Solumspect

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February 8, 2010

Dr. Andrew Rawicz
School of Engineering Science
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Burnaby, BC V5A 1S6

Re: ENSC 440 Project Functional Specifications for a Landmine Detection System

Dear Dr. Rawicz,

Solumspect is in the process of developing a portable landmine detector as our project for ENSC 305W/440W. We aim to build a system that caters to the needs of humanitarian organizations by being both low-cost and robust using off-the-shelf components. The attached document, *Functional Specifications for a Landmine Detection System*, outlines the requirements for our device.

In this document, we provide an overview of our system and its components, list the general requirements, and describe our test plan for the device. We are scheduled to have a working model of our design available for demonstration by mid-April 2010.

Solumspect is a dedicated team of fifth-year engineering students: Michael Ages, John Berring, Graeme Cowan, and Jeremy Yoo. Should you have any questions about our project or the attached functional specifications, please do not hesitate to contact us by e-mail at ensc440-cyab@sfu.ca.

Sincerely,

Michael Ages	*John Berring*	*Graeme Cowan*	*Jeremy Yoo*
Michael Ages	John Berring	Graeme Cowan	Jeremy Yoo

Enclosure: *Functional Specifications for a Landmine Detection System*

Solumspect

Functional Specifications for a Landmine Detection System

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Submitted to: Dr. Andrew Rawicz – ENSC 440
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Executive Summary

Humanitarian demining can be a dangerous and arduous task. Even with the use of metal detectors and demining dogs, the successful identification of an active landmine is accompanied by an extremely high false positive rate. For example, when using only a metal detector, it is not uncommon for deminers to endure a thousand false alarms for every landmine they find [1]. In the best case, this slows the detection process to a crawl; in the worst case, it can result in deaths due to carelessness. In fact, injury reports have shown that veteran deminers are just as likely to be injured due to mistakes as those with less than a year of experience [2]. As such, it can be argued that overconfidence and familiarity with the system can be deadly as ignorance.

At Solumspect, we intend to improve the demining process by focusing on reducing the number of false alarms and correctly identifying landmines before disarmament begins. As well, the company intends to produce its system for a fraction of the cost of the closest competing systems so that the technology can remain accessible to humanitarian demining organizations.

The landmine detection system was conceived with speed, reliability, robustness, and simplicity in mind. The device can be used in replacement of or in conjunction with existing detection technologies. Its performance, safety, reliability, usability, electrical, and mechanical requirements are discussed in this document. Wherever possible, it will adhere to the standards set forth by the International Mine Action Standards (IMAS) committee. However, as this device is based on relatively new technology, there are few universal standards to which it must explicitly conform. In the absence of an agreed upon radar based demining device requirement, we have opted to either adopt previously existing rules for other landmine detection devices or develop our own.

Solumspect is currently in the design stage and will have a working model completed in April 2010. Testing will begin in the lab using a sandbox and simulated landmines. Once successful, field tests will be carried out while potential customers are sought. For the production version that follows, we plan to work closely with humanitarian and military organizations to ensure that the device fully meets their needs.

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Glossary

CEN Comité Européen de Normalisation (European Committee for Standardization)

Clear Area A safe space of land known to be free of any landmines

CWA CEN Workshop Agreement

ERW Explosive Remnants of War

FMCW Frequency Modulated Continuous Wave – A transmitted waveform, often used in radar, having a linearly modulated range of frequencies.

Frame Extendable structure, measuring one square metre, attached to the base of the system and supports the scanning components

GPR Ground Penetrating Radar

Landmine Any of a variety of unexploded ordnance buried beneath the surface of the earth

IMAS International Mine Action Standards

ISO International Organisation for Standardisation

RF Radio Frequency

RoHS Restriction of Hazardous Substances

Sweep A single pass of the antenna along the supporting scan bar

User An adult trained in the removal of landmines, typically belonging to a humanitarian demining organization.

1 Introduction

Solumspect is developing a portable low-cost landmine detector for use by humanitarian organizations. The device uses ground penetrating radar (GPR) technology to scan a region of ground and display a visual representation of subterranean objects within that region. Using the generated images, the user will be able to quickly determine if there are any potential areas of interest for further investigation.

1.1 Scope

The requirements for Solumspect's proposed landmine detection device are detailed in this functional specification document. A full set of requirements for the model version of the device and additional requirements that will be satisfied in the production version are provided.

1.2 Intended Audience

This document is intended for use by the entire Solumspect team to assist in the development of the system. During the design phase, it will serve as a written record for ensuring all design and implementation decisions conform to the intended functionality of the device. It will also assist in keeping track of the project's progress. Once a working model is ready, the team will refer to this document during the testing phase to verify that the model provides all of the necessary functionality as well as meets the high level of quality that is strived.

1.3 Classification

Functional requirements in this document are labelled using the convention *[F-n-C]*, where *F* denotes that it is a functional requirement, *n* is the sequential number of the requirement, and *C* is one of the following classifications:

- I – This requirement shall apply to the model version only.
- II – This requirement shall apply to both the model and production versions.
- III – This requirement shall apply to the production version only.

2 System Requirements

2.1 System Overview

Pictured in Figure 1 is a conceptual diagram of Solumspect's landmine detection system. On the main structure of the device are the low frequency electronics, the batteries, and the user interface. The entire mass of the device is supported by the ground beneath these components. The antennas and RF electronics cantilever out from the base on a one square metre **frame**; the antennas have two degrees of freedom in the horizontal plane within this space.

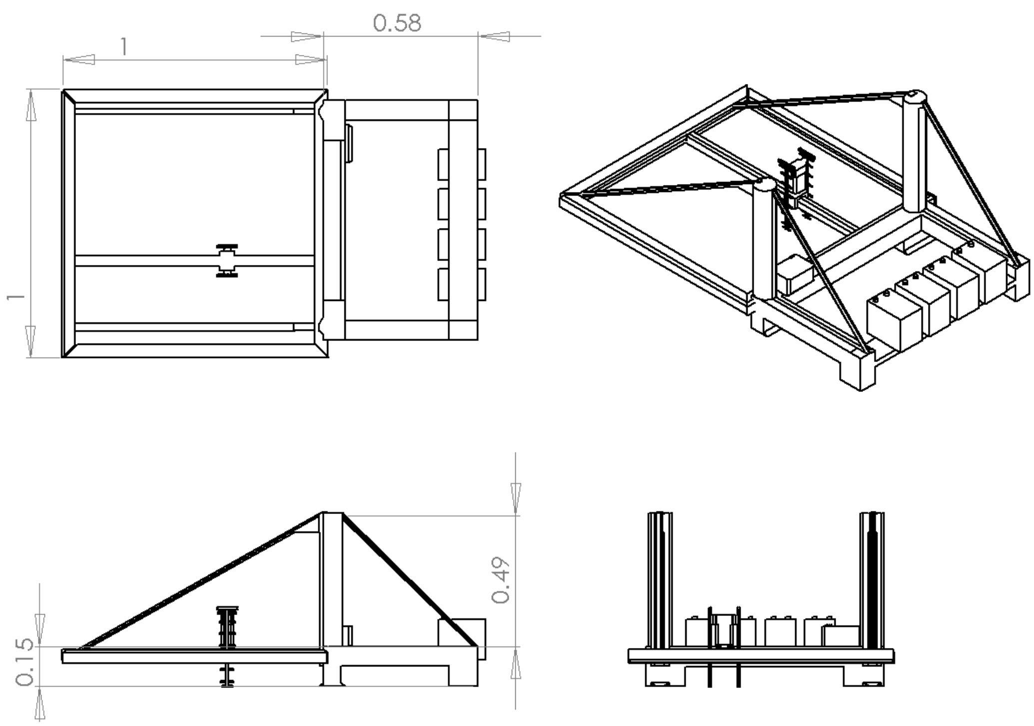

Figure 1: Computer generated schematic of the landmine detection device (all dimensions in meters)

A high-level functional diagram of the landmine detection system is shown in Figure 2.

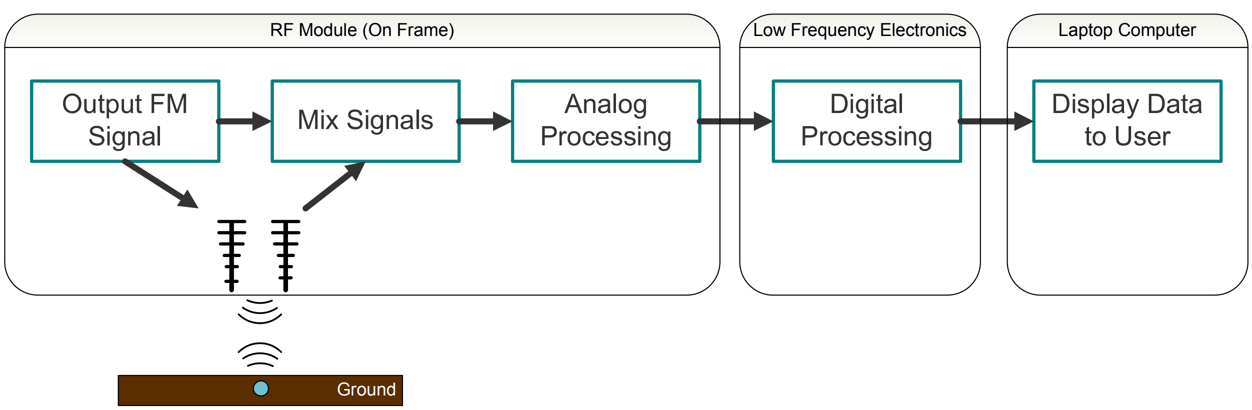

Figure 2: High-level functional diagram of the landmine detection system

Keeping safety in mind, each action required to run the device is carried out from outside the area being scanned. Typical use of the system begins with the **user** unfolding the frame to resemble Figure 1. The device is placed such that the base is sitting in a **clear area** with the frame suspended above the region to be investigated. The user then uses the controls on the base to initialize the scan and move the antennas. The antennas are moved in a straight line across along the supporting scan bar (a **sweep**), with the bar being shifted laterally between sweeps as illustrated in Figure 3.

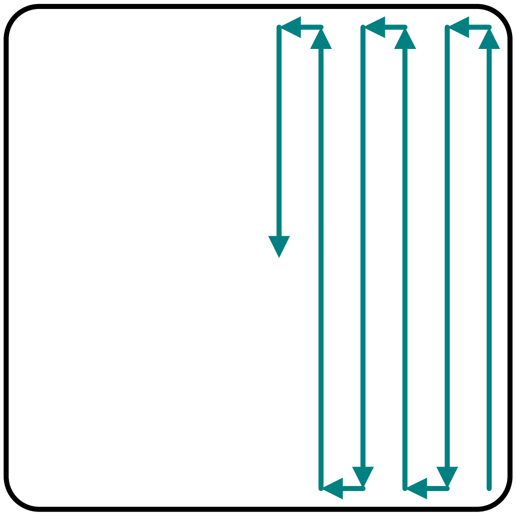

Figure 3: Device scanning pattern

When a scan is finished, the results will be displayed as images to the user. For each sweep, a cross-sectional map of the earth will be produced, similar to the example in Figure 4. In this map, signal intensity will be displayed on a soil depth vs. scan length grid. Pixel intensity at each point will correspond to the intensity of received reflections in that area.

Data from multiple sweeps will be combined and displayed as top-down maps as illustrated in the example of Figure 5. In this case, each pixel colour will correspond to the sum of the reflected signal intensities at a specified depth. The user can view these images to assist in identifying potential landmines in the area.

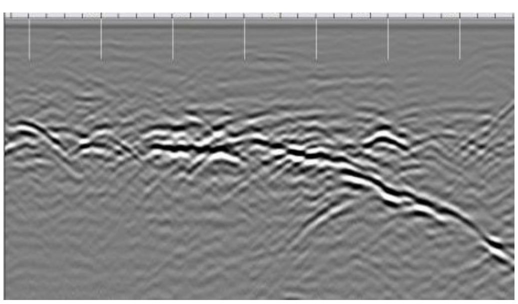

Figure 4: An example of a cross-sectional output from one sweep in a scan [3]

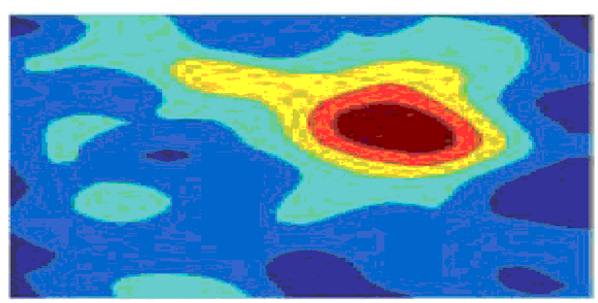

Figure 5: An example top-down output produced from a full scan with multiple sweeps [4]

2.2 General Requirements

[R-1-III] The system shall not cost more than $1000 CAD.

[R-2-II] All collected raw data shall be made available to the user.

[R-3-III] The device shall be movable by a single user.

2.3 Physical Requirements

[R-4-III] The entire system shall have a maximum mass of 10 kg, excluding batteries.

[R-5-II] The frame shall be no larger than 1.2 m × 1.2 m × 0.3 m.

[R-6-II] The base (main structure) shall be no larger than 0.5 m × 1.2 m × 0.5 m.

[R-7-III] The frame shall be suspended 0.15 m to 0.30 m above the ground.

2.4 Electrical Requirements

[R-8-III] The device shall be powered by a maximum of 24V.

[R-9-III] The batteries shall be rechargeable.

[R-10-III] The batteries shall be of sufficient capacity to run the system electronics for a minimum of 12 hours.

2.5 Mechanical Requirements

[R-11-II] Movement of the antennas and RF module shall be hand driven.

[R-12-III] The whole device shall fold small enough for a user to handle and move.

2.6 Environmental Requirements

[R-13-II] All electrical components shall be lead free and RoHS compliant.

[R-14-II] The system shall not emit more than 60 dB of noise.

[R-15-II] The device shall remain operational at altitudes up to 5000 m.

[R-16-II] The device shall remain operational in environments with 0% to 100% humidity.

[R-17-II] The device shall continue operation while placed on saturated ground or submerged in a liquid with a depth of less than 5 cm (up to the tip of the antenna).

[R-18-II] The device shall operate normally in temperatures between 0°C and 60°C.

2.7 Standards

[R-19-III] The system shall conform to the testing standards set by CWA 14747:2003 (CEN Workshop Agreement CWA 14747:2003, Humanitarian Mine Action – Test and Evaluation – Metal Detectors) [5].

[R-20-III] The power module will use a power cell which conforms to ISO 29.220 [6].

2.8 Reliability and Durability

[R-21-III] All components shall be of sufficient quality to maintain daily use for a minimum of two (2) years.

[R-22-III] The system shall be resistant to all weather conditions such as rain, snow, and wind.

[R-23-III] The structure shall be able to withstand substantial physical abuse and transportation.

[R-24-III] All system components will be repairable or replaceable by a trained service technician.

2.9 Safety Requirements

[R-25-II] All power and electrical wires shall be concealed and have protective plastic encasements.

[R-26-III] The frame mounts shall be reinforced with a minimum of one (1) failsafe mechanism to prevent it from making contact with the ground should a joint break.

[R-27-III] The frame shall be designed to fall to the ground in such a way that would prevent it from triggering any landmines in the unlikely event of catastrophic support failure. To ensure this, the mass per unit contact point of the device shall be no greater than 800 g when it is in an unsupported, forward tilt position.

[R-28-III] A self-test routine will run on each power up to ensure that the antenna power is correctly calibrated for detecting landmines.

2.10 Performance Requirements

[R-29-II] The system shall produce valid signals (visually identifiable in one of the display modes) from all varieties of landmines.

[R-30-II] The system shall allow the user to correctly identify the origin of all valid signals in the scanning plane.

[R-31-II] The system shall allow the user to properly distinguish between general metal refuse and landmines by the displayed shape and size of the subterranean object being measured.

[R-32-II] The system shall produce valid results for objects at depths less than 50 cm below the ground.

[R-33-II] Given optimal environmental conditions (saturated, uniform clay), the range resolution of the system shall be at least 2.2 cm.

[R-34-II] Given the worst possible environmental conditions (dry, rocky sand), the range resolution of the system shall be at least 8.8 cm.

[R-35-II] The system shall not be required to identify landmines placed beneath a larger landmine at the same point.

2.11 Usability Requirements

[R-36-III] A user manual detailing the use of the system shall be provided to the user in English.

3 Frame and Mechanical Components

The frame exists to support the RF module and antenna and allow its position to be measured in two dimensions with a high degree of accuracy.

3.1 General Requirements

[R-37-II] The frame shall suspend the antenna above the ground.

[R-38-II] No portion of the frame shall make contact with the ground.

3.2 Physical Requirements

[R-39-II] The frame shall allow the antenna to move in two dimensions, parallel to the ground.

[R-40-II] The frame shall support the two antennas and the RF module.

3.3 Electrical Requirements

[R-41-I] The frame shall require no electricity.

3.4 Safety Requirements

[R-42-II] The structure shall have no obvious sharp or otherwise hazardous components that could injure the user.

3.5 Performance Requirements

[R-43-II] Position of the scanner shall be recorded with a minimum precision of 1 cm.

3.6 Usability Requirements

[R-44-III] The deploying and folding of the main structure shall be easy and intuitive.

4 RF Module and Antennas

The RF module and antennas are mounted to the frame, emitting, capturing, and processing the radar signal.

4.1 Physical Requirements

[R-45-II] The RF module and antennas shall weigh no more than 4 kg.

[R-46-II] The RF module shall be contained in an enclosure of maximum volume of 1500 cm^3.

[R-47-III] The antennas shall be shielded to block any incoming or outgoing signals except in the direction of the ground.

[R-48-II] The antennas shall be positioned to minimize antenna cross-talk.

[R-49-II] Antennas will be mounted facing downwards at a distance of no more than 10 cm above the ground.

4.2 Electrical Requirements

[R-50-II] The system shall output a minimum power of 150 mW.

[R-51-II] The output signal shall sweep frequencies from 1 GHz to 2.2 GHz.

[R-52-II] Reflected signals shall have a power of no greater than 2 mW.

[R-53-III] Generated signals shall not interfere with cellular or radio communication signals.

[R-54-III] Signals from external communication devices shall not interfere with scanning results. The processed signal-to-noise ratio of unwanted frequencies shall be at least 4 times lower than the wanted valid signals between 1 GHz and 2.2 GHz.

4.3 Performance Requirements

[R-55-II] The RF module shall filter out any external signals outside of the transmitting bandwidth of the device.

5 Low Frequency Electronics

The low frequency electronics module, which includes the microcontroller, will be mounted on the main structure, separate from the RF components and the antenna.

5.1 General Requirements

[R-56-II] The system shall interface with the external computer system via USB 2.0.

[R-57-II] All connections shall be hard-wired.

5.2 Electrical Requirements

[R-58-II] The low frequency electronics shall require no more than 1.5 W of power.

5.3 Performance Requirements

[R-59-II] Radar data shall be transmitted to the external computer system at a minimum of 100,000 samples per second.

6 Signal Processing

The signals received to the signal processing unit will be frequency-modulated signals between 1 GHz and 2GHz. After mixing, the low frequency components of interest (less than 50 kHz) will be produced. These low-frequency components will be isolated and sampled. The resulting digital signal will be transformed into frequency domain. A peak at a certain frequency corresponds to a reflection from a certain depth.

6.1 General Requirements

[R-60-II] The system shall generate a two-dimensional visualization of the underground terrain from both the top and side planes.

[R-61-I] Digital signal processing shall be performed using MATLAB libraries.

[R-62-III] Signal processing shall be performed by proprietary software.

6.2 Performance Requirements

[R-63-II] The low-pass filter shall attenuate all signals above 3.5MHz by at least 20dB.

[R-64-II] The post-processing shall be finalized no longer than one (1) minute after scan completion.

7 User Interface

The user interface will consist of software that can be installed on a laptop computer that is provided by the user.

7.1 General Requirements

[R-65-II] The user's screen shall display both overhead and cross-sectional views of the underground terrain.

[R-66-II] All results shall be stored in common image (e.g. PNG) and text formats (e.g. TXT).

[R-67-II] The system shall interface with a graphical user interface software program that can run on the Windows operating system.

[R-68-I] The graphical user interface will run through MATLAB.

[R-69-II] All data shall be completely converted into the spatial domain before presentation to the user.

7.2 Usability Requirements

[R-70-II] Starting a scan and monitoring scan progress shall be intuitive and easy.

[R-71-II] Keyboard commands and navigation shall be intuitive and easy-to-use.

[R-72-III] The user shall be able to perform all commands solely with the use of a keyboard.

8 Test Plan

Our device consists of three main modules that can be easily divided for testing. These sections will be extensively tested individually prior to integration of the system when all components will be tested as a whole and final calibration can be performed.

The device's base and frame tests are purely mechanical and structural. Prior to construction, each component will be verified against design dimensions and specifications. The structure will then be assembled and visually inspected to ensure that the frame has been built with adequate quality.

The radar module can be broken down into emission and absorption. Frequencies and waveforms for the radar to transmit will be specified and verified using a variety of available laboratory spectrum testing apparatuses. The receiving antenna will be tested using data from the transmitting antenna as well as simulated direct-coupled waveforms. This will test the system's response with and without outside noise. For simple cases, correct outputs can be easily calculated from the transmitting wave frequency and the distance of the reflected object.

Data processing algorithms and the computer user interface can be tested using simulated radar readings. The generated visualizations can be verified against expected values in MATLAB. By inviting independent third-parties to test our software without any guidance or user manuals, a level of intuitiveness can be determined and improved based on their feedback.

Once all of the components are ready, the system will be tested in a number of different environments to verify the abilities of the integrated device. These scenarios will involve varying types and densities of soil, surface formations, and levels of moisture. To test the resolution of the device, objects of differing sizes, densities, materials, and shapes will be buried and analyzed using the landmine detection system. The data quality can be determined by comparing the system output with what has been buried in the ground.

9 Conclusion

The requirements outlined in this document describe a device that will serve as a useful and valuable tool to any demining team. Due to the nature of this system, safety is of utmost concern; conforming to these specifications will lend itself to the production of a quality device that is safe, intuitive, and effective. Following through with the test plan will ensure these goals are successfully met.

10 References

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