Solumspect

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January 18, 2010

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

Re: ENSC 440 Project Proposal for a Low-Cost Landmine Detection System

Dear Dr. Rawicz,

Our team, Solumspect, is proposing the development a portable landmine detector as our project for ENSC 305W/440W. Focusing on humanitarian organizations as our primary customer, we aim to build a system that is both low-cost and robust using off-the-shelf components. An overview of our project is given in the attached document, *Proposal for a Low-Cost Landmine Detection System*.

In the proposal, we provide an outline of the overall system, discuss potential design solutions, and detail our estimated budget and timeline. 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. Background information about our team members is included in the proposal. Should you have any questions about our project or the attached proposal, 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: *Proposal for a Low-Cost Landmine Detection System*

Solumspect

Proposal for a Low-Cost Landmine Detection System

Project Team:	Michael Ages John Berring Graeme Cowan Jeremy Yoo
Contact Person:	John Berring jtb1@sfu.ca
Submitted to:	Dr. Andrew Rawicz – ENSC 440 Mr. Steve Whitmore – ENSC 305 School of Engineering Science Simon Fraser University

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Executive Summary

There are currently 100 million landmines buried worldwide [1] covering an estimated area of 40000 km^2 [2] in 70 countries. In 2008 alone, over 5000 people were injured or killed by landmines [3]. There are many military and humanitarian organizations working to clear these affected areas; however, the 270 km^2 of cleared area in 2008 [3] is only a small fraction of what still remains. While governments and activists are working to ban the manufacture and use of landmines, the fact remains that without a dramatic increase in the rate at which landmines are being removed, many people and their countries will continue to be affected for generations to come.

It can be easily seen that a major obstacle in the demining efforts of humanitarian organizations is funding. With the exception of simple metal detectors, many of the machines and devices used by the military, such as radar and infrared equipped robots currently used by the Canadian Army, are prohibitively expensive for humanitarian organizations. A robust, low cost, and simple to operate landmine detection device could provide a massive increase in the rate at which organizations clear mine-affected areas, saving countless lives and improving local economies by freeing land for farming and other community building activities.

This proposal outlines Solumspect's planned development of a low-cost ground penetrating radar (GPR) device for use as a landmine detector. We aim to build a device with functionality similar to commercially available GPR products at a fraction of the cost. The development team consists of four fifth-year Engineering Science students from Simon Fraser University having a diverse skill set that includes high-frequency and analog electronics, electrodynamics, embedded systems, and signal processing.

The Solumspect team has already completed much of the necessary research and is ready to begin the design phase. The cost of the project has been estimated at $1320, a majority of which is anticipated to be provided by the Engineering Science Student Endowment Fund. Following our schedule, a functional model is projected to be completed in April 2010.

Table of Contents

1. Introduction

Wars have an immense human cost and many unfortunately leave a deadly legacy that persists long after the fighting has ceased. This legacy is the landmine. At dollars apiece, landmines are cheap to produce; however, their removal is extremely expensive and time consuming. It costs between $300 and $1000 to clear a single landmine [1] and some existing removal methods require an individual to work for more than a week to clear an area the size of a backyard [4].

There are two main groups involved in landmine clearance—militaries and humanitarians.

Militaries have access to expensive equipment and highly trained personnel. Engineers of the Canadian Army for example, may deploy their remote controlled Improved Landmine Detection System, a robot armed with ground penetrating radar (GPR), a metal detector, forward looking infrared radar, and a thermal neutron activation detector [5]. In a similar vein, U.S. troops have access to a lightweight, handheld GPR and metal detector combination known as the AN/PSS-14. While the actual costs of these devices are not available, one humanitarian demining expert has placed an estimate in the range of $12,000 - $50,000 [6].

Humanitarian groups, on the other hand, are much more limited in their resources. This restricts them to less efficient methods of landmine detection, the most common being handheld metal detectors and animals [7]. While these two methods can be used to effectively clear a minefield, both have significant imperfections. A low-cost device that can operate near the speeds of military grade machines would significantly increase the effectiveness of humanitarian efforts in landmine removal.

Our proposed device is a low-cost ground penetrating radar machine for use as a landmine detector. The device will be a free standing machine that scans a given area and generates a three-dimensional map of objects in the ground. The functionality is expected to be comparable to existing machines; however, using off-the-shelf components to build our device will allow it to be priced at a fraction of the cost.

This proposal document consists of an overview of the system from the user's perspective, an outline of the design, details about information sources, budget and funding information, and an introduction to the team that will design and build the device.

2. System Overview

Figure 1 shows a computer generated model of our device, a fully functional GPR system specifically designed for used in the detection of landmines.

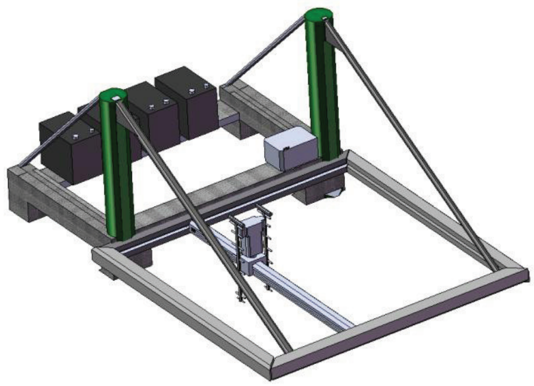

Figure 1: The low-cost ground penetrating radar device for use as a landmine detector

The system structure consists of a supporting base and an extended 1m x 1m frame that supports the radar component. The square metre of ground beneath the frame is the area in which the radar will scan. Attached to the base are the low-frequency circuitry, power supply, and an interface to the user-provided computer system. When the system is in operation, it produces a representation of subterranean objects in the area, down to a depth of about 0.5m. The machine is supported only by the ground beneath the power supply such that no weight is applied to area which potentially contains landmines.

To operate the device, the user places the machine's base at the edge of a "safe" area, with the frame extending 1m into un-investigated ground. The radar moves within the frame to collect scans of the ground; this data is then processed to be displayed as top-down and cross-sectional images of the subterrain.

A possible design modification would be a handheld device. In this handheld mode, the radar component would be mounted to the end of a rod, which the user would pass over the ground much like a traditional metal detector. The user would then be notified of any mine-like objects by an audible beep.

The flow of the data gathering process is summarized in Figure 2.

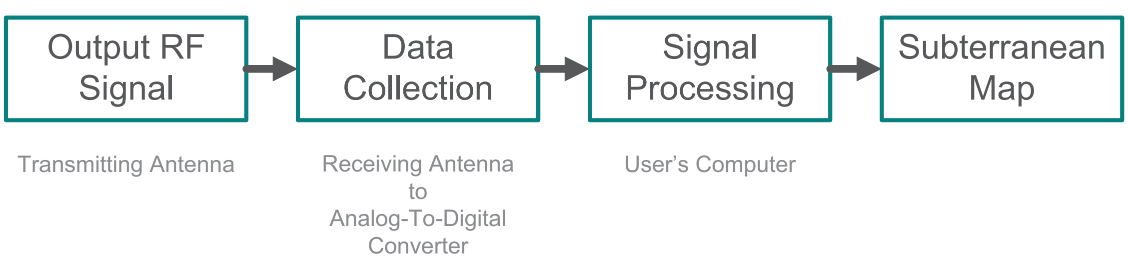

Figure 2: System Flow Diagram

3. Possible Design Solutions

3.1 Metal Detector

The most well-known method of landmine detection is the use of a metal detector. In the past, this was a cheap and effective way of detecting large all-metal landmines. Unfortunately, because of the ease with which metal could be detected, plastic landmines were developed. While plastic landmines often contain a small metal trigger pin which can be detected using a metal detector, more sensitive metal detectors would be required. Unfortunately, this higher sensitivity makes it much harder to tell the difference between a plastic landmine with a metal pin and a small piece of metal shrapnel that has also been left over from war. Consequently, metal detectors can have a very high false positive rate. False positives are extremely time consuming errors because each must be treated as a real landmine and carefully dug up.

3.2 Military-Grade Ground Penetrating Radar

Current ground penetrating radar systems for landmine detection are extremely expensive and are consequently used almost exclusively by the military. Using a high frequency radio pulse or frequency modulated radio waves, these systems can map out an underground area with high accuracy, making them effective at detecting both plastic and metal underground landmines. Unfortunately, due to the lack of a "conventional commercial market," a low cost alternative has not yet been developed [8].

3.3 Passive Infrared Detection

An infrared (IR) scan of an area can be used to find metal and plastic mines, though with varying reliability. Landmines can be detected with IR analysis by observing the surface of the terrain to see if has been recently dug up and filled over [9]. While this method can be quite accurate, it is limited to recently buried landmines because the longer the landmine is in place, the more the disturbed soil will reach equilibrium with the rest of the terrain. Overall, this method can depend significantly on the type and density of the terrain, ambient temperature, and how long the landmines have been buried [9].

3.4 Vapour Detectors

The explosive chemicals in landmines emit a vapour signature that could potentially be used to determine their location in the ground [10]. Vapour detection devices can identify these chemicals; however, minefields may have residual vapours from previous explosions, making it harder to determine the exact location of landmines. Alternatively, animals with a keen sense of smell (most commonly dogs and rats) can be trained to sniff out these chemical signatures. While animal sniffers are more sophisticated than electronic sniffers, they require extensive training and can have limited attention spans [10].

4. Proposed Design Solution

Our proposed method of landmine detection is a low-cost ground penetrating radar system. Its target use will be in humanitarian efforts for clearing minefields in an efficient and effective manner. Our device will be built onto an easily moveable structure that can scan one square metre at a time. With detailed representations of subterranean objects, users will be able to quickly identify if an area is free of landmines.

This device will increase the accuracy of landmine identifications in two ways. First, it will be able detect the presence of landmines with no metallic content and metal mines in highly mineralized soil, a task that metal detectors can't perform well. Second, it will have a low false positive rate by allowing the operator to identify the shape of the buried object without removing it.

While there are already ground penetrating radar systems that can be used for finding landmines (such as the previously mentioned military grade devices), our product is unique in that it is specifically designed for low-cost production, even in low quantities. Its mobility and learning curve will lend itself to easy use by humanitarians.

Our project is very ambitious and our biggest challenge will be limited time. In future endeavours, we could expand our design to implement a highly autonomous device. This would give us higher accuracy for more precise landmine detection and potential non-landmine surveying applications. However, for this iteration of the product, we are focusing on a low-cost device with adequate visualizing capabilities to find landmines.

5. Sources of Information

Our primary sources of information for this project will be textbooks and academic papers.

From the former category, we will be focusing on books discussing radio frequency (RF) electronics, electromagnetism, and analog communication. We have already identified three excellent resources: *Ground Penetrating Radar* [8], *Introduction to Analog and Digital Communications* [11], and *Microwave Engineering* [12]. These texts will be referenced when designing and constructing the RF component of our device.

Academic papers will be used to supplement our knowledge of RF electronics, antenna use, and radar design. In addition, a number of these sources will help us address any potential problems related to signal processing. So far, our principal resources in this category have been a set of four master's theses [13-16] on the topics of frequency modulated continuous wave (FMCW) and pulsed wave GPR for landmine detection. They not only address radar design signal processing, but also investigate theoretical models run by MATLAB and LabVIEW. Journal and conference papers will additionally compliment this knowledge by providing us with an understanding of current research into GPR.

Other sources that have been searched are online electronics engineering forums and newsgroups. However, these have yielded little useful technical information. As such, we will be appealing to faculty members for help.

Dr. Shawn Stapleton, an SFU engineering professor, has agreed to review our project and allow us access to his lab. His radio frequency electronics experience will make him a valuable asset for critiquing our RF design. In a similar vein, a UBC geological engineering student with experience in processing and interpreting GPR data and an SFU Engineering Science alumnus in the field of RF engineering have both agreed to advise us in their areas of expertise.

6. Budget and Funding

6.1 Budget

A tentative budget for producing our model based on our preliminary research and discussions with Dr. Stapleton is given in Table 1. We have included a contingency of 20% to cover unexpected expenses. All costs have been converted to Canadian dollars and include the cost of shipping and taxes.

Table 1: Budget Breakdown

Description	Estimated Cost
RF Electronics	$700.00
Low Frequency Electronics	$20.00
Microcontrollers	$100.00
Power Sources	$80.00
Mechanical Parts and Components	$200.00
20% Contingency	*$220.00*
Total Cost	**$1320.00**

6.2 Funding

While the components may appear to be costly, we note the total cost of our system is a small fraction of commercially available GPR systems with similar capabilities.

To assist the team in covering these development costs, we are in the process of requesting funding from the Engineering Science Student Endowment Fund as well as the Wighton Fund. We will continue to search for additional sources of funding or equipment throughout the development cycle to further help offset the costs.

If these external sources do not fund the entire cost of the project, the Solumspect team is fully prepared to cover the remaining expenses, which will be distributed equally among all four team members.

7. Schedule

A Gantt chart of our timeline is shown in Figure 3.

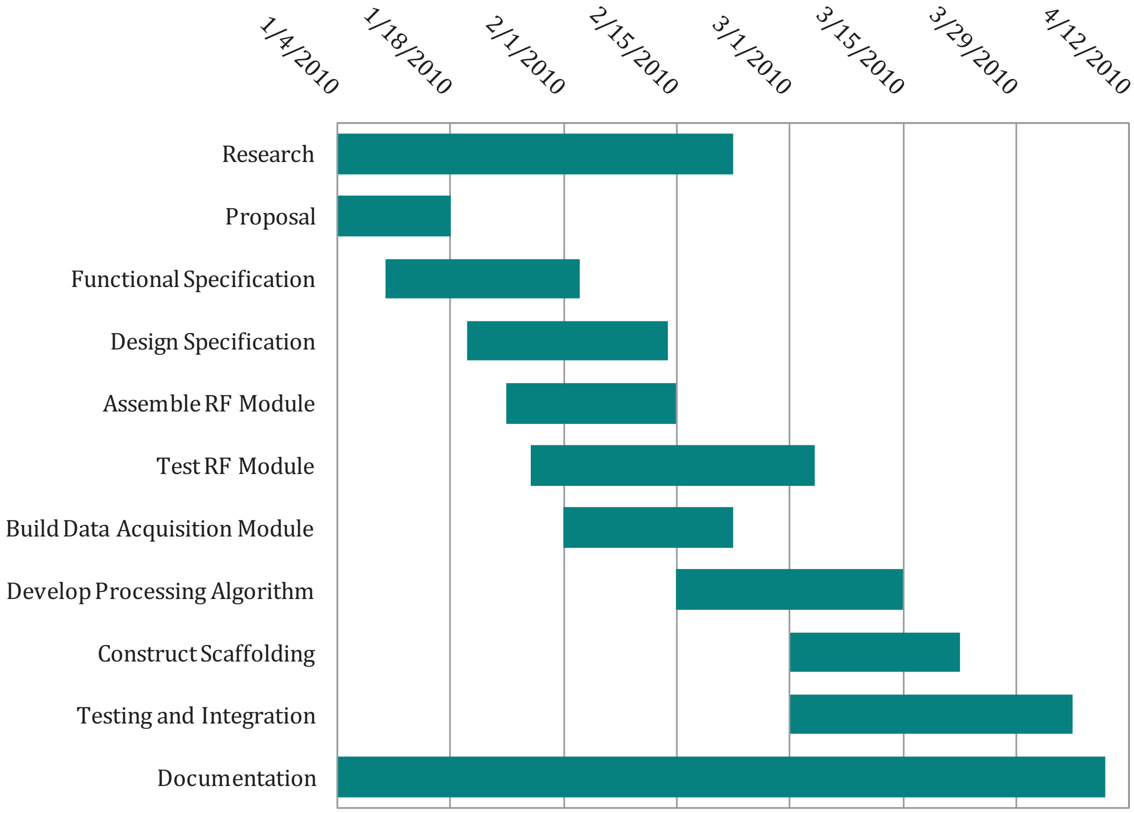

Figure 3: Project Schedule

Our schedule was designed to allow as much time as possible for the construction and testing of the device. As such, we intend to complete the functional and design specifications prior to their due dates so that we may concentrate on assembly and testing. We plan to demonstrate our project by the beginning of April 2010.

8. Team Organization

The management team of Solumspect is composed of four fifth-year engineering students. The group was formed in October 2009 when its members recognized the benefit of creating a team of colleagues with varying engineering backgrounds. This is reflected in Solumspect's organizational structure, with the duties of each individual selected in accordance with their respective areas of specialization.

As Chief Executive Officer, engineering physics student John Berring is responsible for the success of the project. He will be ensuring that each task is progressing smoothly and troubleshooting any problems that arise. In addition, he will be the leading the integration and guaranteeing that the RF module, data capture and processing devices, and system structure will all communicate and operate properly.

Systems engineering student Graeme Cowan is Chief Communications Officer and is in charge of all administrative, legal, and research issues. He is tasked with ensuring that every team decision is well thought out and documented. His technical position is that of lead electronics design. In this role, Graeme will be leading the low frequency electronic design process.

Our Chief Financial Officer, computer engineering student Jeremy Yoo, is responsible for acquiring and distributing all of the team's funds. In addition, he will be managing all of the signal processing and software development for the team.

Engineering physics student Michael Ages has the role of Chief Operations Officer and is the lead of reliability engineering. He is not only tasked with monitoring the projected and actual lifetimes of each module of the device, but also guaranteeing that there are contingency plans in case of failure. Michael's technical role is in RF engineering; he will be leading the RF electronic design, testing, and manufacturing process.

Meetings are held three times a week and range between one and two hours. During the initial stages of development, most of this time will be used for discussion or research. As the project progresses, these meetings will become technical work sessions, with the exception of a weekly one hour high-level discussion, where project progress will be tracked and the direction of the company will be examined. A meeting agenda will be prepared beforehand to keep discussions on topic.

When a major decision must be made during the meetings, it is done by consensus. If this method fails and there is dissent among group members, the meeting will be extended in order to address each person's concerns and create a compromise. Failing that, the group will appeal to an external expert for guidance before reconvening. While this may appear time-consuming, it is the optimal way of guaranteeing that each participant is in full agreement with the direction of the company.

Beyond the five hours of pre-scheduled meeting and work time per week, each team member is responsible for creating his own weekly timetable, in which 25-30 hours should be dedicated to the project. Individual tasks will be delegated based on each person's technical role within the company. However, since not every portion of the device may be built in parallel, there may be multiple people working on one module at a time.

9. Company Profile

John Berring is a fifth year engineering physics student at Simon Fraser University, where he is specializing in electronics and optics. Over the past four years of his education, John has been employed by TRIUMF Canada, The National Research Council's Institute for Fuel Cell Innovation, Kavanagh Lab, and EBA Engineering Consultants. He currently has two pending publications in the field of smart materials for biomedical applications (primary author) and a published article in the *Journal of Membrane Science* (secondary author). John is also a co-author of a recent SFU sponsored patent application related to his undergraduate thesis topic.

Michael Ages is a fifth year engineering physics student at Simon Fraser University. Michael's main skills are in the areas of electrodynamics, electronics, and numerical simulation software. He has prior work experience as a software developer for a MATLAB-based control system tool and has gained knowledge of electrochemistry while working for an automotive fuel cell company. In addition, Michael's previous exposure to reliability engineering will help ensure the dependably of the device.

Graeme Cowan is a systems engineering student in his fifth year at Simon Fraser University. Having worked with several very small start-up companies developing innovative engineering products, Graeme knows very well the pressures of developing an engineering product from scratch. He brings experience and knowledge of product development, beginning with initial idea and design, continuing to prototype construction and testing, and finishing with product release and maintenance. Graeme also has experience in analogue and digital low frequency circuit design and testing which will be useful in building the product's computer interfacing device.

Jeremy Yoo is a fifth year computer engineering student at Simon Fraser University. He has completed four co-op work terms in the software industry, and brings to the team valuable insight and experience in software design, development, and testing. Combined with the knowledge gained from courses in image processing, communication systems, and microcontrollers and FPGA development, Jeremy is well equipped to handle technical challenges and help produce a successful product. Jeremy's strong project organization and communication skills will also be greatly beneficial to the team.

10. Conclusion

In this day and age, civilian deaths caused by landmines from wars long past are unacceptable. At Solumspect, we strive to make minefields a minor inconvenience that can be easily cleared without extensive time, financial resources, or casualties.

Our product is ambitious, yet as we've shown in our timeline schedule, doable. Using our team's wide range of engineering specialties and a strong reference group for design and testing feedback, the basis for this project is solid. With a well thought out budget and financial plan, it is easy to see how our system will achieve its goals without reaching the astronomical costs of military-grade landmine detection equipment.

Overall, our ground penetrating radar system will combine the low-cost of metal detection, the visual benefit of military ground penetrating radar, and the ease of use of trained animals to revolutionize humanitarian de-mining efforts.

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