

# ESTCP Cost and Performance Report



## In-Situ Radiation Detection Demonstration

February 2000



ENVIRONMENTAL SECURITY  
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

## TABLE OF CONTENTS

	<b>Page</b>
1.0 EXECUTIVE SUMMARY .....	1
1.1 TECHNOLOGY DESCRIPTION .....	1
1.2 THEORY OF OPERATION .....	2
1.3 DEMONSTRATION DESIGN .....	2
1.4 DEMONSTRATION RESULTS .....	2
1.5 PERFORMANCE EVALUATION .....	3
2.0 TECHNOLOGY DESCRIPTION .....	5
2.1 BACKGROUND AND APPLICATION .....	5
2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY .....	6
3.0 DEMONSTRATION DESIGN .....	9
3.1 PERFORMANCE OBJECTIVES .....	9
3.2 PHYSICAL SETUP AND OPERATION .....	9
3.3 ANALYTICAL PROCEDURES .....	10
3.4 DEMONSTRATION SITE/FACILITY BACKGROUND .....	10
3.5 DEMONSTRATION SITE/FACILITY CHARACTERISTICS .....	10
3.6 TECHNICAL PERFORMANCE CRITERIA .....	11
3.6.1 Contaminants .....	11
3.6.2 Factors Affecting Technology Performance .....	11
3.6.3 Reliability .....	13
3.6.4 Ease of Use .....	13
3.6.5 Versatility .....	13
3.6.6 Off-the-Shelf Procurement .....	13
3.6.7 Maintenance .....	13
4.0 PERFORMANCE ASSESSMENT .....	15
4.1 FIELD DEMONSTRATION .....	15
4.2 ER SITE 55 STUDY .....	15
4.3 KIRTLAND AFB OT-8 .....	16
4.4 KIRTLAND AFB/SANDIA OT-91 .....	17
5.0 COST ASSESSMENT .....	19
5.1 INITIAL COSTS .....	19
5.2 OPERATIONS AND MAINTENANCE COSTS .....	19
5.3 MOBILIZATION/DEMOBILIZATION COSTS .....	19
5.4 LIFE-CYCLE COSTS .....	19
5.5 EXAMPLE FIELD SURVEY COST .....	20
6.0 IMPLEMENTATION ISSUES .....	21
6.1 PERFORMANCE OBSERVATIONS .....	21

**TABLE OF CONTENTS (continued)**

	<b>Page</b>
6.2 OTHER SIGNIFICANT OBSERVATIONS .....	21
6.3 REGULATORY AND OTHER ISSUES .....	22
7.0 REFERENCES .....	23
APPENDIX A: Points of Contact .....	A-1

## LIST OF FIGURES

---

	<b>Page</b>
Figure 1. Configuration of the LAPS/GPS Equipment for Field Use .....	7

## LIST OF TABLES

---

	<b>Page</b>
Table 1. Field Measurements .....	12
Table 2. Example Cost Estimate .....	20

## LIST OF ACRONYMS

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AFB	Air Force Base
AM	americium
ATV	all-terrain vehicle
cps	counts per second
DCGL	derived concentration guideline levels
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DU	depleted uranium
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
GPS	global positioning system
HPGe	high purity germanium
IT	IT Corporation
keV	kiloelectron volts
LAPS	large area plastic scintillation
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDA	minimum detectable activity
NORM	naturally occurring radioactive material
pCi/g	picocuries per gram
PPE	personal protective equipment
Ra	radium
Sandia	Sandia National Laboratory
SUV	sport utility vehicle
Th	thorium
U	uranium

## ACKNOWLEDGMENTS

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*Technical material contained in this report has been approved for public release.*

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## **1.0 EXECUTIVE SUMMARY**

### **1.1 TECHNOLOGY DESCRIPTION**

The U.S. Department of Defense (DoD) has hundreds of facilities where radioactive materials have been used or are being used, including firing ranges, low-level radioactive waste disposal areas, and areas where past activities have resulted in environmental contamination. Depleted uranium (DU) and radium are the dominant contaminants, and to a lesser extent, mixed fission/activation products, enriched uranium, thorium, and plutonium/americium. Affected sites range in size from a few acres to square miles.

Characterization of surface contamination concentrations has historically been performed using extensive soil sampling programs in conjunction with surface radiation surveys conducted with hand-held radiation monitoring equipment. Selection of sampling locations has been guided in the past by professional judgement or randomly or statistically selected strategies using guidance found in draft NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination." (Berger, 1992) With the advent of implementation of NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)" (NRC, 1997), has come a more formal process of site sampling and survey for affected areas.

Sampling is required within the suspect affected areas classified as Class 1, 2 or 3. Surface soil contaminant characterization using soil sampling and hand-held monitoring are costly, time consuming, and may result in long delays between submission of samples for analysis and obtaining final results. Time delays due to analyses can be minimized by requesting accelerated analysis times, such as seven- to fourteen-day turn around for the submitted samples. However, there is an additional premium to be paid for expedited analysis, and the cost increase may not be warranted or justifiable. Field experience has shown aerial radiation surveys for selection of sampling locations and to characterize DU have not been effective in defining the contaminant footprint, which are costly, and result in long time delays to obtain final survey documentation (Adams, 1999).

This project took an existing, proven radiation survey technology, owned by IT Corporation (IT), that has had limited exposure in the DoD, DOE, and commercial sectors and developed a computer model used to provide radionuclide specific calibration factors. Sandia National Laboratory (Sandia) was responsible for characterization of the detector's performance and for model development. IT was responsible for providing the large area plastic scintillation (LAPS) detector and a DU calibration standard, performance of the field validation surveys, and preparation of the final report, with input from Sandia personnel. Kirtland Air Force Base (AFB) assumed the responsibility of sponsoring this demonstration and providing the field application site at a DoD property at Kirtland AFB.

IT's LAPS system is composed of a 1.5-inch-thick by 3-inch-wide by 33-inch-long plastic scintillator detector that has been designed to detect greater than 300 kiloelectron volt (keV) beta particles and greater than 40 keV gamma photons. The HHD 440A hand-held detector provides high voltage to the detector, data display, and data communication to a laptop computer. A Motorola Global Positioning System (GPS) provides automatic measurement and recording of positional data for the mobile unit. The laptop computer serves as a data logger for both the detector count rate and the GPS positional data. A fixed-base



Motorola GPS operates simultaneously with the mobile unit. GPS data collected from the base unit provides time-referenced correction factors for post-processing of field survey data having 1-meter positional accuracy. A strap type mounting device facilitates mounting the detector on a variety of survey platforms, i.e., 4x4 vehicle, all terrain vehicle, backpacks, etc. Survey speeds are dictated by the terrain and the equipment used to transport the detector. Under ideal conditions up to 25 acres per day can be surveyed. Nominally between 12 and 25 acres is routinely surveyed.

## **1.2 THEORY OF OPERATION**

Application of this system relies on transporting the LAPS detector/GPS equipment over an area to be surveyed and recording the as measured count rates and positional information. At the conclusion of a survey the collected data are used, along with the GPS base station data, to generate a graphical representation of the measured radionuclide near surface concentrations. Several software products are used in the data conversion including Arc View to generate the final figure. Final figure format is determined by client and/or regulator needs, to facilitate communication of the results as clearly and as understandably possible.

## **1.3 DEMONSTRATION DESIGN**

Design of the demonstration project involved three distinct activities:

- Laboratory modeling and calibration,
- Calibration studies using known radioactive large area calibration pads in Grand Junction, Colorado, and
- Field verification studies.

These activities are described in the project demonstration report “Technology Demonstration Plan In-Situ Radiation Detection Demonstration” July, 1999.

## **1.4 DEMONSTRATION RESULTS**

Successful completion of this demonstration plan now allows for the use of the LAPS/GPS detector system to rapidly survey land areas known to be radioactively contaminated with one radionuclide and to estimate the average soil concentration. Presentation of survey results can now be in picocuries per gram (pCi/g) of radionuclides known to be present rather than nominal detector count rates. These data and associated figures can be used to:

- Develop characterization sampling plans which focus to specific areas of contamination that are above limits.
- Guide remedial soil excavation activities to minimize volume of radioactive soils requiring disposal.
- Support final release decisions of land areas for unrestricted civilian use or future restricted use.

Minimum detectable activity (MDA) values were determined as part of this study. Using traditional MDA equations, and the radionuclide specific calibration factors, MDAs were calculated for the LAPS/GPS detector system. Scan MDAs with the detector 30 cm above the ground and traveling at 4 miles per hour were 1.4, 0.8 and 14 pCi/g for radium-226 (Ra-226), thorium-232 (Th-232), and DU, respectively. All of these MDAs are significantly below cleanup limits either known or projected using RESRAD computer models. As discussed below in Section 1.5, the detector's performance for measuring quantified levels of surface depleted uranium contamination was equal to that of a in-situ gamma spectroscopy system.

## 1.5 PERFORMANCE EVALUATION

Performance evaluation was based upon agreement of the model predicted soil concentrations to known soil concentrations measured through traditional soil sampling programs and/or in-situ gamma-ray spectrometry. The model was used to predict calibration factors that were applied to the net count rate data measured by the LAPS to estimate radionuclide soil concentrations in pCi/g. Three Sandia and/or Kirtland Air Force Base sites were used for this evaluation. These sites were Sandia's Environmental Restoration (ER) Site 55, OT-8, and OT-91. Each site was contaminated with a single radionuclide, either DU or Th-232. In all cases the predicted soil concentrations were within a factor of 2 of the known values. The best agreement was observed when the soil radionuclide concentrations were at least one order of magnitude above those found naturally in background soils. For example at OT-8 the in-situ measured values using a high purity germanium (HPGe) detector were 14 +/- 6 and 21 +/- 10 pCi/g for two locations and the LAPS detector in-situ measured concentrations were 7.1 +/- 0.5 and 16 +/- 2 pCi/g, respectively for the same two locations. The HPGe and LAPS detector measured concentrations are not statistically different.

Successful completion of this demonstration has provided an in-situ detection system that can be used as described in Section 3.0 and will result in significant cost savings for characterization and final status surveys and sampling. Typical radioanalytical costs for gamma-spectroscopy is \$125 per sample, and for alpha-spectroscopy \$200 per sample. Typical numbers of samples required on a per acre basis for release of a site for unrestricted use will range from 15 for sites having low contamination potential and no remediation, to 100+ samples for sites having a very high contamination potential prior to remediation. Assuming all radioactive contaminants are gamma-ray emitters and easily detected, results in sample analysis costs ranging from \$1,875 to \$12,500 per acre. These costs do not include field sampling costs, estimated to be \$930 per day, per 40 samples for labor and travel expenses. The LAPS detector can be used to characterize a site for approximately \$60 to \$120 per acre for field costs and \$15 per acre to generate a final figure. These costs differ significantly from traditional soil sampling. This is not to say that use of this technology will eliminate the need for soil samples, but the number of samples can be greatly reduced, even as low as 5 to 10 percent of that required for normal characterization and final release. Using a 90 percent reduction in sample analytical cost would result in the above stated range being \$190 to \$1,500 per acre for sample analysis plus the approximate \$135 per acre cost for performing an in-situ survey. Thus a net cost savings of \$1,550 to \$13,365 per acre just on analytical costs alone. If field sampling costs were accounted for, the savings would be even greater on a per acre basis. Therefore, this technology offers a significant cost advantage over the traditional soil sampling currently used.

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## **2.0 TECHNOLOGY DESCRIPTION**

### **2.1 BACKGROUND AND APPLICATION**

The DoD has hundreds of facilities where radioactive materials have been used or are being used, including firing ranges, low-level radioactive waste disposal areas, and areas where past activities have resulted in environmental contamination. DU and radium are the dominant contaminants, and to a lesser extent, mixed fission/activation products, enriched uranium, thorium, and plutonium/americium. Affected sites range in size from a few acres to square miles.

As the DoD moves forward with military base closure or reuse, there is a responsibility to ensure that these lands and facilities have residual radioactive contamination that is at or below regulatory limits. It is important that radioactive contaminants are remediated to levels that result in acceptable future risk to the public. Of concern at DOE facilities is restoration of the environment from past practices that resulted in the controlled and uncontrolled release of radioactive materials. Site remediation at these types of sites requires sampling and surveys during site characterization to define the affected areas, and during corrective removal actions and final status surveys.

Characterization of surface contamination concentrations has historically been performed using extensive soil sampling programs in conjunction with surface radiation surveys conducted with hand-held radiation monitoring equipment. Selection of sampling locations has been guided in the past by professional judgement or randomly or statistically selected strategies using guidance found in draft NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination." (Berger, 1992) With the advent of implementation of NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)" (NRC, 1997), has come a more formal process of site sampling and survey for affected areas.

Sampling is required within the suspect affected areas classified as Class 1, 2 or 3. Surface soil contaminant characterization using soil sampling and hand-held monitoring are costly, time consuming, and may result in long delays between submission of samples for analysis and obtaining of final results. Time delays due to analyses can be minimized by requesting accelerated analysis times, such as seven- to fourteen-day turn around for the submitted samples. However, there is an additional premium to be paid for expedited analysis, and the cost increase may not be warranted or justifiable. Field experience has shown aerial radiation surveys for selection of sampling locations and to characterize DU have not been effective in defining the contaminant footprint, which are costly, and result in long time delays to obtain final survey documentation (Adams, 1999).

The MARSSIM acknowledges the emerging availability of in-situ radiation survey techniques but, unfortunately, did not have the information available at the time of publication to be prescriptive in its use. Actually, in-situ techniques are capable of providing orders-of-magnitude with more data points per sample area for gamma-emitting radionuclides than would otherwise be necessary to satisfy statistical sampling designs. Significantly, these measurements are easily capable of satisfying the derived concentration guideline levels (DCGLs) established for most site cleanups. These data, coupled with newly available

GPS data logging, make documentation and visualization of site contamination considerably better and easier than ever before.

IT's LAPS system is composed of a 1.5-inch-thick by 3-inch-wide by 33-inch-long plastic scintillator detector that has been designed to detect greater than 300 keV beta particles and greater than 40 keV gamma photons. The HHD 440A hand-held detector provides high voltage to the detector, data display, and data communication to a laptop computer. A Motorola GPS provides automatic measurement and recording of positional data for the mobile unit. The laptop computer serves as a data logger for both the detector count rate and the GPS data. A fixed-base Motorola GPS operates simultaneously with the mobile unit. GPS data collected from the base unit provide time-referenced correction factors for post-processing of field survey data having 1-meter positional accuracy. A strap-type mounting device facilitates mounting the detector on a variety of survey platforms, i.e., 4x4 vehicle, all terrain vehicle, backpacks, etc. Figure 1 shows a schematic of the LAPS/GPS equipment as configured for field use.

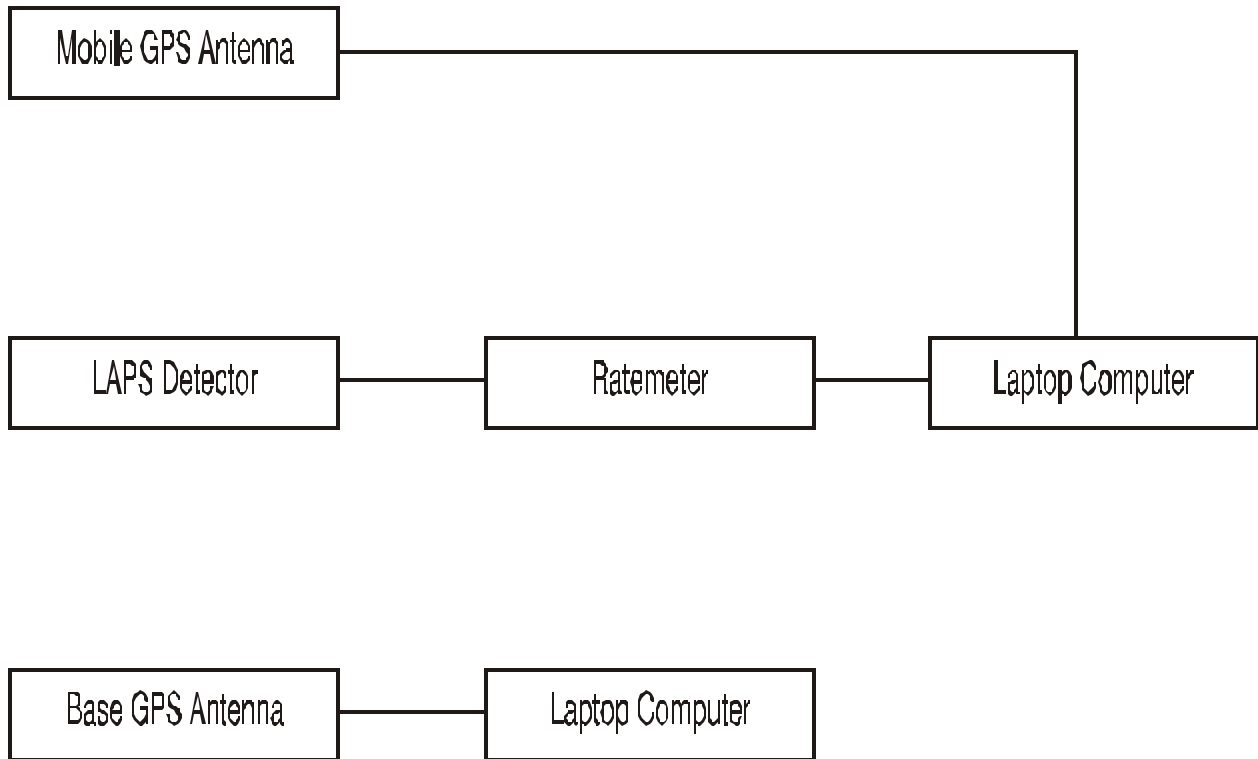
Application of this system relies on transporting the LAPS detector/GPS equipment over an area to be surveyed and recording the measured count rates and positional information. At the conclusion of a survey, the collected data are used with the GPS base station data to generate a graphical representation of the measured radionuclide near-surface concentrations. Successful completion of this demonstration allows the presentation of information in pCi/g of radionuclides known to be present rather than nominal detector count rates, counts per second (cps).

## **2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY**

As currently configured and used, this detector system provides a tool that can be used to rapidly survey large areas of radioactively contaminated land. As many as 25 acres per day have been surveyed using this technology. This detector system has been successfully used at seven DoD, three DOE, one U. S. Army Corps of Engineers, and three commercial sites to grossly characterize radiological conditions on land areas ranging in size from 1 acre to 1,200 acres. At a nominal cost of \$1500/day for equipment and manpower, considerable savings over soil sampling for subsequent laboratory analysis can be achieved. For example, if the survey covered 25 acres per day (with several hundred valid data points per acre), the per-acre cost is \$60, which, when compared to a nominal cost of \$125 per sample for a gamma spectroscopy analysis, is very cost effective.

Site-specific graphical representations of these surveys have been used to guide remediation soil sampling, to demonstrate compliance with final release criteria where criteria were based upon small levels of contaminants above background, and to minimize the remediation area.

As configured and used in the past, the LAPS detector/GPS equipment could only be used to qualitatively assess the data since there were no validated correction factors to convert the count rates into quantitative units of pCi/g. With the ability to apply radionuclide-specific correction factors comes the ability to quantitatively demonstrate compliance to DCGLs with no measurable increase in field survey or data analysis cost, and as discussed in Section 1.5 with quantitation ability very similar to that of HPGe detector systems.



**Figure 1. Configuration of the LAPS/GPS Equipment for Field Use.**

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### **3.0 DEMONSTRATION DESIGN**

#### **3.1 PERFORMANCE OBJECTIVES**

This system uses the LAPS detector in conjunction with a GPS. With the planned enhancements, this operating specialty piece of equipment provides a rapid and cost-effective system for the detection of radioactive materials and their distribution in the environment. Technology enhancements planned for this demonstration project make this equipment and its detection capabilities directly applicable to the DoD and other government agencies such as DOE, U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency (EPA). The ultimate objective of the plan was to improve an existing, proven technology for performing surface radiation surveys by developing a predictive calibration model, with an emphasis on the detection of DU contaminants and other typically encountered contaminants, such as americium-241, Th-232, and Ra-226.

The demonstration focused on the development of calibration algorithms needed to convert the normal detector output, in counts per unit time (i.e., cps), to average radionuclide-specific surface contamination in pCi/g, taking into account various soil types and densities. Additionally, the algorithm was to allow for the calculation of the MDA in pCi/g for specific radionuclides and existing background at a site. Validation of the algorithms was to be demonstrated in field trials at Kirtland AFB/Sandia for those contaminants that were anticipated, i.e., DU and Th-232. Laboratory studies would be used to determine the appropriate parameters to develop calibration algorithms for Am-241 and Ra-226.

Intermediate project objectives were to:

- Demonstrate in field trials that the detector can be used to quantitatively characterize DU soil concentrations.
- Demonstrate use of a computer model that can calculate detector efficiency factors for any gamma-emitting radionuclide distributed within a variety of soil types.
- Demonstrate that MDA limits for static and active surveys are sufficiently low to allow quantification of radioactive material that is relevant to characterization and cleanup criteria.

Achievement of these objectives provides a rapidly deployable survey tool that offers significant cost savings, improved instrument efficiencies, enhanced data collection, and support in reaching waste minimization goals during the characterization, remediation, and release surveys of large radioactively contaminated land areas.

#### **3.2 PHYSICAL SETUP AND OPERATION**

The LAPS detector system can be set up in a variety of configurations, including backpack, 4-wheel all-terrain vehicle (ATV), bumper mount to a sport utility vehicle (SUV), and jogger cart. The specific method of attaching cables, etc. is described in an internal IT user manual. Field personnel use the methods in the manual to connect the various parts of the system, run checks, etc. Field setup time is nominally 1 - 3 hours depending upon the complexity of the mounting configuration. If mounted to an SUV the setup time is normally 1 hour to mount the detector and get both the base and mobile GPS stations operating.



Mounting to an ATV requires more time since a special mounting frame is required. Fabrication time is 1 - 2 hours using materials that are readily obtained from any hardware/lumber store.

### **3.3 ANALYTICAL PROCEDURES**

Once the field data have been recorded to disk, the data disks are returned to the home office where they are used to generate figures that depict the radiological status of the area surveyed. This requires that the data be uploaded into a data file and then using Waypoint® software, apply the coordinate correction to the mobile GPS position data. The result of this step is the generation of a text file that contains all corrected positional data and the detector count rates. The next step in the process is to upload the text file into Microsoft Access® where the data are sorted by increasing count rate in preparation to generating the final figure. The last step in the process is to upload the sorted text file into ArcView® where net background count rates are subtracted from the gross count rates, calibration factors are applied to the background subtracted data, data sort ranges are applied, and a final figure is generated. This typically requires 8 man-hours for a nominal 2-3 days worth of survey data.

Additional enhancements can be applied at this stage such as overlaying the data on an electronic base map or an aerial photo, averaging the concentrations over 10 m by 10 m grids, or other special affects to enhance data presentation.

### **3.4 DEMONSTRATION SITE/FACILITY BACKGROUND**

Sites contaminated with radioactivity were required for field demonstration of this technology. Site selection was based upon two factors:

- The contaminant of concern must be one for which the LAPS detector is capable of detecting (e.g. a beta or gamma emitting radionuclide), and
- The site must have been previously characterized for that contaminant.

Kirtland AFB and Sandia have soil contaminated areas that meet both of these criteria. Sandia Site 55 was contaminated with DU. DU has the radioisotopes of uranium, U-234, U-235, and U-238, and their associated radioactive decay progeny, which are easily detected with the LAPS. Kirtland AFB Site OT-8 was “seeded” with Th-232 for training purposes, which is easily detected with the LAPS. Kirtland AFB site OT-91 was suspected of being slightly contaminated with DU.

Concerning the second criterion, environmental studies and remedial investigations have resulted in several sites having been well characterized for DU or Th-232 in the near-surface soils.

### **3.5 DEMONSTRATION SITE/FACILITY CHARACTERISTICS**

Sandia has a major responsibility for the design and development of non-nuclear portions of weapons systems. Since the mid-1940s some operations have generated low-level radioactively contaminated environmental sites. One of the main radioactive contaminants is DU. In 1984, DOE created a site cleanup program called the Comprehensive Environmental Assessment and Response Program. Through this and subsequent programs, 157 potential waste sites at Sandia have been investigated. Three of these sites had

good potential for this demonstration program; Site 55, Site 277/ OT-91, and Site OT-8. Site 55 is a Sandia ER Site: Site 277/ OT-91 is a shared Sandia/Kirtland AFB site; and OT-8 is a small Kirtland AFB site.

Site 55 is a site of approximately 15 acres where residual DU is present from historical explosive testing. This area was remediated in 1995, and in May of 1998 an “extent of contamination” survey was conducted. During conduct of this survey, residual DU contamination was found. However, the small amount of remaining DU was at levels that justified a “no further action” recommendation.

Sandia ER Site 277 is a location contiguous to Kirtland AFB OT-91 located 0.5 miles due east of the Starfire Optical Range operated by Sandia. Sandia's responsibility for ER Site 277 concerns a small arroyo containing a packing crate and related debris immediately north of OT-91. Sandia is conducting sampling and investigation to identify potential contaminants on the site. Kirtland is simultaneously conducting preliminary investigative studies at OT-91 to identify potential contaminants at that site, which was used for, among other things, test-firing projectiles into a concrete wall. There is a potential for residual DU to remain on OT-91.

OT-8 was a site used by the Air Force for contaminated area site training. The site was “seeded” with Th-232 to simulate contamination from an aircraft accident around which personnel would simulate emergency response actions.

A comparison of field measurements for OT-8 and Sandia Environmental Restoration Site 55 is presented in Table 1.

### **3.6 TECHNICAL PERFORMANCE CRITERIA**

#### **3.6.1 Contaminants**

This detector system is applicable to any beta- and/or gamma-emitting radionuclide present in the near-surface soils, e.g., within the upper 12 inches of soil. The main contaminants of concern for Sandia and Kirtland AFB are DU and Th-232.

#### **3.6.2 Factors Affecting Technology Performance**

Detection of radionuclides in the near-surface soil column is affected by:

- Concentration of the contaminant,
- Concentration of naturally occurring radioactive materials (NORM) in the soil,
- Distribution of the contaminant in the soil column, both vertically and laterally,
- Height of the detector above the contaminated surface, and
- Rate of survey speed.

The lower the concentration of the contaminant in the soil, the harder it is to detect a measurable above-background count rate from the contaminant. The MDA for radiological monitoring equipment is affected by background, where higher NORM concentrations reduce sensitivity to the contaminants of concern, thereby increasing the MDA.

**Table 1. Field Measurements.**

Measurement	Grid 1	Grid 2	Grid 3	Grid 4
<b>OT-8</b>				
LAPS estimated Th-232 (pCi/g)	1.9	15.8	1.9	7.1
Uncertainty	0.5	2.4	0.5	0.5
In-Situ HPGe Detector Th-232 (pCi/g)	4.9	21.5	4.0	13.8
Uncertainty	2.2	9.5	1.8	6.2
<b>Sandia Environmental Restoration Site 55</b>				
LAPS estimated DU (pCi/g)	7.3	7.3	5.2	5.6
Uncertainty	7.4	5.9	7.1	5.5
In-Situ HPGe Detector (pCi/g)	ND	ND	ND	ND
Laboratory Results (pCi/g)	2.0	1.0	0.9	1.0
Uncertainty	0.4	0.6	0.4	0.3

Bkg - background  
 cps - counts per second  
 DU - depleted uranium  
 HPGe - hyperpure germanium detector  
 ND - below detection limit of approximately 4 pCi/g  
 pCi/g - picocuries per gram

Soil acts as a shielding material for both beta particles and gamma rays. Therefore, the greater the depth from the surface, the more radioactive material must be present (more pCi/g) to be detected. Also, the physical surficial distribution (contaminant heterogeneity) affects detectability, where uniformly dispersed radioactive materials will result in lower MDAs than a few isolated point sources.

An important characteristic of the large numbers of data points obtained with this method (one data point per second) is that the data points can be assembled into user-defined sub-areas of surveyed land. These data can be “pooled” to effectively lower (improve) the effective MDA.

Height of the detector will affect the field of view and also the detectability of low-energy beta particles. For a uniformly dispersed contaminant, detector height has little affect. However, if there are low-energy beta particles involved, the air between the soil surface and the detector may shield these particles from detection. If the contaminant is a point source, an increase in detector height will produce a higher MDA.

Rate of speed affects detectability and MDA. The faster a survey is conducted, the less time that the detector is over a particular location. The MDA is inversely proportional to the length of count time. Ideally, the rate of speed should be matched to the width of the viewing window, such that for every second the path length surveyed is equal to the width of the viewing window. For example, if the width of the viewing window is 7 feet, then the survey speed should be 7 feet per second, so that for every second of

survey time the field of view is a 7 x 7-foot square. If it is desired to improve the MDA, then the survey speed should be lowered to allow more viewing time over the area to be surveyed.

### **3.6.3 Reliability**

This system has shown itself to be very field-rugged and durable. Over the course of four years and many hours of surveys conducted in various types of terrain and weather, this system has had very few failures. Those failures fall into the categories of broken cables or weak auxiliary batteries.

### **3.6.4 Ease of Use**

Over the four years that this system has been used, user friendliness has been improved. As currently configured, the system is very easy to configure and use in the field. There are a few improvements that can still be made to enhance user friendliness, but at the present time, are thought to be too costly for the benefit gained.

### **3.6.5 Versatility**

This detector system was designed to mount easily to a wide variety of transport configurations. However, it is limited to the detection of radioactive materials that are either beta particle or gamma ray emitters, with the latter being the most important.

### **3.6.6 Off-the-Shelf Procurement**

This system was procured through a specialized vendor who will custom build a detector and auxiliary hardware/software for each system. They have built several of these type systems to meet specific client requirements. They could easily reproduce a system that would be very similar to the system used in this demonstration. Any detector/rate meter combination that can satisfy the survey MDA requirements can be used when coupled with the GPS.

### **3.6.7 Maintenance**

Maintenance requirements of this system are minimal. It has been returned to the factory, on average, once per year. Average down time has been two days, one for shipping and one for repair and return. Routine maintenance involves annual detector calibration, and inspection and repair of cables.

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## **4.0 PERFORMANCE ASSESSMENT**

### **4.1 FIELD DEMONSTRATION**

Once both laboratory and field calibration factors were established, the Kirtland AFB/Sandia field demonstration was performed. Following the laboratory and field calibration activities, a Kirtland AFB/Sandia site whose DU surface soil concentrations have been characterized by traditional soil sampling methods and non-traditional in-situ gamma spectroscopy, were selected for field trials. Field trials, supported by IT and Sandia, consisted of the following activities.

- Performing static counts at areas where soil samples were obtained or in-situ gamma spectroscopy.
- Performing drive-over surveys of the selected site(s), using a near-100-percent coverage.
- Generating estimates of the “as-measured” radioactivity concentrations using the predicted efficiency factor.
- Comparing the estimates to the known concentrations.

It was anticipated that some variance in surface concentrations would be observed due to the differences found when using discrete soil sampling techniques, in-situ gamma spectroscopy, and the LAPS detector. Both IT and Sandia project personnel evaluated the differences and determined their significance. In all cases, the field comparison results were within a factor of two agreement with the known concentrations.

In most cases, surface contamination does not warrant personal protective equipment (PPE). However, although not part of this ESTCP study, PPE was implemented at a separate site at the client's request. Vehicles and equipment are surveyed prior to leaving the site and the costs involved are insignificant.

### **4.2 ER SITE 55 STUDY**

At the Sandia facility there are several sites where previous soil sampling and in-situ gamma spectroscopy measurements have characterized the residual contamination. One such site is ER Site 55. This site had been previously contaminated with DU while performing simulated nuclear weapons accident scenarios. In the 1990s, this site was remediated by performing walk-over surveys of the area with 2-in by 2-in sodium iodide detectors. DU fragments were gathered as they were found. Once all DU fragments had been found, the site was considered cleaned. However, there were some areas that exhibited elevated count rates even though no DU fragments could be found. These areas were generally in low-lying areas where the weathering process of water erosion would have transported the soil-sized DU-oxide fines, or where the initial deposition resulted in small soil-like DU fines.

Several surveys have been conducted at ER Site 55 by Sandia's Environmental Restoration Group and subcontractors. Soil samples and in-situ gamma spectroscopy have been used to characterize the final residual contamination. In the drainage area four DU test areas were identified to establish the as-found DU concentrations. DU concentrations ranged within these four test areas from background (approximately 1 pCi/g) to 2 pCi/g.

In September 1999, the LAPS detector system was used at ER Site 55 to measure the count rate from each of the four test areas. Then, using the collected count rate data and the correlation factor determined by the calibration model, the DU concentration was estimated. All of the detector values are below the estimated MDA for these measurements. The soil results are at concentrations that are consistent with the MDA for the LAPS detector.

The DU MDAs for static and moving measurements are well below the typical remediation cleanup goal of 35 pCi/g, as well as the cleanup goals for total uranium being used for cleanup of sites that fall under the Formerly Utilized Sites Remedial Action Program. These goals range from 35 to hundreds of pCi/g.

ER Site 55 had been previously surveyed using the LAPS detector during the spring of 1999. The collected count rate data were averaged over 10-m by 10-m grids and the currently determined calibration factor of 10.5 cps/pCi/g was applied to the measured data. These findings do not conflict with the results of the four static measurements previously described, but rather show the added benefit that is gained by having a significantly larger number of data points to “pool” in the determination of the presence of above natural background radioactivity. These data were obtained while driving the detector over the site at speeds between 2 to 4 miles per hour. At these speeds, the predicted MDAs are 10 and 14 pCi/g, respectively. However, by using a larger sample size, i.e., more counts in the pooled data set, the effective MDA is lowered by nearly a factor of two to 5 pCi/g.

Similar measurements were made at Kirtland AFB Site OT-8, which was seeded with Th-232 for training purposes, and Kirtland AFB Site OT-91, which was suspected to have DU present from projectile testing that occurred at the site. The following discussion shows site conditions during the survey and the predicted near-surface concentrations of Th-232 and DU at sites OT-8 and OT-91, respectively.

#### **4.3 KIRTLAND AFB OT-8**

Four locations were selected at the OT-8 site for making in-situ measurements with the LAPS detector. These locations were selected to allow comparison to a wider range of surface concentrations. Both sets of measured results are in excellent agreement, with the reported value uncertainties overlapping. However, the jogger cart tended to “under-predict” the amount of Th-232 present.

Following these static measurements, the LAPS detector was mounted on the bumper of a four-wheel-drive SUV. For this configuration, the detector was driven over the OT-8 site.

#### **4.4 KIRTLAND AFB/SANDIA OT-91**

A drive-over survey of approximately four acres was conducted at OT-91 with the LAPS detector mounted to the bumper of a four-wheel drive SUV. The LAPS detector was held static over the sites and the count rates were recorded.

The LAPS detector had an average reading of 1130 cps. Subtracting a background of 602 and applying the 10.5 calibration factor, a DU activity of  $50 \pm 8$  pCi/g is obtained.



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## **5.0 COST ASSESSMENT**

### **5.1 INITIAL COSTS**

There are no startup costs associated with this particular LAPS detector/GPS equipment. If a new system were to be procured, the costs would be approximately:

- \$12,000 for a LAPS detector
- \$4,000 for a GPS system
- \$5,000 for GPS software and graphical package

A non-quantified cost would be that associated with a new user becoming familiar with the equipment and the software.

### **5.2 OPERATIONS AND MAINTENANCE COSTS**

Operational costs are specified in two different categories, site-specific costs and home-office support. Site-specific costs include such things as: the labor mix utilized to perform a survey, the size of the site, method used to transport the detector during performance of the survey, travel, motel, and per diem costs, and equipment shipment costs. These costs are accounted for when pricing a survey. Typically, for a two-person team, these costs will be approximately \$1,128 per day for labor, based upon an 8-hour day, and \$268 for travel costs, including a sport utility vehicle. If an ATV is required, a rental cost will increase the field cost by \$75 - \$100 per day, depending upon ATV availability.

There are few costs associated with maintenance of this equipment. Those costs that are routinely incurred are for annual re-calibration of the equipment. There are no fixed cycle costs for equipment repair. System maintenance and repair has historically been low, averaging about \$400 per year.

Home-office support includes such things as: data reduction, generation of figures showing the results of surveys, professional staff writing reports, word processing, and document production. These costs have historically been approximately \$5,000 to \$10,000 depending upon size of the area surveyed, the type of figures required, and the complexity of the final report.

### **5.3 MOBILIZATION/DEMOBILIZATION COSTS**

Costs associated with mobilizing staff and equipment to a site and demobilizing from the site are site-specific and include such factors as labor mix, travel costs, and equipment shipping costs. These costs can range widely, but have historically been between \$1,500 to \$5,000.

### **5.4 LIFE-CYCLE COSTS**

Life-cycle costs are primarily driven by GPS equipment upgrades to maintain state-of-the-art capabilities. The LAPS detector is very durable and should be dependable for ten or more years. Given the initial purchase price of \$12,000 and a ten-year use, this provides a \$1,200 per year life-cycle cost.

GPS equipment has been changing rapidly, providing for easier positional tracking and better positional precision, and vendors have ceased servicing “older” technology. Historically, the GPS components of this system have been changed (upgraded) every three years. Given an initial purchase price of \$9,000, this would result in an annual cost of \$3,000.

## 5.5 EXAMPLE FIELD SURVEY COST

The following is provided as an example cost summary to perform an in-situ survey at a site contaminated with Ra-226. The imaginary site selected is a 60-acre site located in the Denver Metropolitan area. It is assumed that the survey will take 1 day for site training and equipment setup, approximately 3 days to survey the 60 acres with the detector mounted to an SUV. A small letter report will be generated that provides the results of the survey. The following table lists the various activities and the costs associated with each activity. These costs reflect current travel, labor, and equipment rates.

**Table 2. Example Cost Estimate.**

Activity	Cost
Mobilization/Demobilization: Includes air fare and equipment shipping cost	\$2,100
Field Survey: Includes labor, SUV rental, LAPS/GPS cost, motel and meals	\$6,440
Data Analysis	\$400
Final Report	\$1,500
Total/Total Cost per Acre	\$10,440/\$170

This cost is compared against the cost for sampling this entire area for unrestricted release. The following assumptions are made:

- Site is a Class 2 area for final status survey purposes
- Each Class 2 area is 10,000 square meters or 2.47 acres, for a total of 25 survey units
- Each survey unit will require 20 samples,
- A two person crew on temporary duty is required to collect 40 samples per day (\$930/day), and
- All samples are analyzed by gamma spectroscopy at \$125 per sample.

Total cost for sampling and analysis is \$74,125. Assuming that the drive over survey allows for a 90% decrease in sample load results in a sample and analysis cost of \$7,413. This added to the cost of the drive over survey results in a total cost of \$17,852, nearly ¼ the cost without a LAPS survey.

## **6.0 IMPLEMENTATION ISSUES**

### **6.1 PERFORMANCE OBSERVATIONS**

This project has taken an existing, proven radiation survey technology, a LAPS detector used in conjunction with a GPS, and improved its data presentation and evaluation capabilities by calibrating the detector response to specific radionuclides.

A predictive model was developed during the scope of work that allows estimation of calibration factors for radionuclides not used in this study. With these specific radionuclide calibration factors, the DoD and others have access to a tool that can perform characterization and final release surveys more quickly than is currently possible and final results can be directly reported in pCi/g of soil. Thus, characterization, remediation, and final clearance surveys of a radioactively contaminated site can now be performed with a detector having detection limits that are as good as or better than current technology. Survey results can be directly compared to required cleanup standards, allowing rapid identification of areas that require remediation or guide surgical removal of contaminated soil that is above remediation guidelines. Post-remediation surveys can document that final radiological site conditions are within the remedial action limits without requiring the extensive sampling efforts formerly used.

Performance of a field demonstration and comparison program at Kirtland AFB validated the effectiveness of the LAPS/GPS equipment. Kirtland AFB assumed the responsibility of sponsoring this demonstration and providing the field application site. Expertise from the DOE through Sandia provided needed modeling and lab verification to determine detector efficiency factors and demonstrate static and active MDA for various typically encountered radionuclides such as Ra-226, U-238, and Th-232. IT performed actual field verification at the Kirtland and Sandia sites using existing soil sample and in-situ gamma-spectroscopy characterization data.

### **6.2 OTHER SIGNIFICANT OBSERVATIONS**

Achievement of these objectives provides a rapidly deployable survey tool that offers significant cost savings, improved instrument efficiencies, enhanced data collection, and support in reaching waste minimization goals during the characterization, remediation, and release surveys of large radioactively contaminated land areas.

Successful completion of these innovations resulted in:

- A two-person crew being able to survey up to 25 acres per day
- Enhanced detection limits, large area viewing footprint ranging from 5 feet by 4 feet to 10 feet by 10 feet depending on detector configuration and radionuclide of interest,
- A high rate of survey speed (up to 7 miles per hour), and
- Automatic data recording of both count rates (convertible directly to pCi/g) and associated latitude and longitude.

In data presentation, use of electronic data files allows great flexibility in presentation format to ensure effective communication, and documentation. Data presentation can include electronic base maps, aerial photographs, or other electronic media that allow for ease of survey data interpretation pertinent to characterization surveys, remediation activities, or post-remediation closure surveys. Determination of radionuclide-specific calibration factors allows straightforward data presentation in pCi/g rather than nominal count rates, cps.

### **6.3 REGULATORY AND OTHER ISSUES**

Expertise from the DOE through Sandia provided needed modeling and lab verification to determine detector efficiency factors and demonstrate static and MDA for various typically encountered radionuclides such as Ra-226, U-238, and Th-232.

This detector system has been successfully used at seven DoD, three DOE, one U. S. Army Corps of Engineers, and three commercial sites to grossly characterize radiological conditions on land areas ranging in size from 1 acre to 1,200 acres.

Most regulatory agencies are recognizing the use and applicability of in-situ measurements for final release surveys and for site characterization.

## **7.0 REFERENCES**

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## APPENDIX A

### Points of Contact

Mr. Stephen W. Duce  
Principal Investigator  
IT Corporation  
312 Director Drive  
Knoxville, TN 37923  
Telephone: (423) 694-7370  
Fax: (423) 690-3626  
E-mail: [sduce@theitgroup.com](mailto:sduce@theitgroup.com)

Mr. David Miller  
Principal Investigator  
Sandia National Laboratory  
P.O. Box 5800 MS-1008  
Albuquerque, NM 87185  
Telephone: (505) 284-2574  
Fax: (505) 284-2616  
E-mail: [dmille@sandia.gov](mailto:dmille@sandia.gov)

Mr. Chris DeWitt  
Project Lead  
Kirtland AFB  
377<sup>th</sup> ABW/EMR  
2050 Wyoming Blvd. SE, Ste 124  
Kirtland AFB, NM 87117-5270  
Telephone: (505) 846-0053  
Fax: (505) 853-0540  
E-mail: [dewittc@knt2.kirtland.af.mil](mailto:dewittc@knt2.kirtland.af.mil)





## **ESTCP Program Office**

901 North Stuart Street  
Suite 303  
Arlington, Virginia 22203  
(703) 696-2117 (Phone)  
(703) 696-2114 (Fax)  
e-mail: [estcp@estcp.org](mailto:estcp@estcp.org)  
[www.estcp.org](http://www.estcp.org)