to vehicle edge at time of initial detection.

(2) Distance from mine edge to vehicle edge at time of verified detection.

g. Range for reliable data transmission (teleoperation only).

Range from the controller vehicle to the host vehicle recommended by the manual or contractor for teleoperation and data linkage.

(1) Minimum range for data linkage and teleoperation demonstrated/measured.

(2) Maximum range for data linkage and teleoperation demonstrated/measured.

(3) Mean range for data linkage and teleoperation demonstrated/measured.

(4) Operator ratings on the ability to control host vehicle at the range(s) prescribed by the contractor.

5.3 Reliability and Compatibility.

Record any compatibility problems noted during operations (human or vehicular platform) or maintenance (vehicular platform).

5.4 Safety and Human Health.

5.4.1 Developer or Contractor's Safety and Human Health Assessment Reports.

5.4.2 Safety problems identified during test and their classification (hazard severity and probability of occurrence.

5.4.3 Electrical, mechanical, or miscellaneous hazards checklist responses and their classification.

5.4.4 Results of equipment or technical publication and training material review (adequacy of warnings, cautions, and notes).

5.4.5 Photographic, audiovisual, or other documentation of hazards.

5.4.6 Results and classification of toxic fumes (vehicle-platform), whole body vibration (vehicle-platform), noise measures (vehicle-platform), and non-ionizing or ionizing radiation levels (human or vehicle-platform).

5.4.7 Adequacy, proper functioning, and need for additional or improved safety and warning devices; i.e., guards, interlocks, alarms, warning lights.

5.4.8 User rating of safety in operating, training, and maintaining the system.

5.4.9 Engineering analysis of potential for and documentation of any safety issues/incidents.

5.4.10 Number and criticality of system-related accidents.

5.5 Climatic Suitability.

5.5.1 Meteorological record to encompass the active phase of test periods for each period of detection with a system ID.

5.5.2 Any difficulties noted in testing which was caused or influenced by natural environmental factors.

5.5.3 Record of controlled climatic tests performed, effects observed, and analysis of impact on life cycle (storage, transport, operation, maintenance, or long term storage).

5.6 Transportation and Handling.

5.6.1 Record of controlled shock and vibration tests performed, effects observed, and analysis of impact on life cycle (storage, transport, or handling).

5.6.2 Record of studies performed or modeling to predict transportation limitations.

5.6.3 Record of unique stability, mobility, braking, steering, or road transport tests performed (vehicular-platform only).
5.6.3.1 Stability. Stability limits on lateral and longitudinal slopes.

5.6.3.2 Mobility. Record of unique problems affecting the prime mover (break-over angle, ground impact of detectors, etc).

5.6.3.3 Braking. Record of effects or problems noted during panic or emergency braking with and without detectors mounted.

5.6.3.4 Physical Characteristics. Record of combined weight, center of gravity, ground pressure, and physical dimensions of the detection system/vehicle-platform combination.

5.7 Integrated Logistics Supportability.

5.7.1 Record of scheduled and unscheduled maintenance activity:

5.7.1.1 Tasks performed.

5.7.1.2 Clock hours of maintenance.

5.7.1.3 Skill requirements of mechanics or technicians.

5.7.1.4 Identification and nomenclature of parts involved in maintenance action.

5.7.1.5 Reason for maintenance action (repair, replace, adjust, calibrate).

5.7.1.6 Adequacy of special tools, test, measurement, or diagnostic equipment.

5.7.2 Adequacy of manuals (legibility, readability, applicability) to include mounting instructions.

5.7.3 Adequacy of training for scheduled and unscheduled maintenance tasks.

5.7.4 Adequacy of access for maintenance.

5.8 Human Factors or Ergonomics.

The use of the term ratings implies a user response to a questionnaire or checklist. The data requirements that follow are suggested.

5.8.1 Demographics and anthropometry data of test participants. Corresponding apparel and configuration of test participant. Data should include skill requirements, time in specialty, years and months of related equipment.

5.8.2 Results of test participant task checklists (time and error data) for each method of search or detection employed, together with summaries showing frequency, consequence, and cause of errors.

5.8.3 Summaries of operator and maintainer questionnaires.

5.8.4 Summaries of observations made by human factors or ergonomics specialists.

5.8.5 Lighting measurements of displays and workspace (vehicle-platform) areas, night and day.

5.8.6 Workspace dimensions and percentile accommodation (vehicle-platform).

5.8.7 Workspace noise levels (vehicle-platform) in dBA, dBB, and dBC and all-pass; octave band center frequencies for steady state, impulse, speech interference, or if appropriate, aural nondetectability (hand-held).

5.8.8 Whole body-vibration levels in each axis (vehicle-platform) at operator station for each principal mode of operation.

5.8.9 Labeling and color coding/marking of safety gear, equipment, and essential station locations.

5.8.10 Weight of test item in packaged and unpackaged state, handholds, latches, etc.

5.8.11 Portability features and human interface features of human-platform test item.

5.8.12 Capability of mine presence signals to inform operators:

5.8.12.1 Description of the types and characteristics of signals.

5.8.12.2 Description of any intensity adjustability of signals.

5.8.12.3 Ratings of the adequacy of the visual signals by operators with and without lenses.

5.8.12.4 Ratings of the ease of discriminating visual display signals.

5.8.12.5 Ratings of the adequacy of audio signal intensity in typical operational environments.

5.8.12.6 Sound pressure levels of audio signals at operator-occupied positions.

5.8.12.7 Operator ratings of the ease of interpreting the meaning of visual and audio signals.

5.8.12.8 Documented tester observations of operator confusion and/or errors associated with displays in all operational conditions.

5.8.12.9 Conformance of display icons to applicable host nation requirements.

5.8.13 Marker visibility under all operational conditions (if applicable).

5.8.13.1 Operator ratings of the ease of seeing markers during the day.

5.8.13.2 Ratings of the ease of seeing markers at twilight and at nighttime without eyewear and during the day while wearing sunglasses and laser protective lenses.

5.8.13.3 Ratings of the ease of seeing markers while using thermal viewers and image intensifier (I2) devices.

5.8.13.4 Documented tester observations of any mine markers missed by test players.

5.8.14 Attachability of test item hardware to human or vehicle-platforms:

5.8.14.1 Ratings of ease of attaching system components to, and removing components from, human or vehicle-platforms.

5.8.14.2 Documented observations of any difficulties with lifting, positioning, and securing components on human or vehicle-platforms.

5.8.14.3 Description of components with respect to the presence, location, and utility of lifting handles.

5.8.15 Degree to which displays inform operators of system operational status.

5.8.16 Ability of soldiers to perform preventative maintenance checks and services (PMCS) in the required time using instructions provided with the system hardware.

5.8.16.1 Ratings of the ease of doing PMCS.

5.8.16.2 Time to perform PMCS during the day and night.

5.8.16.3 Ratings of the adequacy of instructions.

5.8.17 Ability of operators to operate the system while attired in environmentally protective clothing:

5.8.17.1 Listing of all protective clothing ensemble components worn.

5.8.17.2 Compatibility of system hardware with protective clothing with an emphasis on handwear.

5.8.17.3 Documented observations of task completion difficulties experienced by operators and maintenance personnel.

5.8.17.4 Ratings of the ease of adjusting controls barehanded and while wearing Nuclear, Biological, Chemical (NBC), and cold weather protective gloves.

5.8.18 Ability of operators to set up, operate, and maintain the system:

5.8.18.1 Comments about any instances of display fogging and/or frosting and any associated performance difficulties.

5.8.18.2 Ratings of the adequacy of system to alert the operator to mines.

5.8.18.3 Ratings of the adequacy of hardware to verify locations of mines.

5.8.18.4 Ratings of user confidence regarding the ability of system to accurately find and mark mines (if applicable).

5.8.18.5 Description of operator and maintainer errors as well as their consequences on overall system performance.

5.8.18.6 Ratings of the adequacy of new equipment familiarization for operators and maintainers.

5.8.18.7 Ratings of the ease of stopping the vehicle on which mine detectors are mounted when a mine is sensed and verified.

5.8.18.8 Ratings of the ease of marking mines.

5.8.18.9 Ratings of the ease of maneuvering a vehicle around detected mines.

5.8.18.10 Ratings of the ease of manned host vehicle handling while operating the system.

5.8.18.11 Ratings of the ease of system teleoperation with emphasis on controlling and/or downloading data to the control vehicle.

5.8.18.13 Illustrative photographs when measurements or user comments show a problem.

5.9 E3 and Vulnerability.

5.9.1 Results of E3 tests performed as screening tests separate from field trials (E3 radiated emissions, compatibility, interference, conducted emissions, radiated susceptibility, etc).

5.9.2 Identification of any vulnerabilities or susceptibilities of equipment to RF frequency intrusion (deliberate or unplanned).

5.9.3 Identification of any vulnerabilities to natural phenomena (lightning, electrostatics).

5.9.4 Identification of susceptibilities to common battlefield detritus.

5.9.5 Minimum separation distance between two detectors or detection-system/vehicle-platforms before detectors start to interfere (electromagnetic interference) with each other.

5.10 Software.

5.10.1 Record of software version at start of system performance trials.

5.10.2 Record of problems attributable to software related to system diagnostics or system performance.

6. Presentation of Data.

a. Describe inspections, specific test procedures, and results for each item using narration, tables, photographs, x-rays, charts, and graphs as appropriate.

b. Include photographs to show type of container or packaging (when applicable), type of mounting (vehicle platform or human platform if special pack frame), type of detection equipment (when multiple candidates are designed for test purposes), and to document any damage.

c. Reduce, summarize, and analyze data from each subtest. Where unique analytical tools (e.g. models, simulations, statistical techniques) are used, these should be described in sufficient detail to enable the reader to understand the basis for the analysis. Examples, of parameters that may need to be analyzed for detection equipment from system performance or experimental trials are suggested along with suggested methods in Appendix C.

APPENDIX A1. SAMPLES FOR SYSTEM PERFORMANCE TRIALS, PLANNING AND TEST EXECUTION PURPOSES.[6]

1. This appendix contains outline examples that can aid in the organization of those processes associated with planning and execution of trials associated with mine detection. Development of the scope of the trials as well as logical organization of data collection are critical to an orderly examination of any technology. The appendix is divided into three parts:

Part I-Development of the Scope of the Trials;

Part II-Sample Data Forms relevant to performance, human factors, and logistics appraisals and analysis;

and Part III-Organization of the Data Collection and Analysis

Part I-Development of the Scope of the Trials

Table A-1. Test Variables-Examples.

Test Variables (Examples)		
Factor	Control	Condition
Mine lane	Tactically varied	Lanes L_1 through L_n, where n= number of Lanes for trials
Mine type	Systematically varied	Metallic content, anti-tank (AT)/ anti-personnel (AP) mines[a]
Mine placement	Systematically varied	Depth buried, on and off-road. Pattern and density will reflect doctrine.
Soil type and classification	Systematically selected but uncontrolled	Silts and clays (liquid limit<50)(SM type); sand and sandy soils (SC type); gravel and gravelly soils (GC type)
Climatic conditions	Systematically selected but uncontrolled	NATO Climatic Categories A1, B2, and C1.
Operator apparel	Systematically varied	Cold weather clothing
Light conditions	Systematically varied	Day and Night
Operational status	Uncontrolled	Full, partial, down

[a] For illustration only. Please note that many factors (size, shape, explosive content, etc) may be important to determining suitability of surrogates or simulants of landmines. See document "Target standardization for demining testing"

Table A-2. Example, Probability of Detection Required and Desired for Minefield Type with Sample.

MINEFIELD TYPE	PD REQUIRED (DESIRED)	NOTES
Buried, Off-road	P_D (X percent) (100 percent)	Burial depth to not exceed D_1 centimeters for AT mines or D_2 centimeters for AP mines.
Surface	P_D (X percent)(100 percent)	
Buried, Nuisance, On-road	P_D (X percent)(100 percent)	Burial depths to not exceed D_1 centimeters for AT mines or D_2 centimeters for AP mines.

Note: Where P_D (X percent) is a stated percentage (99.1%, 90%, etc) or may be stated as a probability (0.991, 0.90, etc); D_1 is an expressed burial depth....

Table A-3. Example of Scope Development, Sample Sizes vs. Placement Conditions for AT or AP mines.

Metal Content	Placement					Totals
	Buried, On-Road		Buried, Off Road		Surface	
	Buried @D_1	Flush With Surface	Buried @D_1	Flush With Surface		
Metal	N_1	N_1	N_1	N_1	N_1	$5N_1$
Low Metal	N_2	N_2	N_2	N_2	N_2	$5N_2$
Non Metal	N_3	N_3	N_3	N_3	N_3	$5N_3$
Totals	$\Sigma_{i=1,n}N_i$	$\Sigma_{i=1,n}N_i$	$\Sigma_{i=1,n}N_i$	$\Sigma_{i=1,n}N_i$	$\Sigma_{i=1,n}N_i$	$5\Sigma_{i=1,n}N_i$

Note: Where N_i is some real number expressing the number of mines of a specific metal content for a given placement condition. Totals required or desired may be derived through acceptable means based upon user or developer risks and a reasonable assumption of failure rates. Please note that many factors are important to mine detection. There would be several tables to include: a roll-up or total of all events, with supporting tables for a specific set of events or conditions exploring variables above. Examples, supporting tables for Day-Operation, Night-Operation, Close-In, and Standoff Sensor Excursions; Soil Types or Conditions; etc. For each combination of mine type and mine placements condition, it is typical that many measures of performance may be calculated, such as probability of alert (P_a), probability of valid alert (P_{va}), accurate alert (A_a), etc. These measures may be calculated for the defining specific set of events, to define limitations or risks associated with day, night, NBC, climatic, soil, or standoff operations.

Table A-4. Examples of Mine Characteristics Used Towards Establishing Suitable Simulants or Surrogates.

Mine shape factors →	CYLINDER • < 7 cm	CYLINDER • > 7 cm	OTHER SHAPE ❐ ↔ ~ 10 cm	OTHER SHAPE IRREGULAR 3D SHAPE
Mine material factors				
Surface coating				
Metal content				
Type of explosive				
Air void				
Case material				
Fuse characteristics				
Mine internal architectural factors				
Position of fuse				
Position of explosive				
Other accessories				

Note: What are the significant features characterising the test mines? Start by considering a process similar to the above table, which includes mine features relevant to the types of core sensors under test. Distinction should be made between material factors and internal architectural factors characterising the mine. Those features or factors important to a given technology should be of priority when selecting or designing a simulant or surrogate landmine for test. See document "Target standardization for demining testing".

Table A-5. Examples of Soil/Topography Characteristics for Trials.

Soil properties ↓	Soil types →	① SANDY SOIL (USCS TYPE SC)	② CLAY (USCS TYPE CL)	③ SILT (USCS TYPE ML)
Surface roughness				
Smooth (< 5 cm)				
Medium (< 10 cm)				
High (> 10 cm)				
Contamination				
Metal content				
Ferrous				
Non-ferrous				
Water content				
< 5%				
< 10%				
> 10%				
Rocks				
< 7 cm				
> 7 cm				
Debris				
< 7 cm				
> 7 cm				

Note: What are the key types of soils to be considered for the trials? Develop a table for soil classifications required for the application. Prioritise those soil types from highest to lowest probability of encounter. Select trials sites based upon that examination to provide a broad, but representative sampling of soil conditions relevant to the examination. In the example above, the soil considered for the tests could be that of Bosnia, which in turn can be of three different types, according to the principal component (sand, clay or silt). In this way we satisfactorily cover a wide range of realistic significant cases for soil conditions. For a better understanding of soil properties, the test team should investigate expertise existing on site, leverage existing soil topographical and soil surveys of sites, and/or confirm soil types and topography through a pre-trials survey. Where possible, universal or uniform soil classifications should be used in conjunction with a narrative description of the soils to permit comparison with other trials.

Table A-6. Example of Worldwide Distribution of Inhabitable Land Surfaces by Soil Type to Consider When Prioritizing Soil Types Used for an Example Set of Trials.

Soil Type	Worldwide Distribution on Inhabitable Land	
	Each Type (%)	Group Totals
SM	44	66%
CL	22	
CH	9	89%
SC	8	
ML-CL	6	
SP	<3 each	99%
Tundra	<3 each	
PT	<3 each	
ML	<3 each	
GC	<1/4 each	100%
Rock	<1/4 each	
Salt	<1/4 each	
GM	<1/4 each	
GP	<1/4 each	
SW	<1/4 each	
OL	<1/4 each	
MH	<1/4 each	
OH	<1/4 each	
Ice	<1/4 each	

Note: Group totals for each sub-grouping reflect the percentages of each soil type considered in descending percentages from most prevalent to least. Soil types listed are by Unified Soil Classification System (USCS). This example was compiled initially from UNESCO databased on arable and inhabitable soils, then transcribed into the unified soil classification system (USCS). This is shown only to illustrate that test site selection for record field trials should be made carefully and that the local soil conditions should be known or surveyed prior to selection to insure that it is "representative" of the area or areas of interest. It may be quite unique or anomalous.

Part II-Sample Data Forms Relevant to Performance, Human Factors, and Logistics Appraisals and Analysis.

1. FIELD DATA.

1. Mission or Trial Information.

5.2 SYSTEM PERFORMANCE TRIALS DATA REQUIREMENTS	Footnotes
5.2.1 Administrative Data	
5.2.1.1 Trial (or Mission) ID number	
5.2.1.2 Trial (or Mission) Date	
5.2.1.3 System ID number	
5.2.1.4 Platform ID number (if vehicle platform)	
5.2.1.5 Test Player ID number	
5.2.1.6 Test Player Team ID number (if teams of individuals are used); list ID numbers of all test players on team	
5.2.1.7 Test Player Equipment, Clothing, and Accoutrements (as appropriate, for collation to human factors appraisal) • Clothing • Load Bearing Equipment (LBE) • Accoutrements (Night Vision Goggles, Protective Glasses or Masks, Radios, etc)	
5.2.1.8 Data Collector ID number	
5.2.2 Mine/Test Target Data	
5.2.2.1 Target ID Number (document "Target standardization for demining testing"par. 5a)	
5.2.2.2 Target Location (document "Target standardization for demining testing" par. 5b)	
5.2.2.3 Target Burial Depth (document "Target standardization for demining testing"par. 5c and 5d)	
5.2.2.4 Target Orientation (document "Target standardization for demining testing"par. 5e)	
5.2.2.5 Target Weathering Data (document "Target standardization for demining testing"par. 5f)	
5.2.2.6 Target Emplacement Technique (document "Target standardization for demining testing"par. 5g)	

5.2 SYSTEM PERFORMANCE TRIALS DATA REQUIREMENTS	Footnotes
5.2.2.7 Target Characteristics and Features (document "Target standardization for demining testing"par. 5i)	
5.2.2.8 Other Target Information (document "Target standardization for demining testing"par. 5j)	
5.2.3 Minefield/Target Array Data	
5.2.3.1 Minefield or Mine Lane ID number; List target ID numbers of all mines within minefield or lane	
5.2.3.2 Geodetic plots and x-y position spreadsheets of all mines/targets within minefield or lane	
5.2.3.3 Overlay of Mine Lane ID numbers on respective Minefield ID numbers (Route Reconnaissance)	
5.2.3.4 Updated plots and position spreadsheets if deliberate changes are made to a Minefield ID, such as planned disturbance or addition of detritus (battlefield trash or other objects)	
5.2.3.5 Description and location of any combat obstacles used in conjunction with Minefields/Target Arrays (document "Target standardization for demining testing"par. 5h)	
5.2.4 Meteorological Data (regardless of whether natural conditions or artificially developed conditions) on IRIG basis collated with Trial or Mission ID number(s)	
5.2.4.1 Air Temperature	
5.2.4.2 Precipitation - Duration - Intensity - Accumulation - Phase (rain, snow, etc).	
5.2.4.2 Wind - Speed - Direction	
5.2.4.3 Barometric Pressure	
5.2.4.4 Relative humidity	
5.2.4.5 Ground Temperature	
5.2.4.6 Solar Loading	
5.2.4.7 Cloud cover, height	
5.2.4.8 Light level	
5.2.5 Soil Data (for all minefield or mine lane ID numbers)	

5.2 SYSTEM PERFORMANCE TRIALS DATA REQUIREMENTS 5.2.5.1 Geodetic plot of soil survey measurement points and tabulation of classification and characterization by measurement points.	Footnotes
5.2.5.2 Type of soil and soil classification/sampling system or method used to characterize: a. Metal content b. Soil composition c. Soil texture d. Rock distribution e. Surface roughness f. Electrical properties (conductivity, dielectric constant, etc.) g. Magnetic properties (frequency dependence) h. Thermal properties (conductivity, diffusivity, temperature, emissivity, density, specific heat) i. Clutter (natural and man-made; magnetic and non-magnetic; roots, holes, wood, plastic, unusual soil/overburden stratification's and discontinuities). If clutter is placed as a target document IAW document "Target standardization for demining testing"and Mine/Test Target Data requirements	
5.2.5.3 Moisture content and method used to characterize moisture. Description of any method used to control moisture	
5.2.5.4 Other ground truth data unique to the environment, detector type or detector platform (such as vehicle speed/position, radiometric temperatures of backgrounds and/or calibration targets)	
5.2.6 Vegetation/Terrain Data	
5.2.6.1 Narrative description, photographs, and physical surveys of terrain and vegetation	
5.2.7 Mission Data (for each Trial or Mission ID number)	
5.2.7.1 Start Time	
5.2.7.2 Stop Time	
5.2.7.3 Start Point (Geodetically Marked)	
5.2.7.4 Geodetic Path and Swath Path in Lane	
5.2.7.5 Stop Point (Geodetically Marked)	
5.2.7.6 Alert Number	
5.2.7.7 Time of Alert	
5.2.7.8 Alert Status (Initial Alert, Continue, Disappear)	

5.2 SYSTEM PERFORMANCE TRIALS DATA REQUIREMENTS	Footnotes
5.2.7.9 Detection Point for Alert (Geodetically Marked)	
5.2.8 Sensor Experimentation Testing Data	
5.2.8.1 See 5.2.1 through 5.2.7 for common data requirements. Although not all may applicable, these will provide a framework for collection.	
5.2.8.2 Description of test setup to include construction materials of soil bins, special apparatus (if used) to control detector position (x, y, z), detector advance or sweep rates, and detector angular displacement.	
5.2.8.3 Performance and Performance Analysis. provide IAW Appendix C	
5.2.9 Sensor Verification Testing Data	
5.2.9.1 See 5.2.1 through 5.2.7 for common data requirements. Although not all may be applicable, these will provide a framework for collection.	
5.2.9.2 Performance and Performance Analysis. provide IAW Appendix C	
5.2.10 Minefield Testing Data (Human and Vehicle Platform)	
5.2.10.1 See 5.2.1 through 5.2.7 for common data requirements.	
5.2.10.2 Performance and Performance Analysis. provide IAW Appendix C	
5.2.10.3 Measure or analysis of the likelihood of a mine fuse being initiated by the detection equipment	
5.2.11 Minefield Testing Data (Vehicle Platform Unique)	
a. Near real-time performance. 1) Length of time from when each individual detector swath first fully contains the mine until the indicator is displayed on the operator's monitor. 2) Length of time from when each individual detector swath first fully contains the mine until the physical mark is made.	
b. Distance host vehicle travels between encounter of mine by sensor and stopping of the vehicle, when vehicle is travelling at required speed. 1) Vehicle speed. 2) Time from operator receipt of mine detection indicator to application of brake. 3) Time from application of brake to stopping of vehicle. 4) For pressure-fused mines, distance between tire or track of vehicle and mine.	

5.2 SYSTEM PERFORMANCE TRIALS DATA REQUIREMENTS	Footnotes
c. Given a detection, the ability of host vehicle to avoid the mine, when vehicle is travelling at required speed. 1) Vehicle speed. 2) Point of closest approach (PCA) when attempting to avoid the mine. 3) Time from operator receipt of mine detection indicator until steering-around attempt; i.e., until PCA is reached. 4) Success rate (i.e., number avoided/number detected) in avoiding mines.	
d. Advance rate during initial detection or "standoff alert" operation. 1) Vehicle speed, without attempting to verify alerts. 2) Pd and FAR during initial detection operation.	
e. Advance rate during verification of alerts. 1) Vehicle speed, while attempting to verify alerts. 2) Pd and FAR during verification.	
f. Standoff distance. 1) Distance from mine edge to vehicle edge at time of initial detection. 2) Distance from mine edge to vehicle edge at time of verified detection.	
g. Range for reliable data transmission (teleoperation only). 1) Range from the controller vehicle to the host vehicle recommended by the manual or contractor for teleoperation and data linkage. 2) Minimum range for data linkage and teleoperation demonstrated/measured. 3) Maximum range for data linkage and teleoperation demonstrated/measured. 4) Mean range for data linkage and teleoperation demonstrated/measured. 5) Operator ratings on the ability to control host vehicle at the range(s) prescribed by the contractor.	

3. TEST PLAYER SURVEY.

Trials Information

a.	Date			c.	Test Player ID	
b.	Trial ID			d.	System ID	

INSTRUCTIONS

This form is the operator's opportunity to provide feedback about the unit and system. Any comments made will be helpful in developing a system that will perform its mission safely and effectively, and without placing undue stress or hardship on the system operator.

The operator is asked to evaluate each item on this form and give a rating from 1 to 5, with the higher numbers being an easier/more comfortable/better score. Room is available on the last page for explanatory comments. The operator is requested to explain every 1 or 2 rating; any other comments are also helpful.

1. System Operation

a. Assembly:

1	2	3	4	5
Difficult				Not difficult

---

b. Operation:

1	2	3	4	5
Difficult				Not difficult

---

c. Alerts:

1	2	3	4	5
Could not understand				Easily understood

d. Understanding display:

1	2	3	4	5
Difficult				Not difficult

---

e. Changing batteries:

1	2	3	4	5
Difficult				Not difficult

---

2. MANPRINT/Human Factors/Ergonomics

(1) Helmet:

1	2	3	4	5
Uncomfortable				Comfortable

---

(2) Backpack:

1	2	3	4	5
Uncomfortable				Comfortable

---

(3) Holding wand:

1	2	3	4	5
Uncomfortable				Comfortable

---

(4) Moving wand repeatedly:

1	2	3	4	5
Uncomfortable				Comfortable

(5) Audio tones:

1	2	3	4	5
Harsh				Comfortable

(6) Display:

1	2	3	4	5
Hard to Read				Easy to read

(7) Controls:

1	2	3	4	5
Difficult				Not Difficult

3. Other

(1) Manuals and documentation:

1	2	3	4	5
Hard to follow				Complete, useful

(2) Safety during operations:

1	2	3	4	5
Operator is not safe				Operator is safe

(3) BIT:

1	2	3	4	5
Difficult or incomplete				Easy and complete

(4) Daily PMCS:

1 2 3 4 5

Difficult or incomplete Easy and complete

---

4. Comments

Item: ___

Comment:	

Item: ___

Comment:	

Part III-Organization of the Data Collection and Analysis.

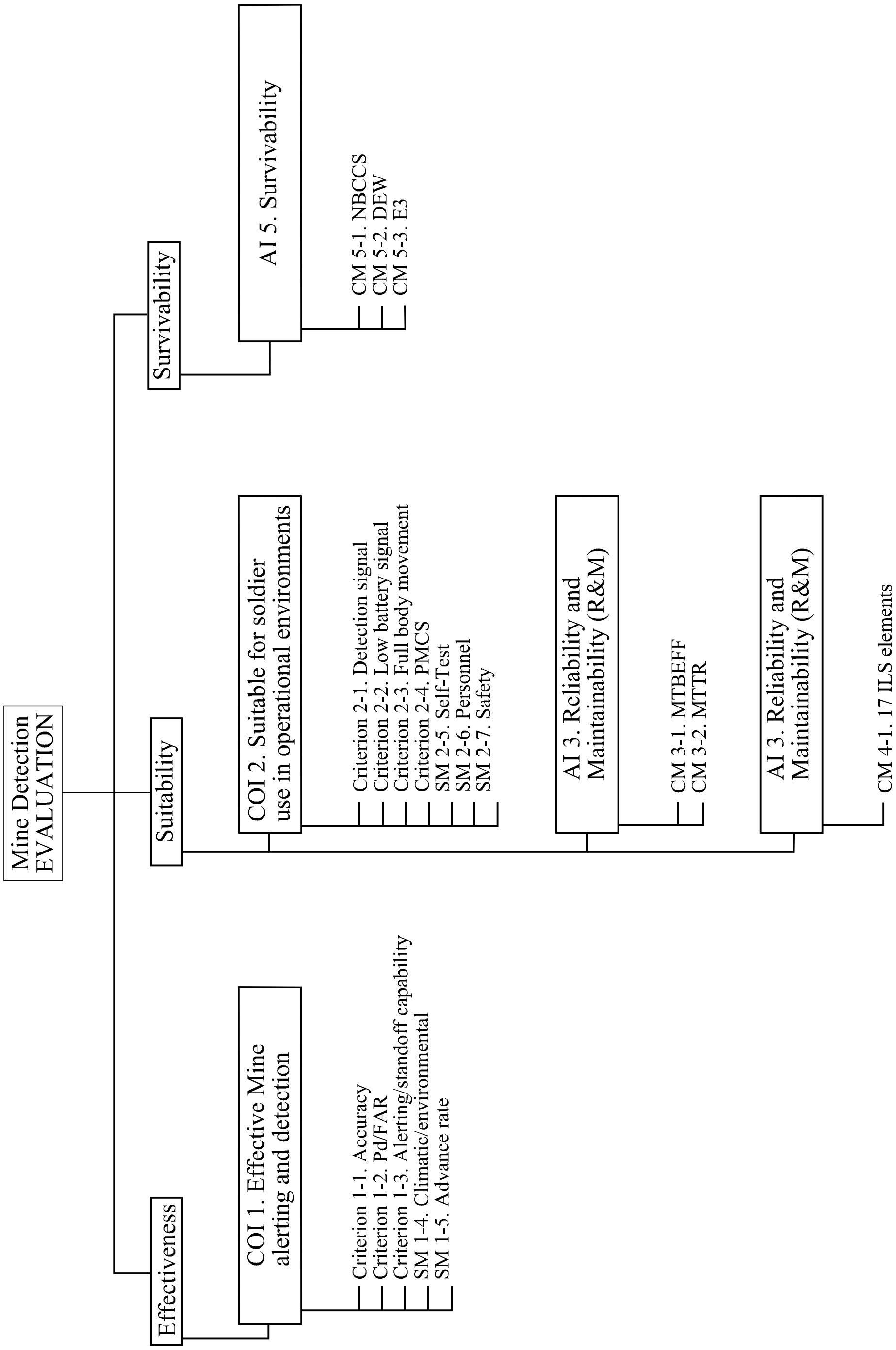
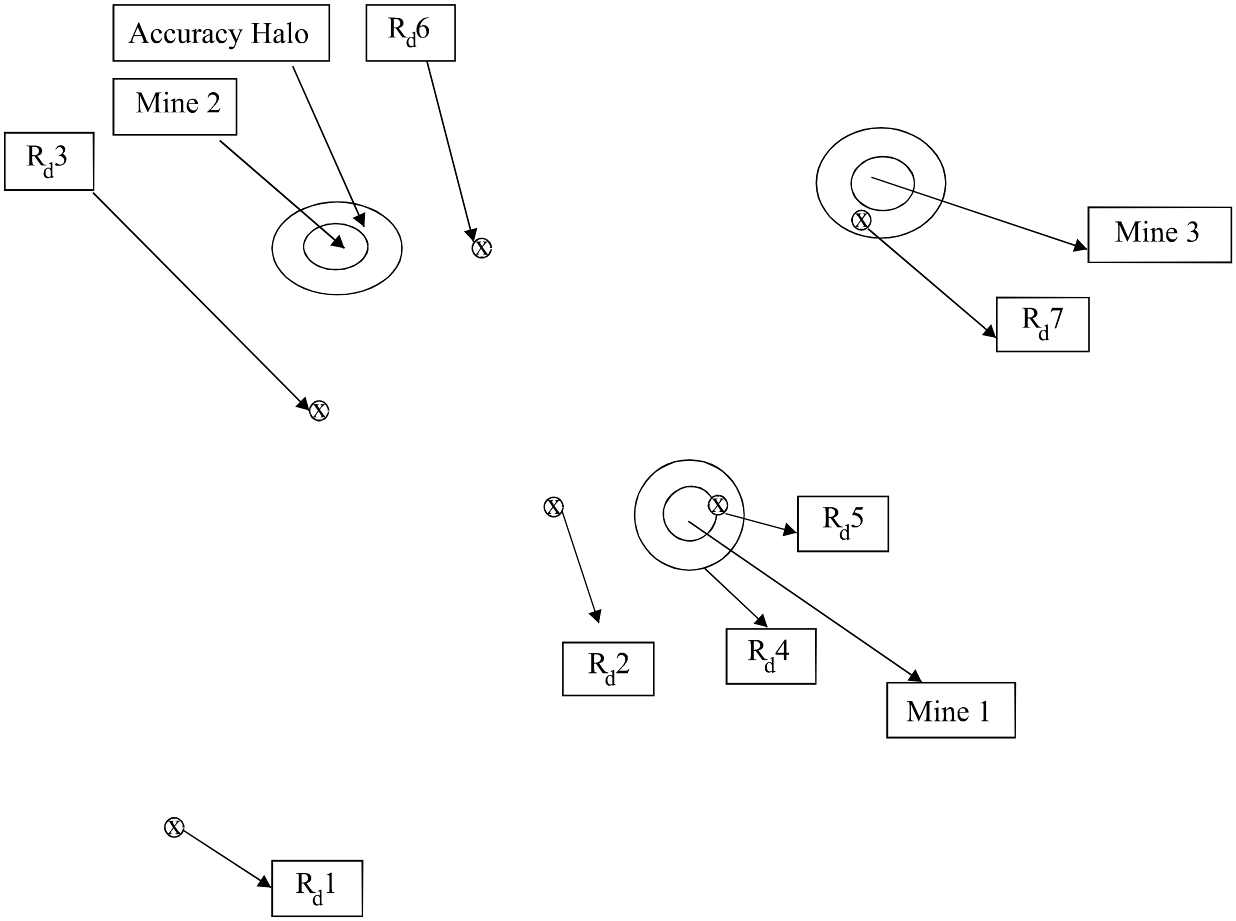


Figure A-1. Example of an Overall Analytical or Evaluation Approach for a Mine Detection System.



ΣE_d = 3 mines encountered
ΣR_d = 7 reported detections
ΣV_d = 3 valid (accurate) detections (R_d4, R_d5, R_d7)
ΣS_d = 2 scored detections (R_d4 & R_d7)
A_d = 1 additional valid (accurate) detection (R_d5)
ΣFA = 4 false alarms (R_d1, R_d2, R_d3, R_d6)
FAR = 4/area searched
Pd = 2/3 probability of detection

Figure A-2. Sample Mine Detection System Performance Trials.

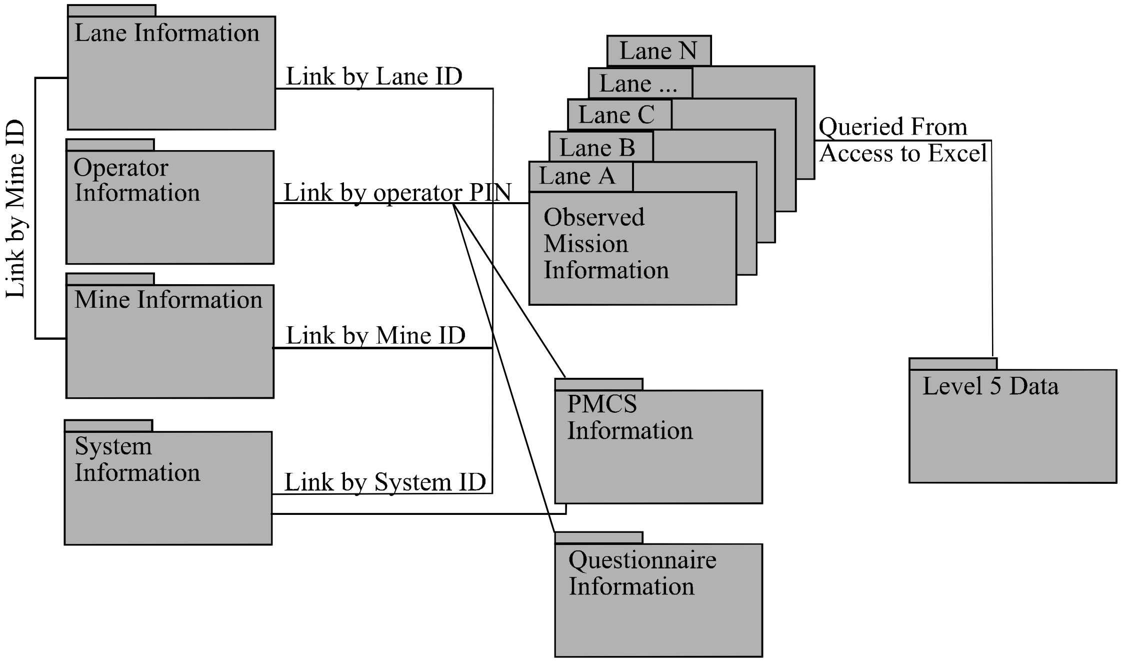


Figure A-3. Database Structure Concept.

The spreadsheet that follows provides an example of a Database resulting system performance trials predicated on the Database Structure Concept.

"EXAMPLE-DATABASE, SYSTEM PERFORMANCE TRIALS" Mission Number - Date - Configuration - Operator ID / Team ID - System ID - Uniform ID.

Mine ID	Mine Type	A11005A 11aug00 M/G S20 / A1 A002 U1	A11011A 11aug00 M/G S17 / A1 A003 U1	A11047B 13aug00 M/G/I S5 / A3 A005 U1	A11057A 13aug00 M/G/I S2 / A2 A003 U1	A11065A 13aug00 M/G/I S17 / A1 A003 U1	A11070A 14aug00 M/G/I S20 / A1 A003 U1	A11082B 14aug00 M/G/I S20 / A1 A005 U1	A11096A 15aug00 M/G/I S15 / A3 A005 U1	A11107A 18aug00 M/G/I S2 / A2 A005 U4	A11119A 18aug00 M/G S17 / A1 A005 U4	A11131B 19aug00 M/G S20 / A1 A002 U1	A11142B 20aug00 M/G S5 / A3 A002 U1	A11149A 20aug00 M/G S15 / A3 A002 U1	A11154A 20aug00 M/G S5 / A3 A005 U1	Totals
1110	SIM20			G	G			MG								3/14
1111	M16	MG	MG	MG	MG	MG	MGI	MG	MG	MG	MG	MG	MG	MG	MG	14/14
1112	SIM9			G												1/14
1113	SIM6			MG		MG										2/14
1114	M16	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	14/14
1115	M16	MG	MG	MG	MG	MG		MG	MG		MG	MG	MG	MG	MG	12/14
1116	M16	MG	MG		MG	MG		MG	MG		MG	MG	MG	MG	MG	11/14
1117	M15	MG	MG	MG	MG	MG			MG	MG	2(MG)			MG	MG	10/14
1118	M15	MG	MG	MG	MG	MG	MG	MG	MG	MG	2(MG)	MG	MG	MG		13/14
1119	M16	MG		MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG	13/14
1120	M15	MG		MG		MG		MG	MG	MG	2(MG)	MG	MG	MG	MG	11/14
1121	M15	MG	MG	MG	G,MG	MG	MG		MG		2(MG)	MG	MG	MG	MG	12/14
1122	M15	MG	MG		MG	MG	MG	MG	MG		2(MG)	MG	MG	MG	MG	12/14
1123	M15	MG	MG	MG					MG		MG	G				6/14
	Totals	11/14	9/14	12/14	10/14	11/14	6/14	9/14	11/14	6/14	11/14	10/14	9/14	10/14	9/14	
	Alarms	14	23	13	30	33	24	23	15	18	25	23	21	10	21	
	Detections	11	9	12	10	11	6	9	11	6	11	10	9	10	9	
	False Alarms	3	14	1	19	22	18	14	4	12	9	13	12	0	12	
	Multiple Hits	0	0	0	1	0	0	0	0	0	5	0	0	0	0	
	P_d	0.786	0.643	0.857	0.714	0.786	0.429	0.643	0.786	0.429	0.786	0.714	0.643	0.714	0.643	
	FAR (m□)	0.064	0.300	0.021	0.407	0.472	0.386	0.300	0.086	0.257	0.193	0.279	0.257	0.000	0.257	
	Time (s/m^2)	36.8	24.8	33.3	21.8	25.4	29.5	26.6	32.4	28.1	33.4	23.5	20.9	16.2	31.4	

NOTE: For the sample spreadsheet, the important variables that uniquely describe a given pass down a lane appear at the top of each column. These include the following: mission number; date; configuration, operator (contractor), team, and system ID; and uniform ID. The mine ID and mine type appear at the left of each table. An alphanumeric entry in one of the boxes indicates the mine was detected and which sensor detected it. Multiple hits are included as well. Totals for each mine ID appear at the right side of the table, and totals for a given test run appear at the bottom of each table.

Statistics for each test run appear at the bottom of each column. “Alarms” are all sensor target declarations that occurred within the lane, “Detections” are mines for which the sensor indicated an alarm within the ##-cm halo, “false alarms” are all alarms not within ##-cm of the edge of an emplaced mine, and “multiple hits” are redundant detections. The sum of detections, false alarms, and multiple hits is equal to the number of alarms. P_d is the number of detections divided by the number of mines emplaced in the lane. FAR is the number of false alarms divided by the area of the lane in which a false alarm can occur. The time to scan one square meter of ground is given in seconds per meter squared.

APPENDIX A2. SAMPLE TEST DESIGN FOR EXPERIMENTAL TRIALS OF MAGNETIC INDUCTION AND GROUND PENETRATING RADAR DETECTION SYSTEM.

1. SCOPE.

1.1 Introduction.

This Appendix provides sample guidance on procedures that may be used in the detectability performance testing of mine detection equipment for demining equipment (handheld or vehicle mounted). Specific test procedures guidance for other testing such as reliability, ruggedness, human factors, etc. is not addressed.

1.2 Limitations.

The Appendix provides a narrative outline for testing of portable or handheld detection equipment using magnetic induction and ground penetrating radar (GPR) sensors. With review and/or slight modification this guidance may also be suitable for vehicle mounted detection systems and detection systems using IR or other sensors.

The Appendix is provided for testing detection equipment in Sensor Experimentation Facilities. With review and/or slight modification this guidance may also be suitable for sensor verification area or minefield test area testing.

The Appendix is provided for testing of detection equipment using simulant mine (SIM) standard test targets (STT's). With review and/or slight modification this guidance may also be suitable for testing using surrogate mine (SUM) STT's or live mine targets (LMT's). The types of targets are described in document "Target standardization for demining testing" Other similar targets are described in references 7 and 8 of Appendix D.

2. TESTING.

2.1 Sensing Envelop Testing.

Record equipment response when passing directly over a surface emplaced target at the manufacturers recommended head operating height. Repeat test passing at increasing offset distances from the target centerline until the target is no longer detectable. Increase distances from the target centerline in either 2 or 4cm increments. For non-symmetrical targets repeat testing along other target axis's. Repeat testing with different size targets and/or targets containing different amounts of metal.

2.2 Target Depth Testing.

Record equipment response when passing directly over a surface emplaced target at the manufacturers recommended head operating height. Repeat test with the same target at increasing burial depths recommended in document "Target standardization for demining testing"until the target is no longer detectable. Repeat testing with different size targets and/or targets containing different amounts of metal.

2.3 Target Size Testing.

Record equipment response when passing directly over a surface emplaced target at the manufacturers recommended head operating height. Repeat testing with different size targets and/or targets containing different amounts of metal until the target is no longer detectable. Repeat testing at increasing burial depths recommended in document "Target standardization for demining testing"

2.4 Test Excursions.

Conduct the above tests with changes to the following variables:

a. Different head/antenna operating heights and tilts

b. Faster or slower sweep velocities

c. Wet detector heads/antennas (mist or immersion)

d. Batteries in varying state of charge

e. Time or temperature effect on sensitivity drift/stability

f. Different sensitivity or control settings on the equipment under test

2.5 Soil/Overburden.

2.5.1 Soil Type Selection. Depending on the type of equipment under test repeat above testing with different type soils. At a minimum consider the following or similar type soils:

a. Dry sand

b. Wet clay/loam

c. Magnetite sand (30%)

2.5.2 Soil Conditions. Consider testing in soils ranging from very dry to those completely saturated from high water table conditions. Consider that some detection equipment may be required to operate in soil with high levels of salts. Soil moisture may be non-homogeneous. Natural or artificial ice/snow can be placed on the soil. The soil may be frozen ranging from just a few centimeters to far below the test targets. The soil surface can be misted or soaked to simulate conditions shortly after a rainfall. Consider that the degree of soil surface roughness can strongly influence the performance of some GPR sensors. Consider that the detection system may have to operate on unimproved roads that may be gravel rather than soil. Consider that the soil may support vegetation.

2.5.3 Soil/Overburden Clutter. Clutter is an object or feature that interacts with a detection sensor in a way similar to or identical to a mine. Clutter can be that naturally existing at the test area or emplaced there just for test purposes. Clutter can be natural or manmade. Clutter location, like target location, can be documented. However if the test site selected is left undisturbed this creates a dilemma in that the natural clutter location might have to be determined using various detection sensors. Clutter includes pieces of magnetic and non-magnetic metal, roots, holes, rocks of various composition and size, unusual soil/overburden stratifications and discontinuities, wood, plastic, etc. The discrimination of mines from clutter is perhaps the most challenging component of effective detection system design.

2.5.4 Soil Condition/Clutter Selection. The ratio of probability of detection to false alarms rates (Pd/FAR) is frequently used as the final measure of detection system performance. This ratio is primarily dependent on the detection equipment capability, its sensitivity settings, the type, number and emplacement of targets in the test area, the soil or overburden, the considerations in paragraph 2.4, and the clutter. To systematically address these variables it is recommended that detection equipment performance first be tested and baselined in homogenous soil conditions (without clutter or any property stratification). Keep the surface soil smooth and without vegetation or clutter. Address equipment performance and test excursions (paragraph 2.4) in different soil types and moisture conditions before introducing other conditions or variables.

3. TEST DESIGN.

3.1 Detection Equipment Testing.

Detection equipment testing should progress logically and systematically from laboratory experimental and sensor experimentation facility testing through sensor verification area and minefield test area testing. Test program phases should be planned together to be synergistic and support each other. Progression through the test program should provide increasing confidence that the capabilities and limitations of the equipment under test are defined and understood better and better.

3.2 Testing Objectives.

Testing objectives will impact on the test design. Some examples of testing objectives are as follows:

a. To benchmark system or subsystem performance.

b. To determine if a change to equipment design has improved performance.

c. To determine what piece of equipment performs better.

d. To determine if a piece of equipment meets minimum performance characteristics.

e. To determine with a very high degree of confidence the exact performance capabilities of the equipment.

f. Quality control/sampling type testing.

Test objectives will impact on what test data should be collected and number of data points required to achieve the desired degree of statistical confidence.

The results from earlier phases of testing can be used to design later phases of testing. For example if targets are undetectable under ideal lab type conditions it is usually not worthwhile to obtain data under more difficult real world type environments. Conversely if targets are known to be easily detectable don't design a test to obtain numerous data points providing redundant verification of this. Keep in mind that certain levels of performance (or test objectives) may require more or less tolerance in accuracy of data than others. If the P_d is 35 ±15% this may be accurate enough. The performance might be unacceptable across the range from 20 - 50%. Why run encounter after encounter vs. a target if the initial data was 0/10? It may be possible to truncate the test at that point. If initial testing indicates that P_d is 84 ±12% under a particular condition, that is a condition that needs more encounters. A real/actual Pd of 96% is very good but an actual P_d of 72% may be far short of acceptable.

Laboratory experiments, sensor experimentation facility testing and sensor verification area testing will be conducted with the targets in locations either known or unknown to equipment operators depending on test objectives.

document "Target standardization for demining testing" including surface emplacement, has a maximum of 6 burial depths. The detection SIM's in document "Target standardization for demining testing" are available in 6 sizes and each size has 6 different levels of metal inserts. To obtain test data against the compete range of SIM/emplacement combinations would require a matrix of 6x6x6 for a total of 216 variations. This results in a large number of data points if more than one encounter were required at each of the 216 conditions. However each condition is not independent. Each of the points (voxels) in the 6x6x6 matrix has 26 neighbor voxels so a good degree of statistically valid data can be obtained with only one target encounter at each condition.

The 6x6x6 matrix can also be reduced by limiting the number of metal inserts and burial depth conditions. Mines on the surface may not be a concern. AP mines can be limited to 2 burial depths since they are usually emplaced close to the surface to be sure the fuse properly activates. AT mines can be limited to 3 depths since burial at 20 and 30cm is rare. By judiciously limiting the number of test conditions the matrix can be reduced to something smaller (e.g. 6x3x3). However this is a tradeoff since more encounters may be required for each condition to achieve the necessary degree of statistical confidence since the voxels are more independent conditions and there will be more voxels at the edge of the matrix with less neighbors.

As testing progresses from the laboratory experiments to the minefield test area test phase work should be progressing in defining the complete possible volume of target/depth/soil parameter conditions as black or white (green/red, easy/can’t do). The more expensive time consuming minefield test area tests might be able to focus on the encounters in the yellow area and in the known red or green areas where a high degree of statistical confidence is necessary.

APPENDIX B. ABBREVIATIONS.

Aa	Additional Accurate Detection
BIT	Built-In Test
BITE	Built-In Test Equipment
EDRS	Electronic Detection Reporting System
EMD	Engineering and Manufacturing Design
FA	False Alarm
FAR	False Alarm Rate
HHA	Health Hazard Assessment
ILS	Integrated Logistics Support
ILSP	Integrated Logistic Support Plan
IR	Infrared
IRIG	Intra-Range Instrumentation Group
LBE	Load-Bearing Equipment
MFP	Materiel Fielding Plan
MOE	Measure Of Effectiveness
MOP	Measure Of Performance
MTBEFF	Mean Time Between Essential Function Failures
MTTR	Mean Time To Repair
OMS/MP	Operational Mode Summary/Mission Profile
OOTW	Operations Other Than War
ORD	Operational Requirements Document
PCA	Point of Closest Approach
P_d	Probability of Detection
PMCS	Preventive Maintenance Checks and Services
RAM	Reliability, Availability, and Maintainability
RCRIT	Critical Radius
SSP	System Support Package
TIR	Test Incident Report
TM	Technical Manual
TMDE	Test, Measurement, and Diagnostic Equipment
TP	Test Participant or Player
TTZ	Target Tolerance Zone

APPENDIX C. DEFINITIONS OF SENSOR PERFORMANCE AND SUGGESTED ANALYTICAL METHODS.[7]

1. Definitions of Sensor Performance and Suggested Analytical Methods are not yet standardized internationally. Certain key definitions of interest to the evaluation of sensor performance and the tempo or efficiency of detection operations are presented below in 1.1-1.7. Specific definitions and sensor performance analytical methodologies are presented in paragraphs 3, 4 (pending), and 5, to provide a starting point for definition of key mine detection parameters or events and analysis of mine detection data in a manner relevant to human or vehicle-platform mounted systems. For detection systems, other than mine detection systems, the term mine may be used interchangeably with ordnance or projectiles without affecting the definitions or analytical methods below.

1.1 ROA = Rate of Advance = Area/Unit of Time (Human Platform)

1.2 ScR = Scan Rate = Area Scanned or Covered/Unit of Time

1.3 SwR = Sweep Rate = Distance Traveled (lateral sweep)/Unit of Time;
AR = Advance Rate = Linear Forward Progress/Unit of Time

1.4 Detection Probabilities:

$P_{d(true)}$ = Number of Mines Detected/Number of Mines $(N)^{\text{see note 1}}$ in Lane or Swept Area

$P_{d(measured)}$ = Number of Declarations that meet the rcrit (mine+halo) criteria/$(N)^{\text{see note 2}}$

Note 1: $P_{d(true)}$ implies that lucky matches may occur.
Note 2: $P_{d(measured)}$ implies that due to target merging, two targets may appear as one or that multiple declarations may need to be rescored as one declaration after review of truth and test data.

1.5 FAR = False Alarm Rate = False Alarms/Unit Area or False Alarms/Linear Distance along a specified track or front width.

1.6 P_{FA} = Probability of False Alarm

1.7 r_{crit}=Critical Radius or "halo"$^{\text{see note 3}}$.

Note 3: Each detector will have a critical radius or "halo" in which a detection can occur at a distance relative to the center of the detector head. This implies that a detection can occur with a standoff distance between the center of the detector head and the edge of the mine(s). The "halo" performance envelope is determined experimentally for each integrated sensor type. It may be circular (implying an equidistance in all directions) or perhaps an irregular footprint area when overlaid on the surface of the ground. Therefore, rcrit or "halo" implies the distance or footprint area in which a detection alert can occur with reasonable probability (see example illustration, Appendix A1, Part III, Figure A-2 Sample Mine Detection System Performance Trials). Hence, a marked detection that occurs within the rcrit or "halo" is scored as a valid alert.

3. Method 1-Definition of Sensor Performance and Suggested Analytical Methods for a Teleoperated Vehicle-Platform Mounted System (Reference 9, Appendix D (unpublished)).

3.1 Analytical Design Concept. In the mine-detection test and analysis arena for a Teleoperated Vehicle-Platform Mounted System which uses a route reconnaissance search method, some determination must be made regarding the “scoring” of reported detections as valid or invalid. The accuracy criterion will be used to make this determination; i.e., if the location of the detection declaration is within a “halo” about the perimeter of the mine that is the distance of the accuracy requirement away from the mine, the detection is considered valid. Thus, all valid detections will, by definition, meet the location accuracy requirement. The method for scoring the accuracy of results will or may be by an electronic detection reporting system (EDRS) that each of the candidates is or may be required to provide; i.e., a recorded output from the detection system which precisely tracks where the detection occurred and can be compared with the ground truth. This EDRS will not necessarily be a part of a fielded system but may be the scoring tool for the test and analysis. The rationale is that the detection capability will be more truly indicated by the EDRS than a physical mark and that detection capability is the focus of the analysis.

3.2 Definitions. Note that, although it is possible for there to be more than one accurate detection of a single mine (more than one indicator within the accuracy requirement), for calculation of the probability of detection (P_d) only one detection per encounter will be counted. This is because P_d is a probability which must be accumulated on a per encounter basis; if the total number of accurate detections (which could be more than one per encounter) and the total number of encounters are merely accumulated, the result might show a higher P_d than was actually demonstrated (the calculated P_d could conceivably be greater than one). However, a count will be kept of the number of additional accurate detections (Aa) per mine encounter and the results will be reported. Although this is or may not be directly related to a user requirement, it is a useful measure, in addition to the false alarm rate (FAR), of the degree to which an overly sensitive system might impede the vehicle’s forward movement. It is intended that P_d, FAR, and Aa be analyzed as a function of operator, soils, climate, light condition, vehicle advance rate, vehicle type, mine type(s), etc. The following defined parameters apply for the detection tests:

E = an encounter of a mine by the sensor ($\Sigma E=N$ see 1.4)
R = a reported detection

A = an accurate detection; i.e., a reported detection within the required accuracy (defined by the critical radii (rcrit)) or “halo” of any mine detection system)

S = a single, “scored” accurate detection for a single encounter

Aa = an additional accurate detection

FA = False alarm: a reported detection outside the allowed accuracy (defined by the critical radii (rcrit)) or “halo” of any mine detection system)

FAR = the sum of FAs per linear km searched

Thus,

$P_d{}^* = \Sigma S/\Sigma E$ (where $P_d \leq 1$)

$\Sigma Aa = \Sigma(A - S)$

$\Sigma FA = \Sigma R - \Sigma A$

$FAR = \Sigma FA$/km or unit area

* P_d for any minefield test area with a given set of conditions should be presented in test reports as a numerical ratio, rather than a point estimate. This will allow for statistical tests and combining of data where possible. For the test, an accepted confidence bound (such as 80%) will be compared with the requirement.

4. Method 2-Definition of the Discriminating Power for a Detection System .

4.1 Definition: The discriminating power of a detection system characterises the distance between two targets under which the detection system can only detect one target instead of two. This distance is also called the discriminating distance. Determining the discriminating distance may be useful to evaluate, for instance, the ability of a system to detect a AP mine buried near a AT mine in order to slow down the demining operations.

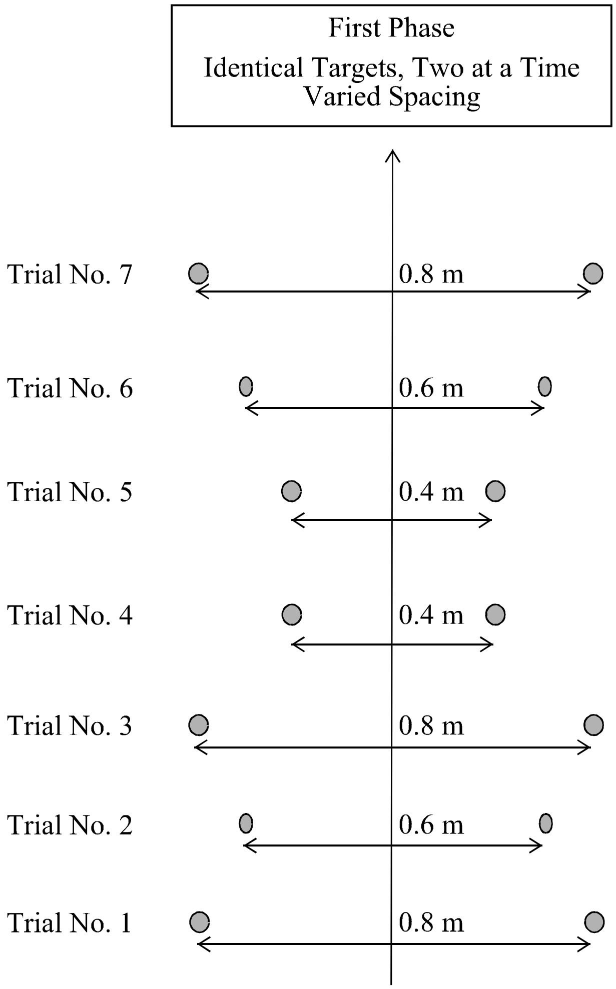
4.2 Method: How the test will be conducted depends on the nature of the detection system under test (GPR, magnetic sensor, etc.) and on the mean used by the system to deliver the information to the operator (sound, spot on computer screen, etc.).

Indeed, in the case of a magnetic hand held detection system the test consists in moving the sensor above two targets separated by a variable distance. The aim is to determine the distance separating the two targets under which the detection system deliver only one continuous sound that doesn't allow to say that there are in fact two targets. In the case of a more sophisticated system, such as a GPR, the system deliver the information through a computer screen. The test consists in moving the antenna above the two targets. The aim is to determine the distance separating the two targets under which the operator can see only one spot on the screen, and therefore can't say that there are two targets.

4.3 In practice, repeat the test several times and change the following parameters:

Burial depths,
The distance between the two targets,
Soil composition and texture,
Types of targets (size, material…).

First the two targets are the same (see Figure C-1). Just change the soil composition, the burial depth, and the distance between the targets. Then, in accordance with the results, use two different targets (see Figure C-2). Below are examples of implementation used for testing a hand held detection system (magnetic sensors):



For all tests, targets are the same.

Trial No. 1: 2 spheres, 10 mm diameter, steel

Trial No. 2: 2 spheres, 5 mm diameter, steel

Trial No. 3: 2 spheres, 5 mm diameter, magnetic method

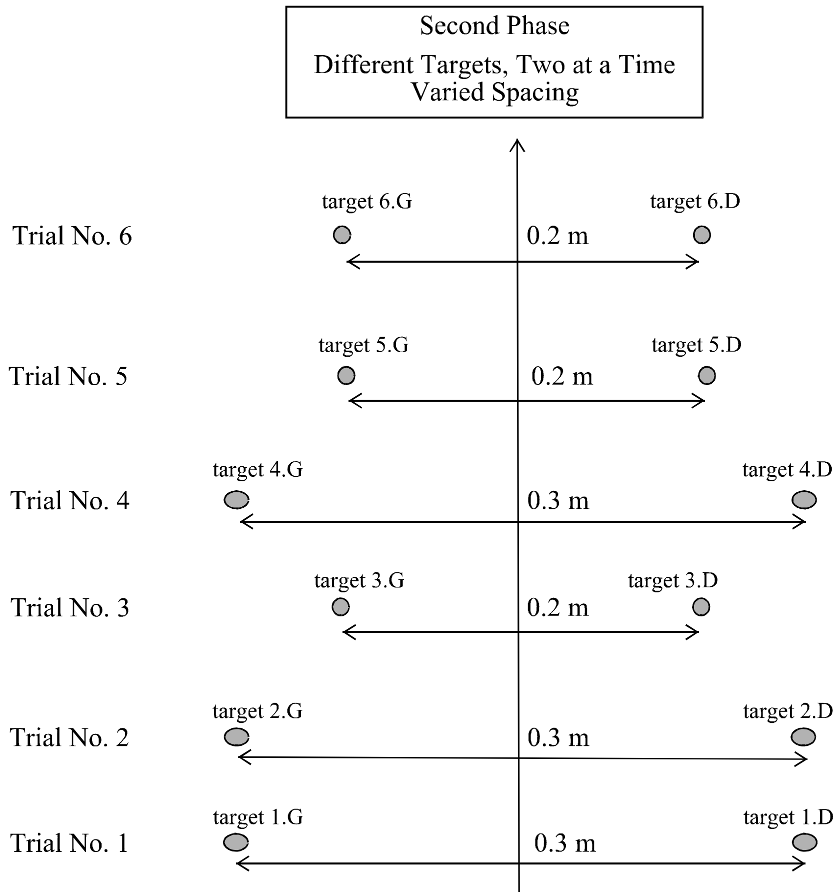
Trial No. 4: 2 spheres, 10 mm diameter, magnetic method

Trial No. 5: 2 spheres, 10.319 mm diameter, non-magnetic method

Trial No. 6: 2 spheres, 5 mm diameter, non-magnetic method

Trial No. 7: 2 spheres, 9.85 mm diameter, brass

Figure C-1. Test Layout for Detection of Identical Targets.



For all tests, targets are different.

Trial No. 1: target 1.G: sphere 10 mm diameter, magnetic method
target 1.D: sphere 10.319 mm diameter, non-magnetic method

Trial No. 2: target 2.G: sphere 10 mm diameter, steel
target 2.D: sphere 5 mm diameter, steel

Trial No. 3: target 3.G: sphere 5 mm diameter, steel
target 3.D: sphere 5 mm diameter, magnetic method

Trial No. 4: target 4.G: sphere 10 mm diameter, magnetic method
target 4.D: sphere 5 mm diameter, magnetic method

Trial No. 5: target 5.G: sphere 10 mm diameter, steel
target 5.D: sphere 9.85 mm diameter, brass

Trial No. 6: target 6.G: sphere 10.319 mm diameter, non-magnetic method
target 6.D: sphere 9.85 mm diameter, brass

Figure C-2. Test Layout for Detection of Different Targets.

5. Method 3- Definitions and Suggested Analytical Methods for Determination of Effective Range for Vehicle Platforms.

5.1 Analytical Design Concept. This technique is suggested as a means to measure the characteristics necessary to quantify the performance of a detection system in respect of range. It is of relevance to systems that may be classed as "high vulnerability" such as vehicle mounted systems for which detection of a target requires a quick alteration to the search pattern. For such situations, the detection range is a vital parameter, because it regulates the search rate, it being an absolutely necessity that an alarm is raised in time for the platform to take evasive action. The foregoing gives rise to the following definitions:

5.2 Definitions.

5.2.1 Detection Range R_d. The distance from a target to the detection sensor at which a given probability of detection, P_d will be achieved. P_d refers to the probability of detecting mines when no distinction between mines and non-mine objects such as battlefield scrap is drawn, and refers to the probability of detecting an anomaly (mine or spurious target) when there is a classification stage following the detection of an anomaly.

5.2.2 Detection Annunciation Time, T_{ad}. The average time taken from initiating a detection system at a distance R_d from a target to the annunciation of an alarm, it being assumed that the detection system either operates by "staring", or, if by scanning, then scanning is limited to cross-range scanning over a narrow beamwidth, such that the scanning time is insignificant in comparison with T_{ad}. In situations where there is a classification capability, T_{ad} refers to the time to annunciate the detection of an anomaly, but not to classify it.

5.2.3 Classification Range, R_c. The distance from a target to the detection sensor at which a given probability of classification, the probability of correctly classifying a landmine when non-landmine anomalies are also present, P_c, will be achieved.

5.2.4 Classification Annunciation Time, T_{ac}. The average time taken from initiating a detection system at a distance R_c from a target to the annunciation of a classified landmine target, it being assumed that the detection system either operates by "staring", or, if by scanning, then scanning is limited to cross-range scanning over a narrow beamwidth, such that the scanning time is insignificant in comparison with T_{ac}.

5.3 From the foregoing, the concept of effective range, and further definitions, follow:

5.3.1 Effective Detection Range, R_{ed}: The distance of the sensor from the anomaly when the presence of the anomaly is signalled. Evidently,

$$R_{ed} = R_d - T_{ad}.V \tag{1}$$

(Where V is the vehicle speed towards the anomaly). This situation is illustrated in Figure C-3.

5.3.2 Effective Classification Range, R_{ec}: The distance of the sensor from a landmine when, following anomaly detection and classification, the presence of the landmine is signalled. Evidently,

$$R_{ec} = R_c - T_{ac}.V \tag{2}$$

The significance of the distinction between R_{ec} and R_{ed} is that a search rate based of the use of R_{ed} would require the platform to avoid all anomalies detected, even any subsequently classifies as non-mine, whereas a search rate based on R_{ec} would allow a platform to continue unless a landmine target were detected.

5.4 A methodology for determining the detection range and related parameters is required; not all these can easily be measured directly. One possibility is to conduct several tests for which the platform is moved towards a mine target at differing speeds, V_1, and V_2. Equation (1) shows that this will generate two effective ranges, R_{ed1} and R_{ed2}, which can be measured directly, given suitable instrumentation. Application of equation (1) gives:

$$R_{ed1} = R_d - T_{ad}.V_1 \tag{3}$$
$$R_{ed2} = R_d - T_{ad}.V_2 \tag{4}$$

Subtraction of these equations yields:

$$R_{ed1} - R_{ed2} = T_{ad}\left(V_2 - V_1\right) \tag{5}$$

As the speeds will be known, T_{ad} can be determined, from which R_d can then be determined. R_c can be determined from measurement of R_{ec} at different speeds in an analogous manner.

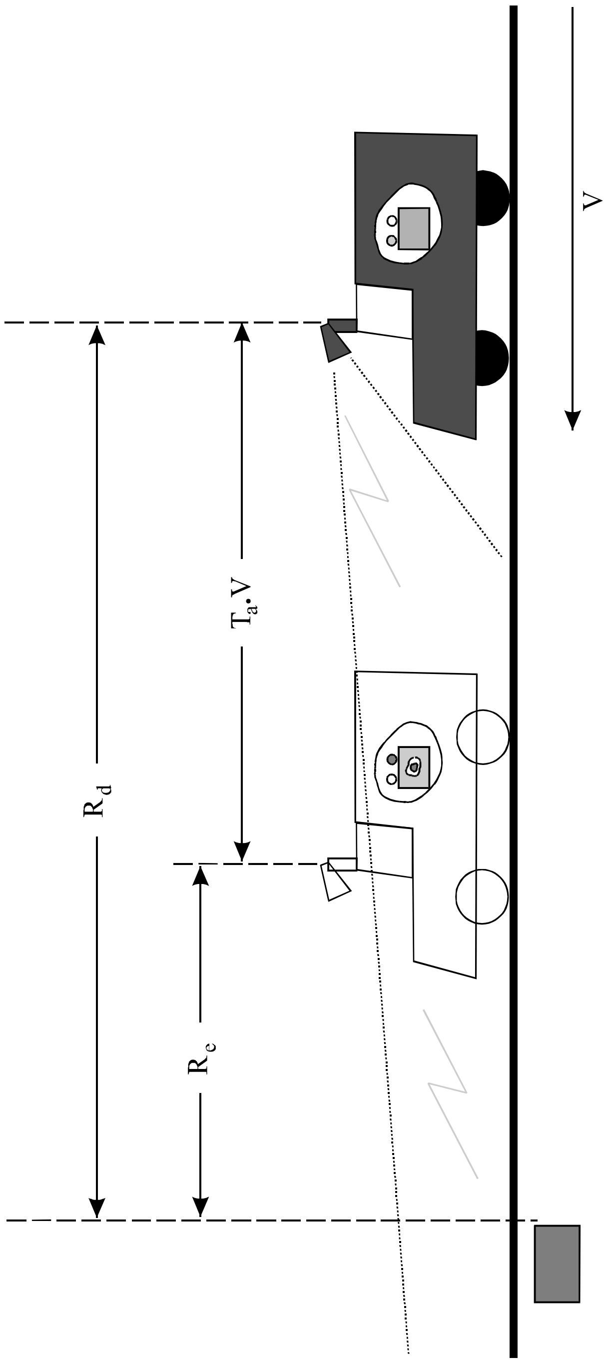


Figure C-3. Effective Detection Range.

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