Airborne Radiological Characterization Surveys in Inaccessible Areas Due to the Presence of Munitions and Explosives of Concern (MEC) - 9358

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ABSTRACT

Ground-based radiological surveys using various forms of Sodium Iodide (NaI) detectors coupled with global positioning system (GPS) data are the norm for characterization of areas potentially contaminated with radioactive materials. However, these types of surveys, gamma walkover (GWS) or vehicle-based drive-over surveys, may not always be possible due to the presence of munitions and explosives of concern (MEC) or other hazardous environments. Aerial based surveys are a highly efficient alternative to conventional site investigation or characterization surveys in these situations as well as modern-day emergency response and anti-terrorism activities.

In 2008, Cabrera Services (CABRERA) completed configuration and deployment of an aerial (helicopter) based platform utilizing multiple large-volume NaI(Tl) detectors connected to a multi-channel analyzer with integrated GPS and a laser based light detection and ranging (LIDAR) system. LIDAR was chosen over conventional altitude GPS data to compensate for variations in terrain which could not be adequately addressed by a GPS based measurement. This system was used to perform characterization of large land areas contaminated with depleted uranium (DU) commingled with MEC. The paper will discuss in more detail the survey platform and methods and review the results of the surveys performed during the project.

The use of light detection and ranging (LIDAR) enabled the characterization and inclusion/exclusion of radiological data based on height above the ground surface, as well as the opportunity for normalization based on altitude. The multi-channel analyzer allowed multiple energy regions of interest (ROI) to be collected and processed independently. The flyover ROI data was post-processed using custom scripts within Arcview® GIS developed for the project to apply data integration and averaging filters over the data to help identify contaminated areas and improve the detection sensitivity. The project also examined the comparison of aerial measurements against ground-based walkover data performed in the same areas previously. For several investigation areas, the post-processed results correlated well with ground based results, which aided the generation of a set of Data Quality Objectives in regards to ideal flight parameters (altitude, speed, and overall survey coverage) which will be used in other areas where the GWS data does not currently exist.

The system described provided excellent value in that it allowed collection of data necessary for remedial planning while keeping risk from MEC to workers and equipment manageable. The dynamic and flexible work processes and real-time data collection capabilities available for systems of this type may be applied

to other radiologically-impacted areas that are also impacted by MEC or any other constituent that makes implementation of conventional surveys difficult or impossible to perform.

INTRODUCTION

Ground based gamma-walkover surveys (GWS) have proven to be effective in the detection and location of DU using field instruments for the detection of low-energy radiation (FIDLER) probes coupled with Global Positioning Systems (GPS) on military firing and testing ranges. However, mobilization of personnel on the ground presents significant potential risk due to the presence of unexploded ordinance (UXO) and MEC. To perform ground based surveys in affected areas like these, each GWS team requires the presence of a UXO technician to aid in UXO detection and avoidance, as well as the occasional donning of protective equipment such as flack vests and helmets (see Fig. 1). In areas where there is the possible presence of Improved Conventional Munitions (ICM), personnel are excluded from the area.

Fig. 1. Typical GWS in UXO area with Technician Wearing Flack Vest and Helmet

Aerial based surveys can be a highly efficient alternative to conventional site investigation or characterization surveys where hazards prevent collection of these data. Aerial-based radiation surveys have been used for years in a variety of emergency response and homeland security applications. However, these tend to be high altitude or higher speed surveys, where large quantities of radioactivity are the acquisition target. In order for these surveys to be deemed acceptable as an alternative to GWS, the detection levels would have to be shown to be comparable in order to achieve project data quality objectives. This paper discusses development and testing of an aerial survey system designed to achieve such objectives.

SYSTEM OVERVIEW

In June and July of 2008, CABRERA constructed and tested an aerial scanning platform consisting of four 4-inch (in) by 4 in by 16 in energy-stabilized NaI(Tl) crystals manufactured by Radiation Solutions Inc (RSI 2008) secured inside a carbon fiber shell and mounted on a lightweight aluminum frame. This system was coined the 'Aerial-CABRERA Large Area Scanning System (ACLASS). The ACLASS platform was mounted to the cargo hook of a Bell Long Ranger helicopter for the surveys described herein. A photograph of the system, as deployed, is provided in Fig. 2. The system was constructed and configured for mounting on helicopter cargo hook(s) in a "break-away" package configuration which conforms to the helicopter's maximum external load (MEL) cargo hook limit capacity and flight characteristics. Prior to live static testing, several short duration test flights were made to assure proper connections, platform stability, and function.

Fig. 2. Bell Long Ranger Helicopter with under-mounted ACLASS System.

The entire system is comprised of a controller, cabling, power supply and ruggedized laptop computer. All components can be run off of the helicopter's "ships" power supply. The ACLASS is energy stabilized using stored reference spectra from several radionuclides that are ubiquitous in the natural environment (Uranium, Thorium, and Potassium).

The survey area chosen consisted of approximately 30 acres on a firing range known to contain DU from previous investigations and ground based GWS (CABRERA 2008). DU is present in the form of metal fragments and visible yellow oxides present on the soil surface and shallow subsurface typically within the first few inches of soil. The results of the ground based GWS were used as a basis of comparison to the airborne survey results.

SURVEY DATA QUALITY OBJECTIVES AND METHODS

Data collection and analysis protocols were established to evaluate results of these surveys and determine the optimum conditions for data collection, characterization, and validation from the aerial survey platform. Data quality objectives (DQOs) developed to evaluate key survey platform parameters are described in Table I below.

Table I. Table of Aerial Survey DQOs

Parameter	Objective	Method / Value
Altitude	Precise Altitude Determination and Control	AGL was determined using a Contour XLR ruggedized laser range finder pointed in the downward direction approximately in line with the systems detector crystals to determine the height of the detectors above the ground surface. Daily checks on the laser's range were conducted on a daily basis to an object of known distance. A potential complicating factor with laser data is the fact that objects such as high grass, large rocks, and trees, as well as range debris can cause the laser range finder to be recorded as an elevation closer to the ground than they actually are.
Scanning Speed	Low Enough to Achieve Survey MDA Requirements	An initial scanning speed was chosen to mimic ground based surveys conducted with forward movement in the range of 1 to 2 meters per second.
Geophysical Position	Precise Spatial Correlation of Survey Data	The system is equipped with an integral Trimble GPS which is checked daily against a second GPS unit as well as the consistency of the GPS at a constant physical position. An external differential GPS may also be used with the system.
Data Collection Interval	Satisfactory Data Resolution	A default data collection interval was set at 1 acquisition per second.
Data Coverage	Satisfactory Data Resolution or Minimum Survey Coverage Requirement	The effective area that the system "sees" will change with altitude. The system "sees" a width of approximately 25 feet at an AGL of 10 feet. Using laser AGL measurements the coverage area of each data point, or sets of points can be determined. Areas may also be cross flown at approximately right angles to each other to achieve better coverage.
Energy Region of Interest (ROI)	Background Reduction, Increased Survey Sensitivity	The system collects 1024 channels of data each second with a set gain of 3 keV per channel. Specific channels for each radionuclide of interest can be set. In this case the system records the each channel of data. Energy regions of approximately 36 channels wide were set for the 766 keV and 1001 keV photons from Pa-234a, a daughter product of U-238.
Energy Stabilization	System Reproducibility and Repeatability	Energy stabilization is critical when performing spectroscopy in outdoor environments with changing temperatures. NaI detectors are well-known to be sensitive to temperature induced gain shifts, which lead to changes in nuclide detectability and sensitivity. The RSI system utilizes multiple ROIs from anthropogenic nuclides of uranium, thorium, and potassium to automatically stabilize the system gain for enhanced performance.
Variable	Reduced System	Using a proprietary script the system can perform different

Integration Radius	Detection Limits	integration and averaging functions based on the distance from the point, or points, of measurement. In this way area averages can be calculated and areas compared to each other.

RESULTS

LIDAR Ranging Performance: Altitude Above Around level

Elevation above ground level was measured using laser ranging during the survey to direct the pilot to adjust altitude to the target, if possible. Due to the presence of trees, large rocks and ravines, safety considerations were often the primary determinate of elevation during the survey. Feedback to the pilot was essential during the survey to optimize the data collection. The elevation data logged throughout the surveys along with the GPS coordinates and radiological data to enable *a posteriori* evaluation and processing. Elevation data collected during the aerial surveys were binned into the following groups: less than 10 feet, between 10-12 feet, 12-13 feet, 13-15 feet and greater than 15 feet. The distribution of elevation data in these groupings is shown in Fig. 3 below.

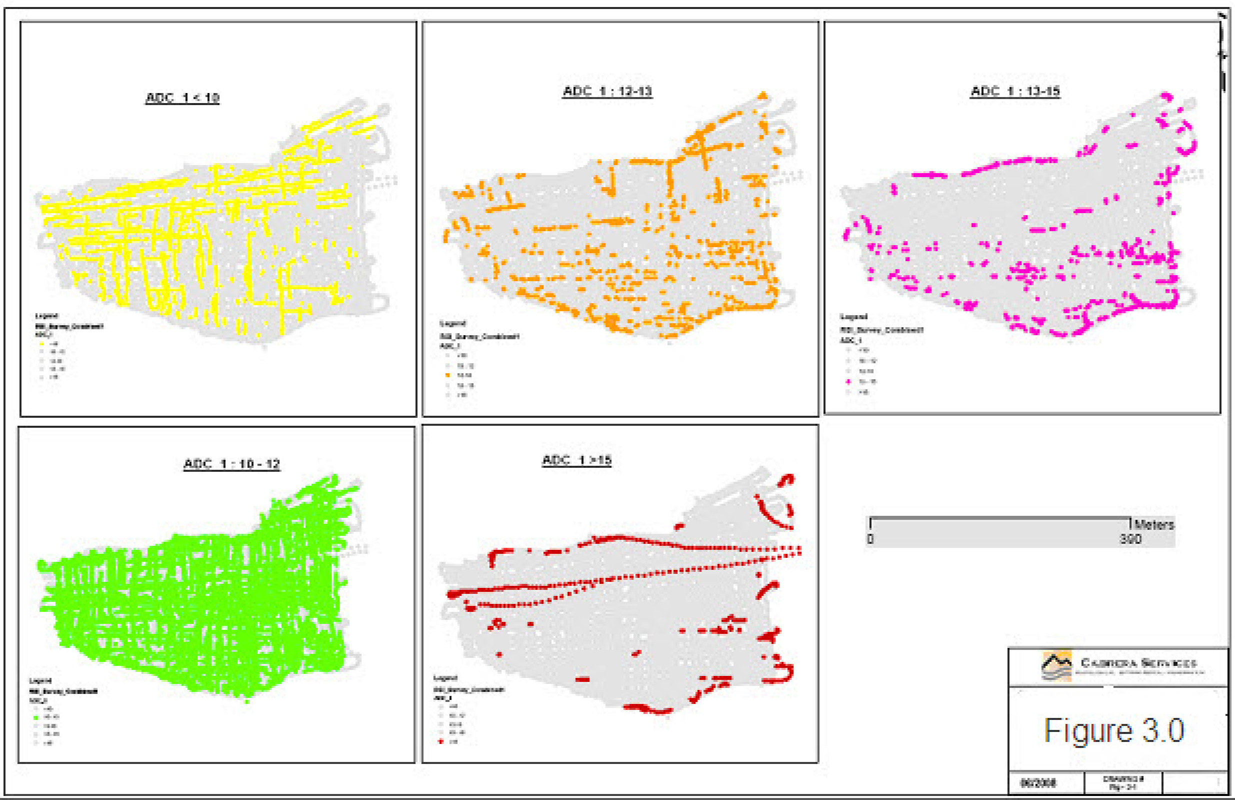

Fig. 3. Distribution of AGL Data Collected During Aerial Surveys

Fig. 3 shows that a majority of the collected elevation data were in the primary data bins of less than 10 ft and 10 to 12 ft AGL. However, a significant number of acquisitions were recorded in the higher data bins during both north-south and east-west flyover patterns. A complication with the use of laser ranging for elevation is variable helicopter rotor wash effect in tall grassy areas. The wash can contribute to variations in AGL readings due to incomplete compression or flattening of the grass. These factors were observed and tested during static platform testing by transiting over the flat and mowed area and an area of high grasses and vegetation. Various ground surfaces such as regular soil, grass, as well as pavement, black and red lava. There was no discernable difference in performance of the laser on these various surfaces.

Collection of these data may be used to normalize the radiation data to a standard AGL, minimizing the effects of variations in flight elevation and aiding the detection capabilities of the system. Another critical use of normalized altitude data is the ability to ensure that altitude is not a factor in the development of spatial radiation distribution patterns. If radiological detection patterns were the result of altitude influence, the plotting of altitude data would likely correlate with plots of Z score distributions of the raw radiation data. Plans exist to normalize data by elevation above ground level are being examined.

Scanning Speed

Ground speed is a variable that is influenced by the weather, terrain, and the pilot. A helicopter speed of approximately 2-3 knots over ground surface or less was initially desired, and appeared to be easily obtainable over flat and level surfaces in the test area. However, the test area was completely level, devoid of vegetation and objects present on the impact ranges. Actual conditions on the range were not entirely consistent with the test area, increasing the altitude which could be maintained while maneuvering to the 10-14 foot range and increased the maintainable airspeed to 3-6 knots due to wind conditions and the presence of surface obstructions.

Lowering the speed would increase residence time of the detectors over the ground (resulting in increased sensitivity) but would alternately increase survey time by a factor of approximately 1.6 based on survey speed alone (resulting in increased survey cost). The decrease in maneuverability impacts the ability to hold straight transit lines, which leads to repeat flyovers in some areas to achieve minimum data coverage requirements.

These data have lead to revised expectations of scanning speed to an acceptable range of between 3 and 6 knots for future surveys.

Geophysical Position:

The system is equipped with an integral mobile-style GPS for navigation purposes. The system also has the capability of using a secondary differentially corrected GPS unit for more precise position logging. The internal GPS or secondary may be used, but only one sensor can be active at a time. Both units were checked daily at a constant physical position as a quality control check. The internal GPS proved adequate for aerial based surveys.

Data Collection Interval:

A default data collection interval was set at 1 second and was determined to be adequate and provided a reasonable interval for accumulating a spectrum. Given the actual flight speed, and interval of one second also enhanced spatial resolution of the scan rather than performing an averaging of the data during collection.

Data Coverage

Area's may be cross flown at approximately right angles to each other to achieve better coverage. The effective area that the system "sees" will change with altitude. The system "sees" a width of approximately 25 feet at an AGL of 10 feet. Using Laser AGL measurements the coverage area of each data point, or sets of points can be determined. The data coverage obtained during the flyover survey was approximately 96%.

Energy Region of Interest (ROI):

The system collects 1024 channels of data each second with a set gain of 3 keV per channel. Specific channels for each radionuclide of interest can be set. In this case the system records the each channel of data. Energy regions of approximately 36 channels wide were set for the 766 keV and 1001 keV photons from ^{234m}Pa. Additional parameters such as gross gamma count rates are also available to plot.

Energy Stabilization

Energy stabilization is a critical factor when performing spectroscopy in outdoor environment with changing temperatures and four detectors as part on a single system. The system achieves energy stabilization on a constant basis by comparing three reference spectrum for natural uranium, natural thorium and potassium-40, stored in memory against the live spectrum accumulated in a buffer for each detector. If a shift in energy is detected the gain of the signal from each detector is adjusted accordingly. This energy stabilization occurs automatically every 1 to 5 minutes depending on the intensity of the background radiation field and the set point of accumulated counts in the energy peaks of interest in the background spectrum (RSI 2008).

Variable Integration Radius

Using a proprietary script, post processing of the data is performed which enables averaging of the count rate in a particular ROI at variable radii from each measurement point. A radius of 20 feet from each individual point provided a pattern of distribution consistent with respect to known ground level survey data and deposition. Using variable radii in this way, area averages can be calculated and areas compared to each other.

CONCLUSIONS

As can be seen in Figure 4.0 the aerial distribution plots of the 766 keV ROI correlate well, although not absolutely, with the Z score plots of the 2007 GWS survey data of the same area. A similar result is obtained by plotting the 1001 keV ROI data. Further refinements with regard to data normalization to a given altitude as well as examining the influence of increasing size of the data averaging area by increasing the radius of data to be included in an area average are in process. Additional analysis of the relative magnitude of the Z-scores of the 2007 GWS data is in progress to determine the best fit of the ground based patterns of DU distribution. Gamma spectroscopic analysis of individual data point spectrums collected and integrated on a geographical position is also in process.

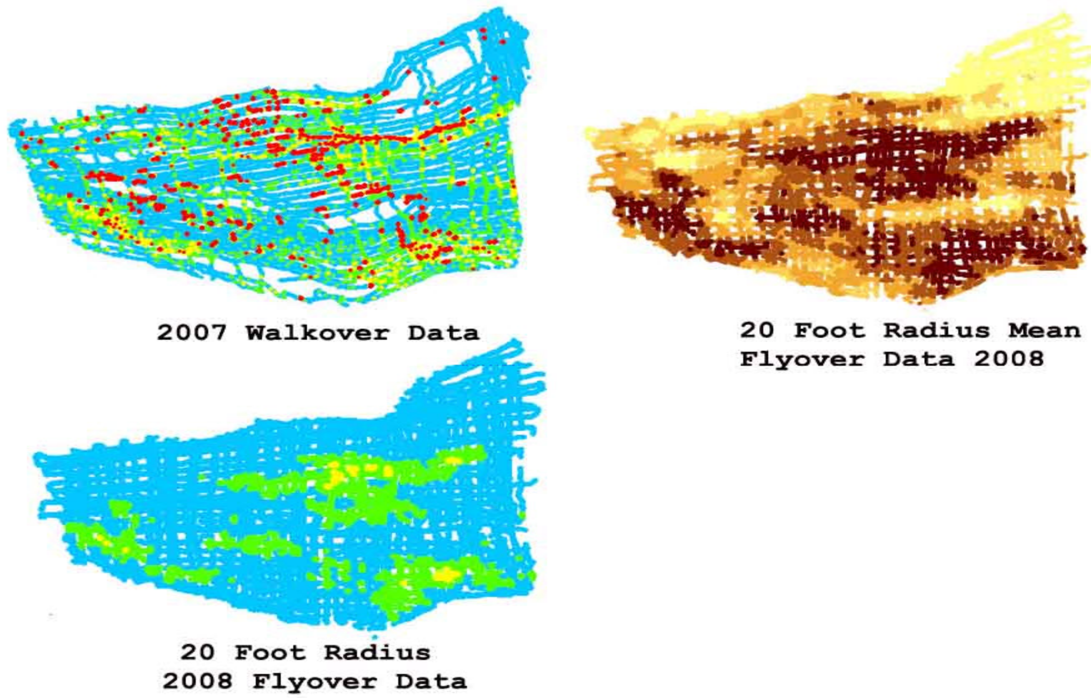

Figure 4.0 Comparison of Walkover and Flyover Data

REFERENCES

1. Cabrera 2008, Cabrera Services, Final Characterization Report, SB Davy Crocket Impact Area.
2. RSI 2008, Radiation Solutions Inc., RS-701 System Users Manual, March 2008.