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ITEP Evaluation of Metal Detectors and Dual-sensor Detectors

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Probability-of-detection ranging from 0% to 100% indicate how often targets are found, and a higher value indicates a better performance. False-alarm rate shows how many false positive indications (false alarms, alarms from other than target) are obtained in one square meter, and a lower value indicates better performance. False-alarm rate reduction indicates how many false alarms the GPR use decreases the number of false alarms found with the metal-detector alone. False-alarm rate reduction of 100% means that GPR use successfully discriminates and rejects all false alarms, and 0% means that no false alarms are rejected. This measure directly relates to efficiency improvements.

Probability-of-detection loss indicates how many mines detected by the metal-detector part are falsely identified as metals and rejected by the GPR. A 0% probability-of-detection loss means all mines are correctly recognized as mines, and a 100% probability-of-detection loss means all mines are falsely rejected. This measure is directly related to the safety of deminers.

Probability-of-detection and false-alarm rate can be calculated at two stages of the dual-sensor detector’s operation: after using only the metal-detector feature and after using both sensors. On the other hand, false-alarm rate reduction and probability-of-detection loss can only be calculated after using both sensors. This means that both can be considered to be performance measures of the dual-sensor detectors’ GPR sensor.

Note that in this data analysis, unlike previously-conducted stand-alone metal-detector trials, metal pieces are considered a source of false alarms, not true positives. In this data analysis, only mine-like objects are considered the source of true positives (see Table 1 below from our earlier article). This is because dual-sensor detectors are supposed to discriminate mines from metals. In this article, this categorization is applied to stand-alone metal detectors as well as their results can be directly compared to those of the dual-sensor detectors.

Results

To demonstrate an overview of the detectors’ performance, results shown in this article are averaged overall soil types. These results, as well as detailed interpolations, will be in the test report.

Figure 1 shows probability-of-detection versus false-alarm rate of ALS and stand-alone metal detectors. The metal-detector part of ALS (blue line) shows a result similar to its base metal detector (CEIA MIL-D1, light blue cross). This result indicates that the metal-detector performance integrated in ALS is not deteriorated by the combined GPR, and it is still as good as the base metal detector. The metal-detector part of ALS declared approximately 2.5 false alarms per square meter, and using the GPR sensor reduces it to about 1.4 false alarms, denoting a 45% reduction. Consequently, the false-alarm rate obtained by ALS is lower than any other stand-alone metal detector tested in the campaign. Since the metal detector is the primary sensor in ALS, the detection performance depends entirely on the base metal detector. In the soils used in this test, the base metal detector achieved the lowest probability-of-detection among all tested detectors. Therefore, the probability-of-detection obtained by ALS is relatively stable and is due to the base metal detector’s performance.

False-alarm rate reduction and probability-of-detection loss are plotted in Figure 2. The stand-alone GPR (red cross) achieved a remarkably high false-alarm rate reduction, indicating that approximately 90% of the false alarms are correctly identified. Furthermore, the false-alarm rate reduction by ALS is much lower, meaning more metal pieces were misidentified and left as mines by ALS compared to the stand-alone GPR. On the other hand, the stand-alone GPR missed more mines than ALS. It is difficult to grade the devices because the results can change with each operator. If an operator is afraid of missing mines and reports mines for all metal-containing objects the metal detector signals, no mine will be missed, but also no false alarms will be rejected, meaning both probability-of-detection loss and false-alarm rate reduction are very low. This is due to the fact that the device only provides information on the objects, and this information must be interpreted by the operator. Thus, the decision is entirely up to the operator. Nevertheless, the figure clearly shows that GPR itself is potentially capable of discriminating landmines from metal pieces. However, from the operational point of view, probability-of-detection loss must be kept as low as possible.

Figure 3a and 3b (on page 78) shows false-alarm rate reduction and probability-of-detection loss as a function of depth. As a tendency, ALS and the stand-alone GPR achieved lower false-alarm rate reductions and higher probability-of-detection losses at shallow depths, which confirm the results in a former test. The depth dependency looks weaker for ALS, especially at the shallowest depth range of 0–3 centimeters in both false-alarm rate reduction and probability of detection loss. This variance might be due to the difference in signal processing employed in the systems and the GPR’s data representation to the operators. The stand-
HALO Trust and HSTAMIDS,” were not included. Therefore, assess-
the Boshoff and Cresci
confirmation of detected objects, which corresponds to the steps 4 and 5
ALIS was twice as slow as the stand-alone metal detectors. In this test,
metal detectors operated by newly trained vs. experienced personnel.
phisticated processing.
robust information on targets than the stand-alone GPR through the so-
inal processing operations. As a result, ALIS may be able to obtain more
reduction versus probability-of-detection
results. However, a rough estimate can be made as follows: Let T0, the total
work time using ALIS (T1) can be expressed as:

\[ T_1 = t_M x + t_E x \]

Assuming ALIS needs twice the time of a stand-alone metal detector for detection and identification of one object, but reduces false alarms by half, the total work time using ALIS (T1) can be expressed as:

\[ T_1 = 2r x + \frac{1}{2} t_M x \]

Additionally, the detection loss for dual-sensor detectors. If an area is assessed as difficult for dual-sensor by the investigation, a dual-sensor should not be used and other methods should be employed. The search speed is directly related to the ef-
ficiencies, and the higher the search speed, the more improvements can be achieved. The test results indicate that dual-
sensor detectors are twice as slow as stand-
alone metal detectors. Even so, the clearance
operation can be accelerated if a certain num-
ber of false alarms are reduced. Furthermore,
an additional attempt in this test indicated that operators of dual-sensor detectors who have more experience and knowledge working with the device can work as fast as operators using standard metal detectors. However, this fact also indicates that more training and/or practice is necessary for dual-sensor de-
tector use when compared to standard metal
detectors. The advantages of experienced per-
sonnel who have trained for a short period of
time appear significant in search speed and performance.
The dual-sensor test allowed us to evaluate detection and discrimination performance in a blind test. Although a very rough estimate of the efficiency improvements has been made, other factors need consideration for the de-
tailed assessment such as excavation time, de-
tector costs, and training and practice costs. Only a long-term field trial can evaluate those factors.

In the test campaign, stand-alone metal
detectors that possess the capability of dis-
 criminating objects were also tested. The evalua-
tion is not discussed in this article, but
readers interested in these devices can find the
results in the test report. 2

Figures 3a and 3b: False-alarm rate reduction and probability-of-detection loss as a function of depth in all soil types averaged. The dashed lines show 95% confidence bounds.

Figures 4a and 4b: Average search speed of ALIS and stand-alone metal detectors in minutes per square meter. The labels “MD” and “MO mf” indicate metal detectors operated by trained operators and the manufacturers, respectively.

Table 1: Differences in categorization of sources of alarms for stand-alone metal detectors and dual sensors.