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## Aircraft Mounted Ground Penetrating Synthetic Aperture Radar

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### Abstract

*Mineseeker Operations is proposing a forward thinking solution which could rapidly detect landmines with great accuracy and more precision when defining minefield boundaries. Now is the time to aggregate and merge available wide area assessment technologies to give safe land back to communities and local people.*

*State Parties to the Ottawa Treaty have a ten-year deadline to clear mines which has passed for the countries that joined the treaty at its entering into force in 1999. According to the Landmine Monitor, technical surveys hold great promise for finding areas of hazard and reducing quarantined areas by segregating areas that actually contain landmines and other munitions from productive land.*

*The five critical parts of the Mineseeker solution are*

- 1. A comprehensive analysis of the terrain and conflict history*
- 2. Assimilation of the right set of sensors appropriate to the terrain and the targets of interest*
- 3. Development of a mock test site to pretest the survey to ascertain frequency response and to set a base line for imaging by bombarding the area of interest with a wide variety frequency bands and sensor arrays*
- 4. Collection of airborne video and data using a variety of flight patterns geared to accuracy for a specific terrain and munitions set*
- 5. Coalescent of the data collected into a multilayer terrain / land hazard map.*

### Introduction

State Parties to the Ottawa Treaty have a ten-year deadline to clear mines. 2009 was the deadline for countries that joined the treaty at its entering into force in 1999. According to the Landmine Monitor, technical surveys hold great promise for finding areas of hazards and reducing quarantined areas to areas that actually contain landmines and other munitions from productive land.

Have acceptable solutions been defined in 2010? According to the Landmine Monitor, "Acceptable techniques for technical survey, and the definition of what constitutes technical survey and how that is distinguished from area reduction, remain a matter of debate within the demining community" [i]

Mineseeker Operations is an innovator and an aggregator of the latest airborne survey and sensing technologies and data collection practices. Mineseeker Operations has embarked on a multi-phase testing and validation process in partnership with the Centre for Testing, Development and Training and the Faculty of Geodesy, University of Zagreb.

The increased accuracy of the Mineseeker Operations solution over prior applications of airborne survey techniques is accomplished through:

1. Comprehensive analysis of the terrain and conflict history
2. Assimilation of the right set of sensors appropriate to the terrain and the targets of interest
3. A pre-survey of a mock test site to ascertain the best data collection frequencies and to set a base line for imaging and sensor array settings
4. Airborne video and data collection using a variety of flight patterns
5. Coalescing all data collected into a multilayer terrain / land hazard map for analysis.
- 6.

### Terrain and Historical Analysis

Soil and terrain composition have a tremendous influence on the success rate of airborne wide area surveys. The density and composition of the soil alter the probabilities of detection of targets. According to Geophysical Survey Systems, Inc. (GSSI), the amount of success using GPR varies due to the composition of soil, the type of material being surveyed and the frequencies used during the survey. GPR signals have the capacity to penetrate ice, rock, and soil and asphalt though each varies due to that material's electrical properties [ii]. Ž

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### Conflict Analysis

The other key portion of pre-survey information to gather is the status and the history of the contamination by landmines in the particular region. [iii] A comprehensive analysis of the conflict and the historical strategies of engagement and encampment protection enhance the way data is collected and images delivered after processing the data. This analysis begins with collection and review of archive maps and surveys. Plastic explosives, for example, reflect electrical and magnetic impulses differently than metal explosives. The goal of this exercise is to create a data set of all munitions used in the conflict to better understand which signal frequencies to use to gain the best signal response from a buried hazard.

### Assimilation of the right set of sensors

At the core of the solution is to mount some combination of Ground Penetrating Radar, Electro Optical Sensors and high definition video systems on a fixed wing or rotary aircraft appropriate to the terrain and the type of munitions used at the locale.

For example, heavy-based clay or humus soil doesn't allow a great deal of frequency contrast while using Ground-Penetrating Radar (GPR). A medium density soil yields reasonable probability of detection relative to depth, size, shape, and conductivity contrast. Rocky / limestone / sandy based environments are good environments for GPR sensing as is fresh or brackish water. For detection on beaches and in shallow sea water, infrared sensors combined with high resolution video are a powerful combination for data collection.

For example, soils at Los Alamos National Laboratory have been studied for explosive and munitions chemical contamination. This area has been used in the past for explosive testing and explosive research. The high explosives most commonly found included hexahydro-1,3,5-trinitro-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5, 7-tetrazine (HMX), 2,4,6-trinitrotoluene (TNT), 4-amino- dinitrotoluene, 2-amino-4,6-dinitrotoluene, and 1,3,5-trinitrobenzene [iv]

Foliage can offer clues about potential explosive and war remnant contamination when photographed using infrared sensors and high resolution video. Plants have been found to absorb explosive compounds after being exposed to TNT and RDX for as few as 50 days. [v] This change in chemical composition may not be seen by the human eye but will be readily detected by an infrared camera. Infrared lights and sensors see energy emitted by objects versus color and shape as with the human eye. The current infrared sensors see objects at a photon level and can identify changes in chemical composition in soils and in plants. [vi]

### The mock test site

Previous airborne sensor attempts faced frustrating results due to the high number of false positives. The hope of flying over square kilometers of land and receiving a detailed and complete dig map were largely a miscalculation of technology capabilities. This was especially true since most airborne solutions were first tested in a controlled test site where the results were found to be unpredictable. Regardless of those staged results, the gap between a test site and a real mine field remained large.

To reduce the amount of false positives, the best solution involves ways of adding human intellect to the data collection process in an organized and regimented way. The creation of a mock test site at the place of a field survey will add much intelligence to the airborne survey results.

The first outcome of a landmine field mock up is to ascertain the best frequencies for data collection of this particular munitions set in this locale's soil. Secondly the landmine field mock up can be used to set a base line for imaging. This is done by bombarding the targets of interest with signals from a wide variety frequency bands and sensor arrays on munitions planted at a variety of depths. The outcome of the mock test survey is a "cheat sheet" of results to which the results of the real landmine field survey can be compared. The mock site results are further tested by breaking off a small portion of the quarantined landmine field to survey then compare to the mock test site. Once the success rate is determined from this pre-test, the survey team can make good decisions about how to approach the large areas of quarantined land.

### Video and data collection

There are several aircraft platforms and flight patterns that have proven successful in data collection and video efforts. A large stretch of land with few land features such as mountains and rivers can successfully be surveyed with a fixed wing aircraft. An example of a good utilization of this aircraft platform is surveying levees, rail road tracks and roadways. Areas with mountains, rivers and a variety of tree lines will be better surveyed by a rotary aircraft.

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The first flight over the land is to create a 2-dimensional map of the surface that identifies the areas of interest and hazards. For stretches of land with few land features, flight patterns are simply straight lines up and down the area of land or perhaps a checkerboard flight path. The outcome of which is the identification of "areas of interest" or a minefield "footprint".

Once areas of interest are identified, the next set of flights will focus on characterizing the areas of interest. The aircraft, typically the rotary aircraft, flies in a 360 degree pattern around the areas of interest bombarding the areas with signals along the appropriate frequency range established during the mock test. With this set of data, the number and pattern of anomalies, the burial depth and the dimensions of the unknown objects should be exposed.

All of these outputs are synthesized in the creation of three-dimensional (3D) maps of the landmine field. The detail of the depth and size of munitions overlaid with any munitions layout patterns noted overlaid with land features combined with video and/or other optics will provide more clues about the landmine field than ever before. The field manager consolidates this information to guide the decision to quarantine areas identified or to send a team to the location for further exploration or clearance.

**The multilayer terrain / land hazard map**

The data collected from these systems will be geo-referenced within centimeters' accuracy. The goal is a multilayered visual representation of the terrain to provide more accurate intelligence about the safety of the location. The GPSAR will show surface and subsurface landmines and ordinance with a geo-referenced visual mosaic layer showing a detailed view of the ground. The thermal imaging layer will show both munitions versus other ground anomalies and also soil and foliage contamination.

**Now is the time to join forces to eradicate land mines once and for all...**

Now is the time to aggregate and merge available wide area assessment technologies to give safe land back to communities and local people. Airborne multi-sensor technologies have evolved to now provide an effective means to differentiate lands without munitions and release them. The mistakes of the past have been typically been expecting the technology to do more than is reasonable and not having a process that synthesizes the best of the outcomes of the technology with the human interpretation of military strategies and land features. This more accurate solution maximizes the effectiveness technology with the intellects of the analysis team so land free of hazards can be quickly ascertained and freed for productive use. The best additional outcome is to maximize the precious funds designated for demining and land restoration to only those lands that have been proven to contain landmines and munitions

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- testing of demining methodologies, technologies and equipment
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- preparation for introducing quality management in demining companies as per ISO 9001:2000
- lease of test sites
- implementation of research and development projects in the field of mine action
- field testing and evaluation of technologies used for mine contaminated area detection and mine suspected area reduction
- scientific and professional cooperation with national and international institutions.