New Training Tools: Enhancing Mine Detection Performance

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New Training Tools: Enhancing Mine Detection Performance

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### Background

The effectiveness and proficiency with which a handheld buried ordnance detection system operates is contingent on two properties: the detection capabilities of the sensor and the operator's skill in manipulating it while interpreting meaning from its audio output. With recent advancements in buried ordnance location technology, adding ground penetrating radar (GPR) with electro-magnetic induction (EMI) sensing places much greater importance on detector sweep motion as a prerequisite to improve detection and reduce false alarm performance. Proper operation requires the user to sweep an area completely without gaps, with the detector head motion controlled within proper speed and height above ground limits. Proper employment of the detector within acceptable ranges of each of these variables is required to maximize the detection capabilities of the system.

The U.S. Army is developing two new operator training capabilities to ensure that the improvements in detector performance are matched by improvements in operator proficiency. The first, deployed in 2003, is the Sweep Monitoring System (SMS). A further advancement on the SMS, called the Software-Driven Virtual Minefield (SDVM), is expected to be ready in 2006.

The Sweep Monitoring System

The SMS tracks the movement of the wand's detector head using an advanced video tracker, which allows for operator training and proficiency measurement independent of detector performance. The SMS employs two video cameras and a real-time tracking algorithm to track the movement of a target through space (Figure 1). In this application, the "target" is a brightly colored foam ball, which is mounted atop the detector. A functional block diagram for the SMS is provided in Figure 2. The SMS is programmed to track the movement of this ball continuously in real time, and it computes a
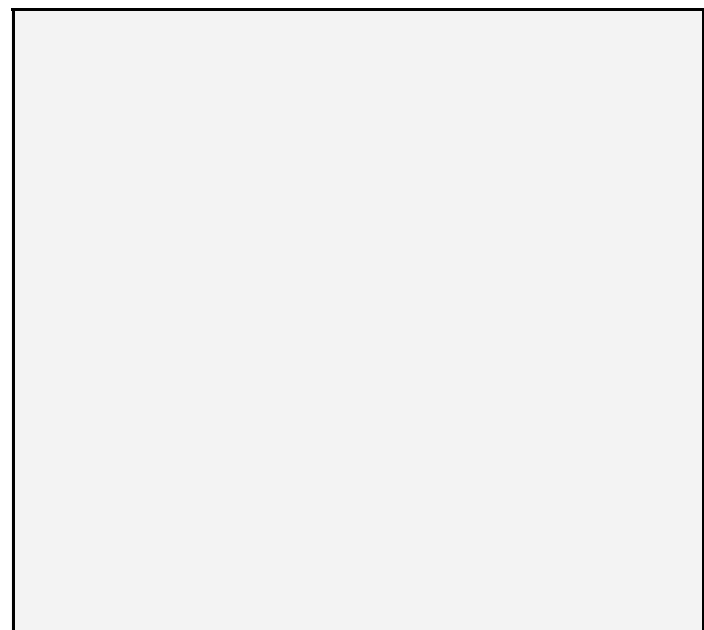
three-dimensional location (x, y, z with time) for the target ball 30 times per second. From this positional data, the SMS measures sweep parameters essential for optimal use of any handheld detector: speed or rate of sweep, height of the sensor above ground, coverage gaps and coverage area. The system is configured to monitor a mine lane up to two m wide by 25 m long. The lane may be established on a plot of ground allowing inert training mines or mine simulators to be buried at selected locations throughout the lane. In such applications, the trainee using any handheld detector may train to the acoustic signal output of the detector while the SMS independently monitors the trainee's performance. The SMS may also be used indoors or shipboard allowing trainees to establish or refresh operational skills.

Figure 1

Although the SMS is suited for use with any handheld mine detector, it has been specifically adapted for use with three different detectors: AN/PSS-14 Mine Detection Set, AN/PSS-12 and Minelab F1A4.

Figure 2

Employment of the SMS

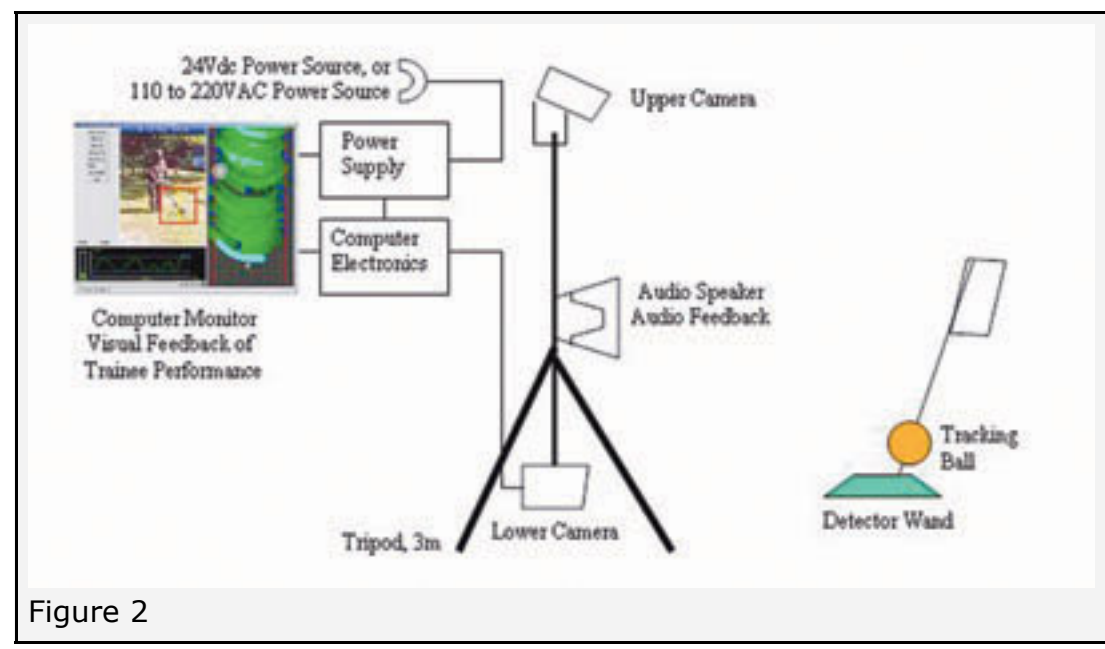The SMS is a portable training aid that can be set up anywhere and readied for operation within 15 minutes. It can be used to begin initial skill acquisition on each critical variable individually. These critical skills can be trained in any order or combination. Particularly noteworthy concerning coverage gaps is the tendency to leave a gap in coverage after interrupting the sweep pattern. This behavior is seen most often after detecting a mine and localizing the object, a task that requires the trainee to alter the sweep pattern.

Upon successfully acquiring the critical skills individually, the 25 m lane creates the opportunity to train the integration of each of these skills to competently employ a battlefield mine detector. It is likely that instructors will use several of these approaches. The goal for the SMS includes providing a system with the capability to allow flexible use by the instructors.

Whether the instructor is training critical variables individually or collectively, immediate performance feedback is a critical part
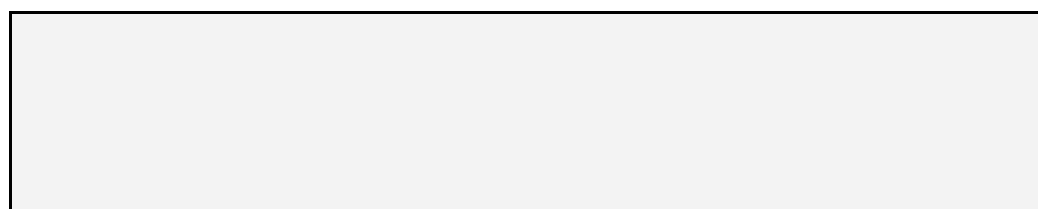
of the training process.

The SMS provides trainee feedback in the real-time graphical displays using color, coverage and a speed/height dynamic line-bar graphic display. At the end of every training session, quantitative summary performance measurement is computed in terms of coverage rate statistics, covered area statistics and mine target location. Real time audio feedback is provided in verbal messages based upon the acceptable ranges selected for the critical variables. These messages include, "too fast," "too slow," "too high," and "gap."
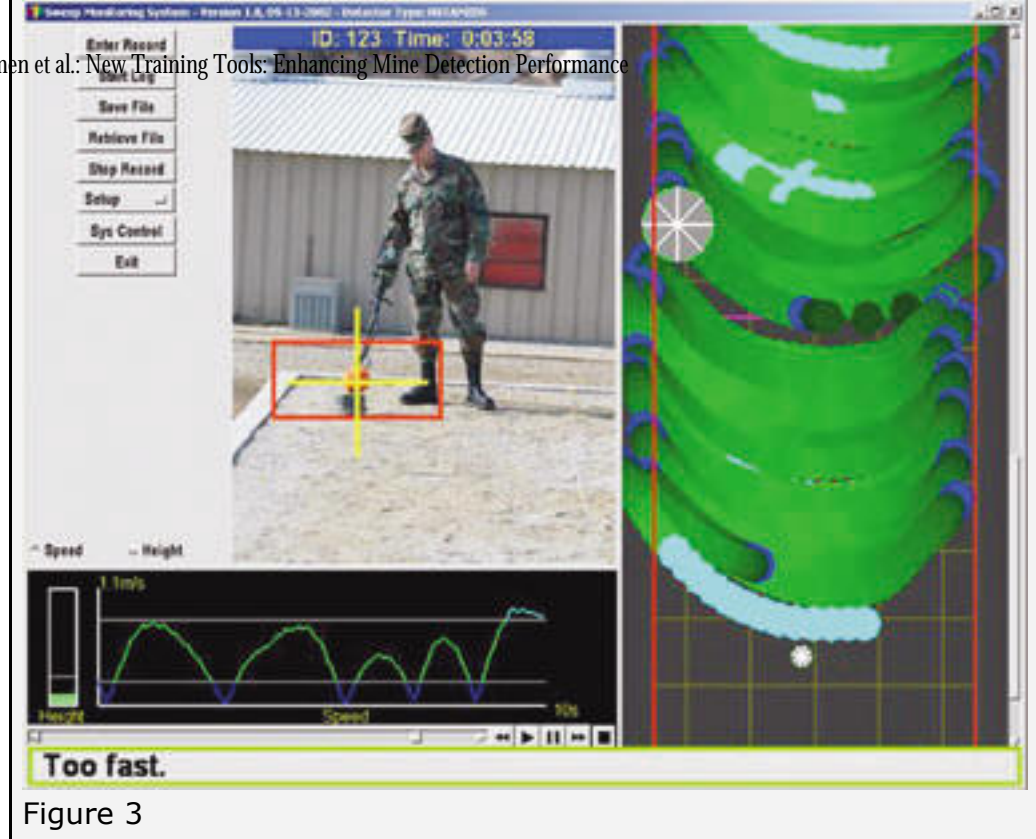
Figure 3

The main display window (Figure 3) appears after system initialization. This display is divided into the following six sections:

1. The left side of the display is the master control panel.
2. At the upper center is the live video presentation.
3. The right side of the display is the coverage area display.
4. The lower left is the speed/height display.
5. Below the speed/height display are the playback controls.
6. Across the bottom of the display is the status bar.

In the normal training mode, the video presentation window shows the top camera video. Crosshairs are provided to indicate which object the camera is tracking. The locations of mine markers are also overlaid on the video display and the coverage area display. Each mine begins to spin as the sweep approaches and they change color as the sweep passes: green if the parameters are correct and red if incorrect.

The coverage area display shows the progress of the trainee in real time. The display can provide coverage and either speed or height data selected using the speed/height buttons. In Figure 3, the sweep performance speed is overlaid on the area coverage display by color; blue indicates the sweep speed is too slow, green indicates acceptable speed, and aqua indicates the sweep speed is too low for good detection performance.

Software-Driven Virtual Minefield

A good training site is one of the most important components of a successful training program for landmine detection. A perfect site would consist of numerous mine lanes with each lane presenting the different conditions that the operator will encounter operationally. For example, one lane may have a mixture of mostly anti-tank, low metallic (AT-LM) mine lanes with a few anti-personnel low-metallic (AP-LM) mines, while another lane might have only AP-LM. In addition to the layout and the type of buried mines, an ideal training site would also vary the type of soil and ground surface. A mine that can be detected easily when it is buried in sand might be very difficult to detect when it is buried in moist topsoil with grass cover. Another complicating factor in setting up mine lanes for

training is clutter. In some training situations, clutter is desirable, but in other situations it is desirable to remove as much clutter as possible. Controlling the amount of clutter requires the area to first to be cleared completely of metallic objects and debris. In aggregate, these factors contribute to the complexity, expense and time required to set up a proper training area. Additional complications and expenses are encountered if changes in the mine layout and types are required, necessitating recovery of all the buried mines and burying them again at different locations.

SDVM is being developed to address these issues. It offers an additional new training capability built on top of the SMS. The SMS provides a training capability with cueing and subsequent feedback based on tracking both the position and sweep rate of the detector head. SDVM adds to that capability the
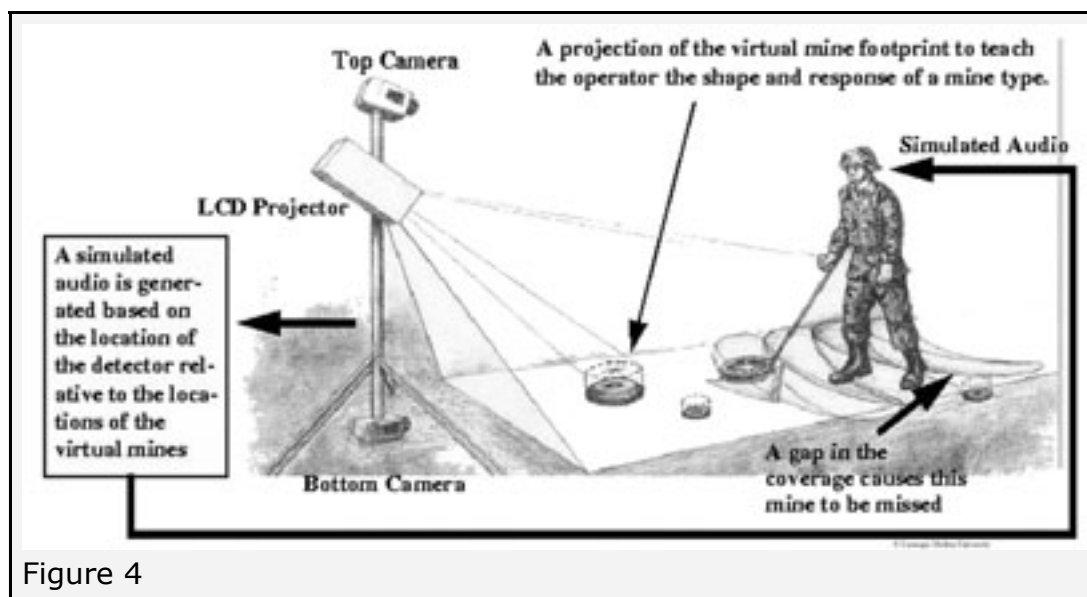

Figure 4

virtual experience of operating in a computer-simulated minefield in which real-time feedback is provided to the operator from modeled sensing of physical mines and the corresponding detector response. Visual feedback can be provided to the operator being trained by projecting texture of the minefield on the surface under the trainer's control, and by projecting additional information such as landmine and clutter footprints. The overall concept of SDVM is depicted in Figure 4.

Many of the factors of ground conditions, target signature, clutter and detector response are replicated or simulated using numerical methods in a virtual environment. Operators can be trained anywhere and at any time. The training area can be any indoor or outdoor surface. An important benefit of SDVM compared to physical mine lanes is the relative ease in changing the types of buried mines and their locations. Different layouts, mine types and soil conditions can be loaded into SDVM, allowing the operator to be trained in a variety of scenarios. SDVM also allows the operator to be trained separately on different detectors, whether EMI, GPR or their fused combination.

In essence, the SDVM will provide the operator of handheld landmine detection systems a virtual training experience with a realistic detector's output that corresponds to actual target signatures in various soil and environmental conditions. It will provide feedback to the operator for performance enhancement, support operator training and reorientation to a new environment, and allow experimentation with operator cueing formats. When development is completed, SDVM will provide a high-fidelity effective simulator that supports training for handheld landmine detectors that combine electromagnetic induction and GPR sensors. Despite its advantages, SDVM is not intended to completely replace physical mine lanes for training but to complement them.

The first step in using SDVM is to define the locations and types of the virtual mines. SDVM uses the location of the detector relative to these virtual mines to compute the simulated response of the detector. Once SDVM computes the effect of each virtual mine on the detector, the proper audio output is generated to simulate the actual audio output of the physical detector. Because SDVM simulates both the landmine and the detector,

One factor affecting coverage is the availability of visual cues on the soil surface. When there is a non-uniform surface providing visual cues, the operator can use those cues to differentiate between the areas that have been swept and those that the detector has not swept. However, when the ground cover is uniform, such visual cues are minimal and the operator must rely upon his learned dexterity to maintain good coverage. To test this hypothesis, SDVM was designed to project different surface textures. The surface can look like sand, grass or any other type of surface. Figure 5 shows the texture and graphical feedback projected on the surface of a floor. Depending on which training phase the operator is in, different graphical feedback can be projected on the floor. At the trainer's discretion, footprints of landmines or clutter objects can also be projected on the textured surface as a training aid during early stages of learning. The SDVM can switch from one surface projection mode to another during a training session.
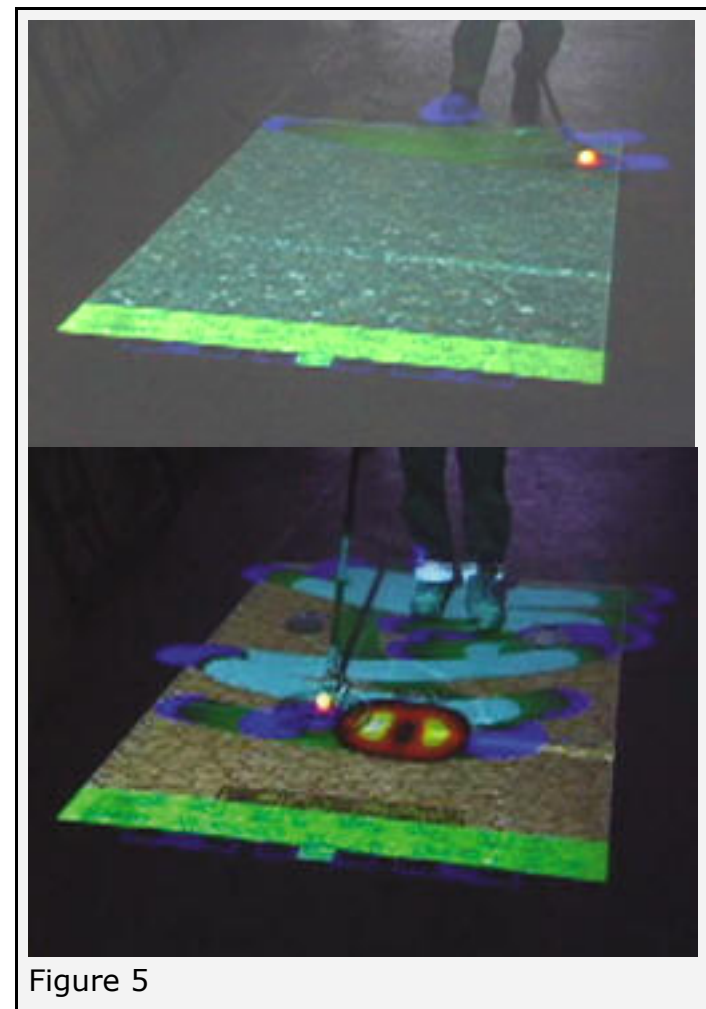

Figure 5

The simulated audio tones that cue the operator to the presence of a buried object are produced from the SMS audio speaker mounted on the video tracker tripod (refer to Figure 2 above). In order to virtually simulate the detector audio cueing, the response of a detector to a landmine must be modeled in the SDVM software. Our approach is to apply numerical electromagnetic computational tools to model the raw sensor response of EMI and GPR sensors followed by software modeling of the detection processes used in specific detectors. The numerical models are calibrated with physical data collected from training sites.
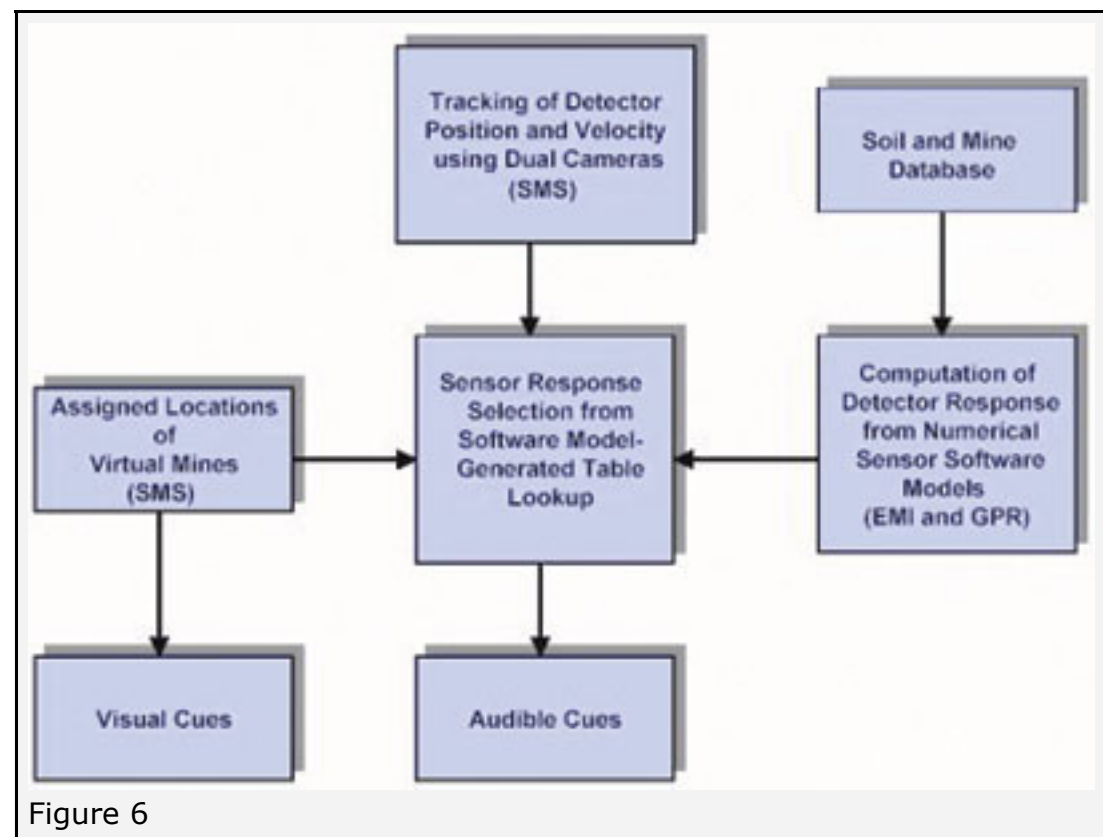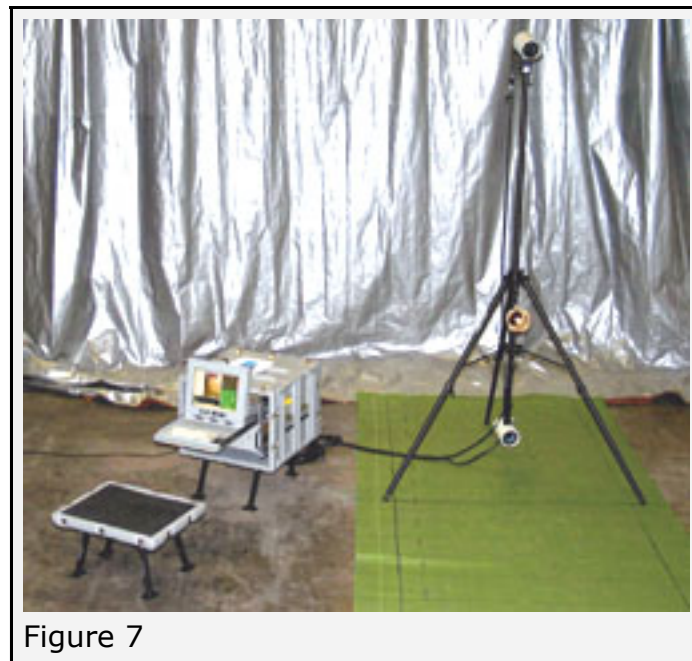

Figure 6

A schematic diagram of the SDVM architecture is shown in Figure 6. Much of the software

implementation of SDVM relies upon lookup tables generated by numerical modeling of sensor response coupled with simulation models of the detection process. Also contained in the database are parameters of different types of soils subject to different environmental conditions. SDVM will have the flexibility to mix and match the different landmine, detector, and soil characteristics under software control. SDVM will also have the ability to use actual data collected in the field in lieu of simulation models.

Conclusions

The U.S. Army has made significant investments in new, advanced countermine training aids to ensure that operator proficiency keeps pace with improvements in detection technology. The SMS and SDVM provide the trainee with the ability to visualize his/her sweep motion and integrate this motor skill development with mental processing of the audio cues provided by the detector. Early field experiments showed that a comprehensive operator training methodology, which includes the use of SMS technology, significantly increases the probability of detection for hard-to-find low-metal AP mines.

Figure 7

The U.S. Army has completed development of a military, rugged SMS (Figure 7) as a part of the AN/PSS-14 mine detection set. The technology has been transferred from its initial developer, Carnegie Mellon University (CMU), to the manufacturer, Engineering Technology Inc. (ETI), which is currently in low-rate initial production with 16 systems scheduled to be delivered in spring and summer 2004. Full rate production is scheduled to begin in 2005. ETI is working with CyTerra Corporation (manufacturer of the AN/PSS-14) to provide the SMS to foreign military and humanitarian demining agencies.

An initial laboratory capability for SDVM providing a virtual simulation of EMI detection has been completed. SDVM is currently in a two-year applied research effort, conducted by ETI, CMU and Duke University. It is funded by a Small Business Innovation Research (SBIR) grant sponsored by the Army Research Office (ARO). An initial operational EMI and GPR simulation capability is expected in 2006.

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