INNOVATIVE TECHNOLOGY
Summary Report

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ISOCS for Free Release

Deactivation and Decommissioning
Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

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OST Reference 2098

Deactivation and Decommissioning
Focus Area

Demonstrated at
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho

INNOVATIVE TECHNOLOGY

Summary Report

Purpose of this document

The purpose of this Innovative Technology Summary Report is to describe the benefits of using the In Situ Object Counting System for Free Release. This system identifies and quantifies radiological contamination to guide cleanup efforts required to release facilities for unrestricted use.

The In Situ Object Counting System for Free Release provides near real-time nuclide-specific activity and concentration of gamma-emitting radiological contamination. Engineers demonstrated the efficacy of this system at the Idaho National Engineering and Environmental Laboratory as part of a Department of Energy Large-Scale Demonstration and Deployment Project.

Innovative Technology Summary Reports describe waste cleanup technologies developed and tested using funds from the Department of Energy's Office of Science and Technology. The reports compare baseline and competing technologies, considering readiness, performance, regulatory acceptance, commercial availability, and cost. The reports are available online at http://www.em.doe.gov/ost under "Publications."

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SECTION 1
SUMMARY

Technology Summary

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontaminating and decommissioning nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area of DOE's Office of Science and Technology (OST) sponsors a “Large-Scale Demonstration and Deployment Project” to test new technologies. As part of this project, developers and vendors showcase new products designed to decrease health and safety risks to personnel and the environment, increase productivity, and lower costs.

The Large-Scale Demonstration and Deployment Project at the Idaho National Engineering and Environmental Laboratory (INEEL) has generated a list of statements defining specific needs or problems where improved technology could be incorporated into ongoing decontamination and decommissioning (D&D) tasks. One of the stated needs was for developing technologies that would reduce costs and shorten D&D schedules by providing radiological characterizations to allow buildings, rooms, or facilities to be free released, that is, released for reuse. Engineers at the INEEL have identified the In Situ Object Counting System (ISOCS) for Free Release (IFR) as being one such technology that could provide economic and safety benefits to the INEEL D&D program. Benefits of using the IFR include:

- Cost reductions in release surveys – reduction in labor hours by 96% to identify hot equipment and by 75% to analyze whole rooms
- Improved presentation of data
- Accelerated D&D schedule – shorter final survey times and confirmation of free-release status following D&D activities
- In situ near real-time radiological measurements – allows field teams to take immediate action without waiting for laboratory assay results
- Reduced personnel radiation exposure – remote operation of the unit after placing it in the area to be surveyed and no time-consuming hand-held instrument surveys are required.
- Improved worker safety – walls and ceilings equipment can be evaluated from ground level in most cases, without working from scaffolding; InSitu gamma spectroscopy can be done in most cases, without the hazards of extracting a concrete/steel/wood/soil sample for lab assay
- Less probability of missing hidden contamination – because gammas are used, instead of betas as in the baseline method, they are not easily hidden by paint, dirt, floor/wall coverings, floors, etc.

Baseline Technology

Historically at the INEEL, free-release surveys have been conducted using hand-held radiation detectors (see Figure 1 for an example). For meeting the free-release criteria, the radiation control technician (RCT) uses a standard Geiger-Mueller pancake probe to gather radiological information. This is a small detector [about 5cm diameter], and primarily responds to beta emission from the sample or area being tested. The user must carefully scan all or a large fraction of the surface, in order not to miss elevated areas of localized contamination (hot-spots). The detector is calibrated with a source that is assumed to be representative of the actual nuclides to be found, and of their actual distribution with depth. However, since the instrument is quite sensitive to the particular nuclide being measured, and is also quite sensitive to the actual distribution, there is a wide uncertainty. The surveys are conducted by attempting to cover most of the available surface with the probe, and evaluating the meter reading. If any elevated readings (e.g. greater than 100 counts per minute above background) are detected during the survey, these areas require further action, typically laboratory analysis, further decontamination, and re-surveying. As a continual part of this process, good records must be kept to prove that this manual process was adequate to meet the requirements. This requires creating a location numbering system [e.g. grids], and manually recording the survey results for each grid.

Figure 1. Baseline technology used to characterize a grid.

The baseline device does not provide nuclide information about the survey. For release purposes, each nuclides has different release limits. Some of them are quite low, while others are higher, and the natural nuclides of Radium/Thorium/K-40 have no limit. When there is a mixture of nuclides present the most conservative one must be chosen, which may un-necessarily make otherwise clean sites difficult to release. When there is a variation in natural background [due to different Ra/Th/K concentrations, or the presence of outside sources] these also create a signal that is indistinguishable from the site nuclides, and may also falsely prevent the site from being released with the baseline technology.

New Innovative Technology

At the INEEL, the Environmental Surveillance Program (ESP) operates the ISOCS to collect surface radiation measurements. The ESP uses the data obtained to trend the radionuclide concentrations in the surface soils over time. This system was used to demonstrate the capability of the ISOCS system for releasing buildings which may have previously be contaminated by radionuclides. The ISOCS for Free Release (IFR) used for this demonstration (Figure 2) containes the following components, however the critical components [detector shielding/collimation] can be optimized for improved performance for specific jobs.

- 55% efficiency germanium detector with adjustable collimator (shield)
- detector contained within a portable liquid nitrogen cryostat (5-day holding time BigMAC)
- Portable cart for holding the detector along with the associated shielding.
- Battery or AC-powered InSpector (a portable spectroscopy analyzer)
- Laptop computer with mathematical efficiency calibration software (i.e., Genie-2000 and PROcount)

Figure 2. The IFR used at the INEEL..

Key improvements in the IFR as compared to the baseline technology are derived from the use of high resolution gamma spectroscopy [e.g. Ge detectors]. But the major innovation here that makes the IFR particularly useful is the mathematical efficiency calibration. In the past, radioactive sources were required for energy-vs.-efficiency calibration, which was expensive and time-consuming and required a high degree of expertise. Now, it can be done quickly and accurately in the field by the user, without any radioactive sources. The ISOCS detector has undergone a "detector characterization" process at the factory. This process accurately defines the response function for all locations within a 1000 meter diameter sphere surrounding the detector, and at all energies from 45 to 7000 keV. The user then enters the description of the item being measured, any collimation or shielding, the location of the item with respect to the detector, and the name of the detector being used. Many different templates [sample shapes] are available, allowing the user to perform a variety of efficiency calculations for a wide variety of shapes, sizes, densities, and distances between the detector and the area of interest, allowing the user the ability to compensate for different conditions occuring in the field.

Figure 3 shows an example of the effective ground/floor area being measured by a detector 1 m above the ground based on the relative contribution to the fluence from different rings of the ground area about the detector for the typical Cs-137 fallout (gamma energy of 662 keV). When used in an un-collimated mode, the ISOCS detector has a wide field of view, and can be used to assay large areas with a single measurement. The ISOCS detector field of view can be reduced (collimated by shielding) to quantify specific areas of interest.

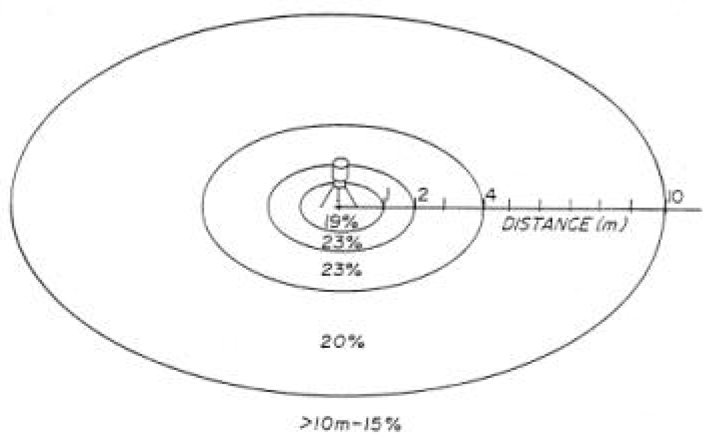

Figure 3. Contribution to total 662 keV primary flux at 1 m above the ground for a typical Cs-137 source distribution.

Demonstration Summary

This demonstration investigated the costs and time required to collect and evaluate the radiological characterization data generated by the IFR compared with the baseline technology. The IFR performs in situ, near real-time analyses to quantify radiological contamination. But unlike the baseline, the IFR also provides in situ, near real-time isotopic identification.

The initial IFR demonstration started in October 1999 and took place at the INEEL's Central Facilities Area (CFA) laundry in CFA-617 (Figure 4). This building is scheduled for D&D; however, it will be placed back into service as a training facility for INEEL crafts personnel. For the baseline technology, the rooms were divided into one meter square grids and hand surveyed. The IFR, with the collimator, was used to survey these same one meter grids. After surveying the gridded areas, the collimator was removed from the instrument and another measurement performed. This measurement assayed the entire room at one time, providing additional information to verify that cross-contamination did not result from any of the D&D activities, and that there were no contaminated areas missed by previous surveys. At this facility, cobalt-60

(Co-60) and cesium-137 (Cs-137) radionuclides are known contaminants. The project was completed in December 1999.

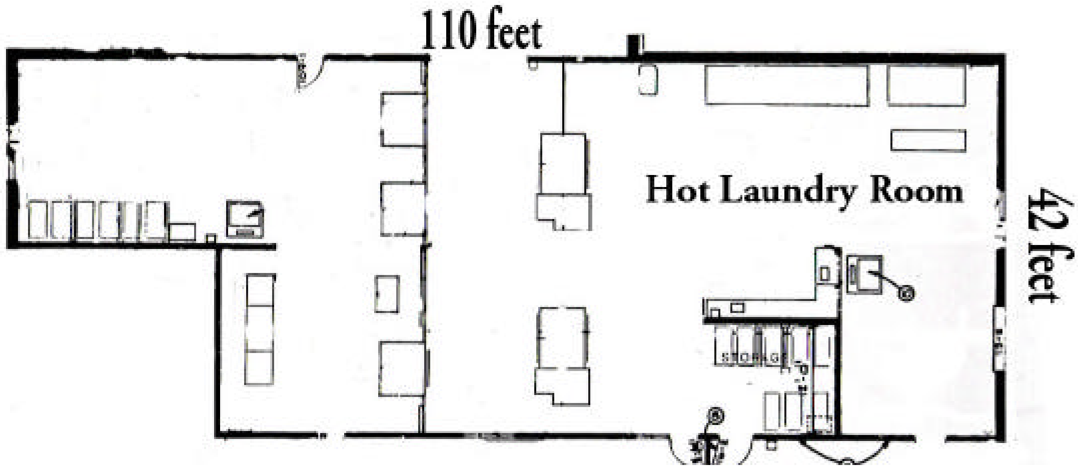

Figure 4. CFA Laundry Facility

The IFR was used to verify and compare rooms that are using baseline technology for unrestricted release. Once the rooms were characterized, i.e., surveyed by the IFR, known radiological sources europium-152 (Eu-152) and cesium-137 (Cs-137) were strategically placed on the walls and inside or behind equipment to check the validity of the new technology. The collimator was placed on the IFR for this survey. By using the collimator, the field of view is narrowed and specific grids can be analyzed individually. This part of the demonstration was conducted in August 2000.

All measurements collected from the IFR were evaluated against the derived concentration guide values established in *Development of Criteria for Release of Idaho National Engineering Laboratory Sites Following Decontamination and Decommissioning*, August 1986 (EGG-2400), specifically Tables B-1 and B-2 (See Appendix B). Table B-1 addresses soil concentration guides derived from Criterion D for the farming scenario, while Table B-2 addresses surface radioactivity guides for materials, equipment, and facilities to be released for unrestricted use. Currently, the unrestricted release survey methodologies approved for use at INEEL do not include this technology. This demonstration showed that the IFR technology can be used to provide more thorough survey information at less cost. Currently at the INEEL the IFR is being used to release equipment from contaminated areas and to take measurements of contaminated soil and debris. The INEEL is currently seeking acceptance of the IFR for use in free releasing buildings, it is hoped that its use for free-release surveys will be approved.

Key Points

The key points of this demonstration are summarized below. Detailed descriptions and explanations of these results are found in Section 3 of this report.

- Cost reductions in release surveys
- Increased data accuracy and quality
- Accelerated D&D schedule
- In situ, near real-time radiological measurements
- Less physically demanding
- Isotopic identification.
- Safer

Contacts

Technical

Technical Information on the ISOCS:

Frazier Bronson , Canberra, 800 Research Parkway, Meriden, CT (208) 639-2345 fbronson@canberra.com

Technology Demonstration:

Brad Frazee, D&D Manager, INEEL, (208) 526-3775, bjf@inel.gov

Neal Yancey, Test Engineer, INEEL, (208) 526-5157, yancna@inel.gov

Management

Steve Bossart, project manager, DOE Federal Energy Technology Center, (304) 285-4643, steven.bossart@netl.doe.gov

Chelsea Hubbard, DOE Idaho Operations Office, (208) 526-0645, Hubbarcd@inel.gov

Dick Meservey, project manager, INEEL Large-Scale Demonstration and Deployment Project, (208) 526-1834, rhm@inel.gov

Cost Analysis

Wendell Greenwald, Army Corps of Engineers, (509) 527-7587, wendell.l.greenwald@usace.army.mil

Web Site

INEEL Large-Scale Demonstration and Deployment Project Web site: http://id.inel.gov/lsddp.

Licensing

No license was required. The ISOCS used for this demonstration had already been purchased by the INEEL from Canberra.

Permitting

No permitting activities were required.

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://www.em.doe.gov/ost under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for the IFR is 2098.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The overall purpose of this demonstration was to assess the benefits from using the IFR to make free-release determinations. The IFR was compared with the baseline technology, which involved dividing the area into grids and hand surveying each grid individually. The primary goal of the demonstration was to collect valid characterization data to make a legitimate comparison between the IFR technology and the baseline technology in the areas of:

- Cost
- Productivity rates
- Ease of use
- Limitations and benefits.

Description of the Technology

The IFR used for this demonstration was the Canberra ISOCS system. It is designed with the following materials:

- 55% efficiency germanium detector with a portable liquid nitrogen cryostat (a 5-day Big Mac [dewar])
- Battery- or AC-powered InSpector (a portable spectroscopy analyzer)
- Adjustable collimator (shield)
- Laptop computer with Canberra software (i.e., Genie-2000 and PROcount)
- Portable cart for holding the detector along with the associated shielding.

The specific detector used in this demonstrtation has been mathematically prepared by the manufacturer using source measurements and the Monte Carlo process. This allows the user to perform on-site a variety of efficiency calculations for a wide variety of shapes, sizes, densities, and distances between the detector and area of interest. The count time for the detector was set at 15 minutes, however shorter or longer count times may be selected, depending upon the site conditions, in order to meet free-release criteria or other task criteria.

Further information on the specific details of other ISOCS applications is available from the Innovative Technology Summary Report from the Chicago Pile 5 Research Reactor Large-Scale Demonstration Project at Argonne National Laboratory-East.

The IFR, located at the INEEL's CFA-689, was transported to the CFA laundry facility by ESP personnel. A portable generator was used for electical power. For cases in which electrical power to the building is disconnected, the IFR setup includes battery packs. Each day, the IFR had a gain and efficiency check prior to going to the field to collect measurements.

Once in the field the IFR can be operated with or without the collimator, depending upon the specific application. The collimator is used to selectively assay areas where contamination may be present (i.e., on a wall, floor, ceiling, or building equipment, as shown in Figure 5). For large-area surveys, the IFR was used without the collimator to see if any contamination can be detected above the unrestricted release criteria. If any contamination was detected above the limit, the collimator was used to better quantify the activity. This information was documented in field notes and survey results and reported to the appropriate D&D facility manager. Each IFR measurement is also stored in a computer record (the Canberra CAM file). This record contains all parameters associated with that measurement and analysis [equipment settings, original spectrum, data processing parameters, calibrations, results]. This provides a record to prove the equipment was operating properly, and for future investigation and independent re-analysis.

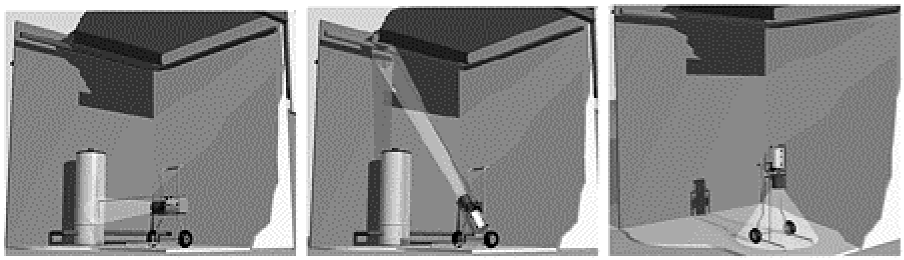

Figure 5. IFR identifying different areas of contamination.

System Operation

Table 1 summarizes the operational parameters and conditions of the IFR demonstration.

Table 1. Operational parameters and conditions of the IFR demonstration.

Working Conditions	
Work area location	• CFA-617
Work area access	Access controlled by use of locked doors and posting.
Work area description	• CFA-617 (old laundry facility) is designated as vacant. The initial demonstration was done in the hot dryer room. Another room, the clean dryer room, was used to demonstrate IFR ability to identify a known source in various locations.
Work area hazards	• Tripping • Temperature extremes • Falls when working on elevated platforms • Taking samples for off-site laboratory analysis
Equipment configuration	The IFR instrument was transported to the work site by the test engineer and the RCT. The IFR is located at CFA-689 and controlled by the ESP. Personnel must be trained source handlers to perform the daily response check on the equipment.
Labor, Support Personnel, Specialized Skills, Training	
Work crew	Minimum work crew: • 1 RCT
Additional support personnel	• 1 data collector • 1 test engineer • 1 health and safety observer (periodic)
Specialized skills/training	• Canberra representatives have trained ESP personnel on the operation of the ISOCS • Occupational Safety and Health Administration • Source-handler training is required to check out the radiological source used to response check the equipment and for parts of the demonstration.
Waste Management	
Primary waste generated	No primary wastes were generated.
Secondary waste generated	The only secondary wastes generated were cotton liners and rubber gloves.
Waste containment and disposal	No waste other than personal protective equipment (PPE) was generated, so no containment was necessary.
Equipment Specifications and Operational Parameters	
Technology design purpose	To confirm that any remaining surface gamma radionuclide contamination is below regulatory limits to support free-release determination.
Specifications	▪ 55% efficiency germanium detector with a portable liquid nitrogen cryostat (a 5 -day BigMAC [dewar]) ▪ Battery- or AC-powered InSpector (a portable spectroscopy analyzer)

	▪ Adjustable collimator (shield) ▪ Laptop computer with Canberra software (i.e., Genie-2000 and PROcount) ▪ ISOCS mathematical efficiency calibration software
Portability	A portable cart for holding the detector along with the associated shielding was provided with the IFR for the demonstrations. Although the cart+shields weighs approximately 300 lbs, it is on large wheels allowing mobility over flat surfaces, and the shield is modular allowing manual movement in smaller pieces.
Materials Used	
Work area preparation	Survey grids were established for both baseline and some ISOCS demonstrations. Additional radiological instrumentation was brought along as was PPE for working in a radiological environment.
PPE	Cotton liners, rubber gloves, and safety shoes were the only required PPE. Since the original survey was completed some time prior, additional instrumentation and PPE were brought along in case any radiologically elevated areas were identified.
Utilities/Energy Requirements	
Power, fuel, etc.	No specific utilities/energy requirements for this demonstration. The baseline technology instrumentation utilized batteries for operation, while the IFR used either the site's electrical power or batteries for operation.

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

As with other DOE facilities, the INEEL is in the process of decontaminating facilities, buildings, and areas that have been or have had the potential for being radiologically contaminated. A characterization tool enhancing the data generated by the surveys needed to be developed. As part of the data process, this tool should provide more accurate and reproducible survey information to eliminate transcription errors in locating contamination. In addition, visually displaying the extent of gamma contamination is highly desirable. This would allow the D&D facility manager to show regulators how their cleanup criteria will be satisfied.

The purpose of this demonstration was to compare the performance of the innovative technology of IFR with the baseline technology of hand surveying. This demonstration was conducted at CFA. In addition to comparing these two technologies, D&D Facility Management personnel will also use this information to document the decision for this area to be considered clean and to meet the criteria established for free release.

Demonstration Site Description

The INEEL site occupies 569,135 acres (approximately 890 square miles) in Southeast Idaho. The site consists of several primary facility areas situated on an expanse of otherwise undeveloped, high-desert ecosystem. Structures at the INEEL are clustered within the primary facility areas, which are typically less than a few square miles in size and separated from each other by miles of undeveloped terrain.

CFA is the main service and support center for the programs located at the INEEL's other primary facility areas. Eighty percent of the activity at CFA consists of INEEL-wide programmatic support such as transportation, maintenance, capital construction, environmental and radiological monitoring, security, fire protection, warehouses, calibration laboratories, and a cafeteria. The old laundry facility, designated as CFA-617, is currently vacant and is scheduled for decontamination; but it will be placed back into service as a training facility for INEEL crafts personnel. The facility is approximately 11,494 square feet in plan area. At this facility, cobalt-60 (Co-60) and cesium-137 (Cs-137) radionuclides are the known contaminants.

Major Objectives of the Demonstration

The major objectives of this demonstration were to evaluate the IFR against the baseline hand surveying for free release in the following areas:

- Cost effectiveness
- Safety
- Ease of use
- Limitations.

Major Elements of the Demonstration

The intent of this demonstration was to gather information helpful in deciding if the IFR would improve D&D activities through a reduction in cost, speed up in schedule, improvement in safety, or more reliable data. This demonstration included several demonstration areas. The major elements for this demonstration were:

- Surveying time
- Documentation
- Number of workers required
- Safety
- Cost
- Feedback

- Advantages/disadvantages.

The IFR demonstration started in October 1999 at the CFA laundry in CFA-617. This building is scheduled for D&D; however, it will be placed back into service as a training facility for INEEL crafts personnel. For the baseline technology, the rooms were divided into grids and hand surveyed, after which the IFR, along with the collimator, was used to survey these same grids. After collecting the measurements from the grids, the collimator was removed from the instrument and another measurement was collected. This provided the D&D facility manager with additional information to verify that no cross-contamination resulted from any of the D&D activities. This part of the project was completed in December 1999.

The second demonstration involved strategically placing a known cesium-137 (Cs-137) large-area diffuse source and a europium-152 (Eu-152) point source in various locations within the CFA-617 facility and using the IFR to locate the source. This validated the technology's ability to identify and locate radiological contamination. The collimator was placed on the IFR for this survey. By using the collimator, the field of view is narrowed. This part of the demonstration was conducted in August 2000.

All measurements collected from the IFR were evaluated against the derived concentration guide values established in *Development of Criteria for Release of Idaho National Engineering Laboratory Sites Following Decontamination and Decommissioning*, August 1986 (EGG-2400), specifically Tables B-1 and B-2 (see Appendix B). Table B-1 addresses soil concentration guides derived from Criterion D for the farming scenario, while Table B-2 addresses surface radioactivity guides for materials, equipment, and facilities to be released for unrestricted use. Currently at the INEEL, the approved unrestricted release survey methodologies do not include this technology. However, the IFR technology has been shown to provide more thorough survey information at less cost. By using the IFR to free release equipment and facilities the INEEL can reduce the cost associated with characterization.

Results

The performance of the two technologies is compared in Table 2. The IFR was used to survey for release of three laundry dryers. The IFR identified an area with elevated cobalt-60 contamination in one hour, compared with the baseline technology requiring 25 hours of hand surveys to locate the same spot on one of the three dryers. Laboratory analysis was required in order to identify the specific nuclide. The elevated contamination was on one of the dryer doors at the old laundry facility (CFA-617). Only four measurements were necessary to identify this location with the IFR.

The IFR was also used to perform a survey of the room in which the dryers were located. Although no contamination was found on the walls, it took only 10 hours to survey the same section of the room that it took 40 hours for the baseline technology to survey. The IFR also successfully identified a diffuse source and point source that were placed in a number of locations in the facility. This test confirmed the capability of the IFR technology to quantify the contamination and accurately identify the nuclide.

For the baseline technology, RCTs use a Geiger-Mueller radiation detector to check for radiation readings in excess of 100 counts/minute above background. Using the IFR, the measurements can be made in total activity [e.g. uCi], concentration [e.g. pCi/g], or surficial concentration [e.g. pCi/cm^2]. The detection limit of the IFR is well below the baseline technology, however the specific detection limit of both techniques is dependant upon the isotope being measured, the distribution of that activity, the size and efficiency of the detector, and the background present in the areas. The ISOCS system, under optimal conditions [well defined source] is capable of providing accurate results within 5-10% for energies >150 keV, and within 10-20% for energies < 150 keV. But, for field conditions, the exact source boundaries are rarely well known, which results in field accuracy of factors of 1.3 – 2 or higher.

By using the IFR, workers can complete the characterization work faster and safer. Rather than requiring workers to work long hours performing repetitive surveys, sometimes in elevated areas on ladders, scaffolding, or manlifts, or having to maneuver on or around equipment, the IFR can remotely provide the same quality of results. Currently at the INEEL the IFR is being used to release equipment from contaminated areas and to take measurements of contaminated soil and debris. The INEEL is currently seeking acceptance of the IFR for use in free releasing buildings.

Benefits from using the innovative technology of IFR include:

- Cost reductions in release surveys – reduction in labor hours by 96% to identify a hot spot
- Cost reductions in release surveys – reduction in labor hours by 75% in surveying whole rooms
- Increased data accuracy and quality – less susceptibility to hand survey and transcription errors and improved visual presentation of documentation, data file stored has all parameters used and inherent QA built-in; gamma measurement technique being used is less susceptible to missing hidden contamination
- nuclide identification and activity provided
- Accelerated D&D schedule – shorter final survey times and confirmation of free-release status following D&D activities
- In situ near real-time radiological measurements – prompt feedback to measurement team that additional measurements are needed, or to the decontamination team that more work is needed
- Less physically demanding (eliminates the need for elevated working conditions)
- Reduced exposure of personnel to radiation – remote operation of unit after placing it in the area to be surveyed and no time-consuming hand-held instrument surveys are required.

Table 2. Performance comparison between the IFR and the baseline hand-surveying technology.

Performance Factor	Baseline Hand-Surveying Technology	IFR Technology
Personnel/equipment/time required to survey	Personnel: • 1 RCT Equipment: • 1 portable sodium iodide (NaI) detector • Ludlum 2A detector • 1 field logbook Time: • 40 hours	Personnel: • 1 sample technician (operator) Equipment: • 1 ISOCS • 1 field logbook Time: • 10 hours (15 minutes per scan)
Time required to establish grid	Personnel: • 2 sample technicians Equipment: • Used concrete blocks as basis for grids Time: • 15 minutes	Personnel: ▪ 2 sample technicians Equipment: • Used concrete blocks as basis for grids Time: • 15 minutes
Time required to generate report	Personnel: • 1 RCT Equipment: • 1 personal computer • 1 field logbook Time: • 5 hours	Personnel: • 1 RCT Equipment: • 1 personal computer • 1 field logbook • 1 Canberra application Time: • 5 minutes
Total time per technology	• 40 hours	• 10 hours
PPE requirements	• Rubber gloves • Safety shoes • Clothing adequate for surveying	• Rubber gloves • Safety shoes • Clothing adequate for surveying
Superior capabilities	• Technology is well known and	• ISOCS was considered much easier

	accepted for the performance of free-release surveys	to operate • This innovative technology has a larger field of view • It is much faster and more efficient in collecting data • It can provide more near real-time data • The final report includes a visual display of the energy of the gamma emmission found and a report of the analysis of the spectrum. • The final report defines the nuclides detected, gives the concentration or activity of each of them. • The stored data includes all information known about the status of the instrumentation, the raw data, the analysis parameters used, interim computation results, as well as the final result.

Although personnel contamination and personnel exposure are not normally significant for these demonstrations (potential free-release areas), the IFR can be effective in reducing the potential for personnel contamination when taking samples of unknown areas, and to reduce exposure of personnel when taking measurements at earlier phases of the project (characterization, decontamination) where there are higher levels of radioactivity.

During the validation phase, eight scans were taken of sources that were placed strategically around the clean laundry room in CFA-617. The results of the scans are given in Table 3.

Table 3. Data from the IFR measurements.

	IFR Measurements		Actual Source Values	
Scan	Isotope Found	Activity Measured Bq	Isotope	Activity Bq
1	Cs-137	520 +/- 33%	Cs-137	475
2	Cs-137	82000 +/- 20%	Cs-137	67,600
3	Eu-152	17000 +/- 35%	Eu-152	15,000
4	Eu-152	<100,000	Eu-152	15,000
5	Cs-137	84000 +/- 4%	Cs-137	67,600
6	Cs-137	63000 +/- 66%	Cs-137	36,000
7	Cs-137	520 +/- 40%	Cs-137	475
8	Eu-152	18000 +/- 27%	Eu-152	15,000

Note: IFR uncertainties are combination of counting statistics uncertainties and estimates of uncertainty in source efficiency modeling errors.

Based on these results, the ISOCS accurately identified the isotope present. With the exception of one measurement (Scan 4), the activity of the source could not be determined. While the reported errors are somewhat high, they include both the counting and the modeling uncertainties. The counting portion of the uncertainty can be reduced by increasing the counting time. The modeling portion can be reduce (where necessary) by multiple measurements from different directions.

The eight scans listed above were taken at the following locations in the CFA Laundry facility:

1) Directly in front of the IFR with no obstructions present.

2) The source was placed inside of one of the dryers.
3) The source was placed behind the dryer on the back of the dryer body.
4) The source was placed behind the dryer on the back of the motor (this was expected to be the most difficult measurement as the source was shielded by the dryer and the dryer motor).
5) The source was placed inside of a wooden cabinet.
6) Again, the source was located inside another wooden cabinet.
7) The source was placed directly on the wall at a height above the detector.
8) The source was placed on top of an air duct and the IFR was directed upward through the duct from directly below.

The ISOCS system, under optimal conditions (good statistics, known source dimensions), should provide accurate values within 5-10% for energies >150 keV, and within 10-20% for energies < 150 keV. However, the results above are more realistic uncertainty estimates for these D&D field conditions (i.e. factors of 1.3 to 2 or greater).

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline Technology

The baseline technology for this demonstration consists of dividing the area into individual grids and hand surveying using a portable Geiger-Mueller pancake probe to count beta emissions. Where necessary, samples are taken for laboratory analysis to determine nuclide-specific activity, and/or a portable sodium iodide (NaI) detector and portable MCA is used to identify the major nuclides where possible. There are various manufacturers that produce variations of the baseline technology.

Other Competing Technologies

A broad range of survey technologies are available such as plastic scintillation, NaI detectors, and germanium detectors. The IFR technology can combine the visual coordinates with the radiological information. Once the data have been recorded onboard the computer (nuclide identity and concentration for that grid location), the file can be downloaded and interpreted through standard mapping software to visually display the extent of contamination.

Ortec is one of the competing technologies that manufactures similar germanium (Ge) and NaI detectors and has a similar product to the ISOCS. The company's Web site is http://www.ortec-online.com.

Technology Applicability

The technology for this innovative process is fully developed and commercially available. Its superior performance over the baseline technology makes it a prime candidate for deployment throughout the commercial sites. Many similar systems are being used across the DOE complex in other applications and provide equivalent data measurements. The INEEL has deployed this type of technology on a variety of projects involving surface contamination.

Patents/Commercialization/Sponsor

The ISOCS with the patented mathematical calibration software is commercially available from:

Canberra Instruments
800 Research Parkway
Meriden, CT
Phone: (203) 238-2351

Contacts:

Carlton Green [Northwest USA]
Cgreen@canberra.com
(208) 788-8925

Frazier Bronson [Canberra Factory]
(203) 639-2345

SECTION 5
COST

Introduction

This section compares the cost of the innovative and baseline technologies for general area release surveys. The basis of all costs is the demonstration survey of a 120-square-foot area within a room with a ceiling approximately 10 feet high containing a few objects and equipment. The innovative technology cost is approximately one-third of the baseline technology cost for a general area release survey.

Methodology

This analysis for general area release surveys is based on government ownership of the innovative technology equipment and baseline equipment. At the INEEL, an IFR is government owned and operated by the ESP for conducting routine soil measurements outside the facility fence lines to assess changes in radionuclide concentrations in the soil. This equipment was used in the demonstration. Government ownership of the equipment was used in this analysis, because it provides the most favorable cost comparison for the innovative technology to the baseline technology.

This cost analysis assumes both the innovative technology and the baseline technology use site labor. Crews used in the cost analysis are based on the test engineer's judgment and include two RCTs, one industrial hygienist, and one job supervisor for both the innovative technology and the baseline. Crews include an industrial hygienist at one quarter time and a supervisor at half time, because these individuals are not required to be present for the duration of survey work. The assumption is that both would perform duties at multiple jobs. The cost analysis is based on the standard labor rates used at the INEEL. The rates for common construction equipment and vehicles are based on the standard rates that the INEEL charges projects for use of equipment from its fleet pool.

In some cases, the activity duration observed during the demonstration does not represent the cost of typical work because of the artificial effects imposed on the work. These artificial effects are the result of the need to collect data, first-time use of the equipment, and other effects associated with the demonstration. In these cases, the observed duration is adjusted before using them in the cost analysis. An example of this type of artificial effect on the work involved a situation at the startup of the final IFR demonstration in which there were difficulties performing an energy calibration of the equipment. This calibration, which normally takes 10 minutes, took two hours.

The following day, a similar problem occurred in which the software installed on the computer was not recognizing the MCA. The problem was corrected and scanning was completed without further problems. It is assumed these problems were a result of borrowed equipment and incomplete setup of the newly installed software. In the typical work situation, this type of problem is not anticipated because the custodians of the system would have all equipment functioning as a unit prior to conducting surveys in the field. A second example of this type of artificial effect on the work involved the decision for reduced manpower for the demonstration only. These types of events were not included in the cost analysis. No other potential discrepancies between the demonstration and typical work were observed.

Additional details of the basis of the cost analysis for the surveys are described in Appendix C.

Cost Analysis

Costs to Procure Innovative Equipment

There are two alternatives available for acquiring the innovative technology. The costs associated with these acquisition alternatives are indicated in Table 4. During the validation phase of the demonstration, a technician from Canberra was contracted to operate the INEEL equipment during that portion of the demonstration. The cost during that phase of the demonstration, which lasted three days, was $1500 the first day and $1000/day there after.

Table 4. Innovative technology costs.

Acquisition Option	Item Description	Cost
Purchase	ISOCS and Ge detector	$97,000
Vendor-provided service	Crew (three days based on weekly rates and allowance for travel)	$3,355
	Equipment (two days based on weekly rates)	$1,000
	Vendor-provided total	$4,355

Note: Rates shown are preliminary and actual rates will vary depending on the specific scope of work. Rates are based on a 55% Ge detector.

Unit Costs and Fixed Costs

Table 5 shows the unit costs and fixed costs for the innovative and baseline technologies. The fixed costs are the sum of the line items shown in Appendix C, Tables C-2 and C-3, that do not vary directly with the size of the job. The unit costs are the sum of the line items shown in Tables C-2 and C-3 that do vary with the size of the job. For both technologies, each sum is divided by the floor area of the room surveyed (120 square feet).

Table 5. Summary of unit costs and fixed costs.

Cost Element	Innovative Cost	Baseline Cost
Fixed Costs	$126.49	$101.68
Unit Costs	$27.29 per square foot of floor	$98.88 per square foot of floor

Note: The fixed costs are the sum total of individual tasks that are fixed, as indicated in Appendix C, Tables C-2 and C-3. The unit costs are the sum total of all costs that vary with the quantity of work. Those line items that make up the unit cost are indicated in Appendix C, Tables C-2 and C-3.

Break-Even Point

The innovative technology is more cost-effective than the baseline technology. Consequently, the point where break-even occurs for the innovative technology is less than one square foot and can be seen in Figure 6 where the two lines intersect. After the point of intersection, the cost of the IFR is less that the baseline in all cases.

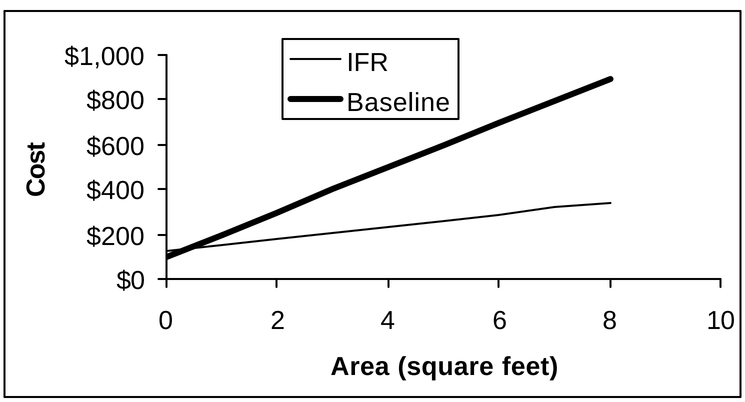

Figure 6. Breakeven Point

Payback Analyses

For cases in which the innovative technology is purchased, the savings over the baseline technology is approximately $71.59 per square foot of room floor area ($98.88 minus $27.29) over the baseline technology for scanning a typical room containing several pieces of equipment or stored items. At this rate of savings, it would require scanning rooms of approximately 1,355 total square feet of surface area, to make up for the purchase price of the innovative technology equipment ($97,000/$71.59 per square foot of floor area = 1,355 square feet of floor area).

Observed Costs for Demonstration

Figure 7 summarizes the observed costs for the innovative and baseline technology based on scanning a 120-square-foot area (walls, floors, and ceiling) and the contents of the room. Contents of the demonstration room were three dryers, cabinets, and small miscellaneous items. The details of these costs are shown in Appendix C and include Tables C-2 and C-3, which can be used to compute site-specific cost by adjusting for room size, different labor rates, crew makeup, etc.

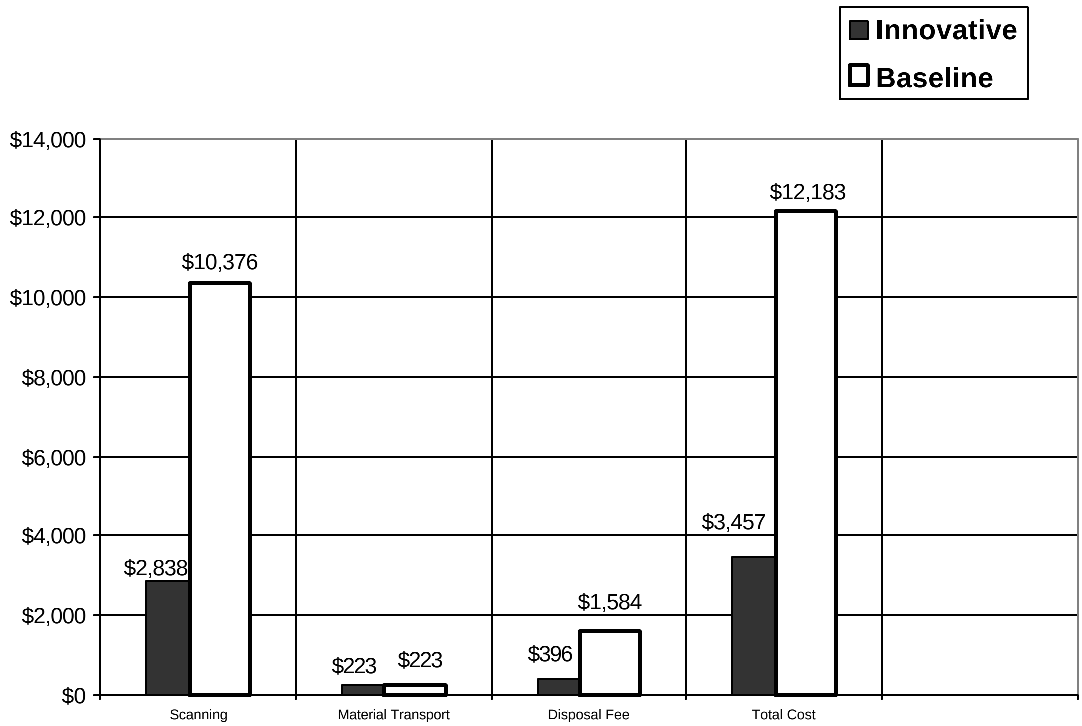

Figure 7. Summary of technology costs.

Cost Conclusions

The innovative technology costs for "Investigation and Monitoring/Sample Collection" (Appendix C, Work Breakdown Structure [WBS] 4.07.14) are primarily variable costs associated with time, labor, and equipment to conduct a room survey prior to free release of the facility. The cost also depends on the specifics of each individual project. Examples of individual variables may include requirements for specific isotope detection, the field of view desired, the level of detection, and the geometry of each scan.

Innovative costs are based on a typical area of 120 square feet, with a ceiling approximately 10 feet high. As the room size increases, the fixed costs remain relatively constant and are less of a factor in the total cost. Consequently, the comparison of the innovative technology to the baseline technology is sensitive to job size.

The innovative technology and baseline technology costs for "Materials Handling/Transportation" (Appendix C, WBS 4.13) and "Disposal Facility" (Appendix C, WBS 4.32) may vary in cost from one DOE site to the next. But, the variation in these costs is not anticipated to affect the cost comparison between the innovative technology and the baseline technology.

The innovative technology cost savings over the baseline technology will vary depending on the site-specific requirements of the work. For most real work situations, the innovative technology should cost approximately 30% of the baseline cost for general area release surveys.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

The IFR meets the requirements for 10 CFR, Chapter III, Department of Energy, Part 835, "Occupational Radiation Protection." It also meets the requirements specified in DOE-STD-1098-99, "Radiological Control," dated July 1999. In order to properly perform the daily response check, the operator(s) must be trained as a source user (INEEL 1998) and check the gamma source out from the CFA RCTs. For this demonstration, a test plan and the technical procedure covered the use of the IFR under the INEEL Large-Scale Demonstration and Deployment Project.

Safety, Risks, Benefits, and Community Reaction

The safety issues associated with the use of the IFR are primarily moving the instrument for each scan. These risks are mitigated by the use of a cart to move the instrument with its shielding and other components. Risks associated with the use of the IFR are routinely acceptable to the public.

The benefit is 100% coverage on a single survey, which minimizes the risk of missing contamination based on a manual grid survey. As a result of the characterization, the D&D workers has been able to remove the contaminated dryers and has made progress toward releasing the facility.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The IFR technology is mature and provided meaningful, near real-time survey data during the INEEL demonstration. Operating the survey unit and the Canberra software requires initial user training and a good familiarity with its operation. According to the users, this technology is much faster and easier to use than the baseline hand-survey methodology typically used for free-release surveys. The system generated higher-quality documentation of the survey, with visual presentation of contamination results. Items that should be considered before implementing the IFR include the following:

- Daily response check on the detector should be conducted prior to performing surveys to ensure the detector is responding properly.
- Preventative maintenance needs to be performed on the detector
- During this demonstration, there were complications with the energy calibration due to improper equipment setup which was not determined by the Canbera technician ahead of time. It is important to allow for time to work out any unforseen problems before a job begins.
- Although it is expected to be an uncommon occurrence, in this demonstration a component failure resulted in a delay of several weeks while waiting for the vendor to replace the component. If this is important, then adequate spares should be obtained, and/or the available 24 hr critical response service contract be obtained from the vendor.

At the INEEL, there are different detection limits set for each situation based on the risk associated with the future use. For a facility or piece of equipment to be released from a CERCLA area, the release limit is 23pCi/g. If a facility is going to be reused, the type of reuse factors into the release requirements. Risk calculations are made based on IFR measurements or sample results to determine what the acceptable levels are. For instance, a facility being reused for office use would have different release requirements than would a storage facility. Both the detection limits of the equipment and the release requirements are also dependant upon the background present at the facility. In using the baseline technology, the release requirements are that the readings must be less than 100 counts per minute above background readings. This is true unless the background is greater than 300 counts per minute in which case, the building would need further decontamination before it could be released anyway.

It is not possible to compare the detection limits of the baseline technology and the IFR directly, as the two are not directly related. The baseline provides measurements for surface beta emissions (no isotopic identification) in units of counts per minute. The calibration is estimated based upon the assumed nuclides and distribution conditions. The detection limits for the baseline technology are a function of distance, speed at which the detector is moving across the surface, background radiation readings, and isotope of concern. Human reliability is a large factor in the quality of the results. The IFR can provide quantitative results at levels below those observed using the baseline technology. The detection limits of the IFR are also variable and depend on count time, isotope of concern, and background levels.

Technology Limitations and Needs for Future Development

A primary limitation is that the IFR technology only detects X and gamma radiation. Nuclides that decay without X or gamma emission cannot be detected. Nuclides with weak gammas will have higher detection limits, which may not be acceptable. However, for most reactor or Uranium contamination areas, there are few of these nuclides and they do not normally determine the releasibitlity of the item or area. And, the baseline technology is also only suitable for certain nuclides [beta emitters] and distributions [surfaces accessible to the operator/detector]. The IFR was able to identify a hot spot in much less time than the baseline technology of hand surveys, but multiple readings are necessary to precisely locate it. Now, this is an iterative process, but future software implementations could easily automate it. Likewise, multiple counts of the same item can improve the accuracy, and future software improvements would automate this process. The IFR has not yet been recognized as an approved methodology for performing free-release surveys for buildings at the INEEL. This regulatory/administrative issue currently limits the use of the IFR to confirmatory surveys or hot spot identification. If the IFR technology obtained greater regulatory acceptance and could be used independent of the baseline technology for free-release surveys, significant cost savings and positive schedule impacts could be realized.

Technology Selection Considerations

Based on the INEEL demonstration, the IFR technology is a better method for conducting free-release and large-area survey measurements than using the baseline technology of hand-held instruments. The IFR can provide better coverage of the survey area and provide visual representation of the extent of contamination, including isotopic results.

At the INEEL, IFR technologies are being used to release soil, debris, and equipment from CERCLA areas and radiation contamination areas. The INEEL is currently trying to obtain acceptance for use of the IFR for free release of buildings.

The initial capital invested in this technology can be paid off in a relatively short time, depending on the amount of free-release and large-area survey work needed. If the end user has a limited need for large-area or free-release surveys, its significant initial capital cost may not be justified. In many cases, the end user may already own equipment that can be adapted to this application, which would lower capital equipment expenses. If this still isn’t economically justified for small jobs, the vendor offers a measurement service and provides the equipment, operators, and technical experts.

When purchasing a new system, it is important to allow several weeks of class-room and hands-on training and trouble shooting, along with some preliminary field experimentation to ensure the system is operating as expected and the user becomes familiar and gain confidence in its capabilities, potential problems, and calibration methodologies.

APPENDIX A
REFERENCES

Argonne National Laboratory-East, September 1999, Chicago Pile 5 (CP-5) Research Reactor Large-Scale Demonstration Project Argonne National Laboratory-East, "Innovative Technology Summary Report - In Situ Object Counting System", OST/EM-0477, OST Reference #2098.

Idaho National Engineering and Environmental Laboratory, MCP-137, "Radioactive Source Accountability and Control," February 16, 2000, Rev-5.

10 CFR, Chapter III, Department of Energy, Part 835, "Occupational Radiation Protection."

DOE-STD-1098-99, "Radiological Control," dated July 1999

APPENDIX B
FREE RELEASE CRITERIA

Table B-1. Soil Concentration Guides Derived From Dose Criterion D for the Farming Scenario.

Radionuclide	Concentration (pCi/g)[a] in Soil Corresponding to an Effective Dose Equivalent of 100 mrem in First Year After Release
Mn-54	10
Co-57	200
Co-58	30
Co-60	4
Sr-90	50
Ru-106	60
Sb-125	20
I-129	200
Cs-134	6
Cs-137	10
Ce-144	300
Eu-152	10
Eu-154	7
Eu-155	400
Ac-227	7
U-232	3
U-233	400
U-234	400
U-235	60
U-238	200
Pu-238	300
Pu-239	300
Pu-240	300
Pu-241	10,000
Am-241	80

a. Assumes uniform contamination of an area adequate for subsistence farming and behavior and assumption patterns specified in Scenario E.

APPENDIX B

FREE RELEASE CRITERIA

Table B-2. Surface Radioactivity Guides for Materials, Equipment, and Facilities for Unrestricted Use[a].

Group	Radionuclides	Activity Guide[b] (d/m)/100cm^2	
		Removable	**Fixed**
1	I-125; I-129; Pb-210; and all alpha emitters except Uranium and Thorium isotopes.	20	300
2	U-232; U-233; U-234; Th-Nat; Th-228; Th-232; Sr-90; I-126; I-131; I-133; Ra-223; Ra-224, Ra-228[c]	200	1,000
3	All radionuclides not specified in Groups 1 and 2 except beta emitters with the E_{max} less than 150 keV[d]	1,000	5,000

a. Derived from ANSI/HPS Draft Standard N13.12 (HPS 1985).

b. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the guide values.

c. These are the radionuclides undergoing beta or electron capture decay that present the greatest hazards as surface radioactivity. Ra-228 is included even though it emits beta particles below the 150 keV minimum energy because it is readily detectable through its short-lived decay products.

d. The beta emitters with the maximum energy less than 150 keV are excluded because the detection by direct methods is not practical and they must be treated on a case-by-case basis. However, radionuclides that are detectable by direct measurement with the appropriate instrumentation through emission of low-energy x-rays and gamma rays (as in electron capture) or through the presence of short-lived decay products are included in this category.

APPENDIX C
COST COMPARISON

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work. In the estimate, the activities are grouped under higher-level work titles per the WBS shown in the Environmental Cost Element Structure.

Costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing hourly rates:

- The government owns the innovative technology equipment.
- The hourly rates for equipment owned by the government and for which there are no standard fleet rates are based on general guidance contained in the Office of Management and Budget (OMB) Circular A-94, “Cost Effectiveness Analysis.” This involves amortizing the purchase price of the equipment over its anticipated service life. It also includes a procurement cost of 5.2% of the purchase price and annual maintenance costs. A service life of five years is assumed for the innovative technology equipment.
- Some of the equipment such as vehicles used in the course of the demonstration is commonly included in the site motor pool. The rates for this equipment are based on standard fleet rates for the INEEL.
- The standard labor rates established by the INEEL are used in this estimate and include salary, fringe, departmental overhead, material-handling markups, and facility service center markups.
- Equipment and labor rates do not include the Bechtel BWXT Idaho, LLC general and administrative markups. These markups are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. General and administrative rates for each DOE site vary in magnitude and in the way they are applied. Decision-makers seeking site-specific costs can apply their site’s rates to this analysis without having to first back out the rates used at the INEEL.
- Crews used in the cost analysis are based on the test engineer's judgment and include two RCTs, one industrial hygienist, and one job supervisor for both the innovative technology and baseline. Crews include a hygienist at one quarter time and a supervisor at half time because these individuals are not required to be present for the duration of survey work. The assumption is that both would perform duties at multiple jobs.

The analysis does not include costs for oversight engineering, quality assurance, demonstration administration, or work plan preparation.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity are described in this section.

Investigations and Monitoring/Sample Collection, Contaminated Building/Structure Samples (WBS 4.07.14)

PICKUP (CHECK) (CALIBRATE) EQUIPMENT: This activity includes picking up the IFR from a storage facility in the case of the innovative technology and transporting baseline technology equipment from a storage facility to the work area. This activity includes the initial complete calibration of the equipment. In the case of the innovative technology, the time required for this activity is based on the duration observed in the demonstration, whereas the time required for the baseline technology and equipment is based on the judgment of the test engineer.

TRAVEL TO WORK AREA: This activity is the crew’s travel time to the work area based on the duration observed in the demonstration.

PREJOB BRIEFING: The duration for the prejob safety meeting is based on the observed time for the demonstration. Activities included the worksite check-in and a review of the safety plan. The labor costs for this activity are based on the assumed crew (rather than the actual demonstration participants), and all subsequent activities are based on the assumed crew.

EQUIPMENT CHECKS: The time required for daily checks and calibration is based on duration observed in the demonstration.

DON PPE AND ENTER: This activity includes the labor and material cost for donning the articles of clothing listed in Table B-1 and entry into the radiological control zone. The RCT that allows the crew into and out of the radiological control zone and the job supervisor do not enter the zone with the crew (do not don or doff PPE). The estimates assume that the workers leave the radiological control zone for lunch breaks, and this requires an additional doffing and donning of PPE.

Table C-1. Cost for PPE (per man/day).

Equipment	**Cost Each**	**Number of Times Used Before Discarded**	**Cost Each Time Used ($)**	**Number Used Per Day**	**Cost Per Day ($)**
Boot covers each	$0.19	1	$0.19	4	$0.76
Rubber boots with liner pair	$35.30	50	$0.71	1	$0.71
Glove liners pr. (cotton inner)	$0.40	1	$0.40	2	$0.80
Rubber gloves pair (outer)	$1.20	1	$1.20	2	$2.40
Coveralls (white Tyvek)	$3.30	1	$3.30	2	$6.60
Hood	$0.85	1	$0.85	2	$1.70
Hard hat	$11.45	30	$0.38	1	$0.38
Safety glasses	$4.80	30	$0.16	1	$0.16
Total Cost/Day/Person					$13.51

MARK GRIDS: This activity applies only to the baseline. Hand surveying requires the rooms to be divided into 1 m^2 grids. For the demonstration, however, the mortar joints of the concrete blocks were used to establish the grids. Later, during the demonstration, a 1 m^2 grid was measured by the test engineer. The time required to calculate the cost of typical work for this activity is based on the duration observed in the demonstration.

HAND SURVEY OF THE DRYER ROOM: This activity applies only to the baseline. After the grid is established (the concrete blocks), the hand survey is conducted using a Geiger-Mueller pancake probe and portable NaI detector. The grids were traversed covering one block at a time. Four passes per block were observed. Radioactivity above background is surveyed by the NaI detector to identify the isotopic source. Areas and objects scanned for the baseline and innovative technology are the same. The time required for this activity is based on observations during the demonstration.

SET IFR: This activity applies only to the innovative technology. Tasks include unloading the equipment, setting it within the room, and collecting a background measurement. The time required for this activity is based on observations during the demonstration.

IFR SCANS (Walls, Ceiling, Contents): This activity applies only to the innovative technology and includes the IFR scan of the room and equipment by strategically placing radiation sources on a wall, inside a dryer, on the back of the dryer, on the back of the dryer behind a motor, and inside a cabinet. The activity also includes completing a simulated ceiling scan and conducting a scan with the sample inside a pipe. Wall scans were collected by placing the IFR a distance of one meter from the wall. To simulate a ceiling scan, the radiation source was placed high on a wall, with the IFR located a distance of three meters from the wall. The time required for the tasks under this activity is based on the duration observed during the demonstration.

REMOVE IFR: This activity applies only to the innovative technology. Tasks include disassembling and loading the equipment. The time required for this activity is based on observations during the demonstration.

DECONTAMINATE EQUIPMENT: This activity applies to the innovative technology and includes decontamination of the IFR equipment. Decontamination was not required for the demonstration. However, decontamination is anticipated for a typical work condition and is included in the estimate. The time required for this activity is based on observations in similar survey demonstrations using light work equipment.

DOFF PPE: This activity applies to both the innovative technology and the baseline technology and includes the labor costs for doffing PPE. It is based on the duration observed in the demonstration.

TRAVEL BACK: This activity is the crew's travel time from the work area based on the duration observed during the demonstration.

RETURN EQUIPMENT TO STORAGE: This activity applies to both the innovative technology and the baseline technology and includes transporting the equipment back to the respective storage facilities and unloading it. The activity duration is based on the duration observed in the demonstration and the test engineer's judgment.

Disposal Facility, Disposal Fees, and Taxes (WBS 4.13)

DISPOSAL: This cost is for disposal of PPE used in the course of the work and is based on the assumption that each worker generates 0.66 cubic feet of waste per day. For both the innovative technology and the baseline technology, there are two workers that don PPE for each day of work. Disposal costs at the INEEL are assumed to be $150 per cubic foot of waste based on historic costs observed at the INEEL for operation of the disposal cell. These costs do not include the expense for transportation, packaging the waste, closure of the disposal facility, or long-term maintenance and surveillance.

Materials Handling/Transportation (WBS 4.32)

SOLID WASTE TRANSPORT: This activity applies to both the innovative technology and the baseline technology and includes loading the waste onto a truck, transporting it to the disposal area, and unloading the waste. The activity requires 1 hour to load, 1/2 hour to transport, and 1 hour to unload the waste for each trip based on previous experience at the INEEL.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, labor rate, piece of equipment used, equipment rate, activity duration, and production rate so that site-specific differences in these items can be identified and a site-specific cost estimate can be developed.

Table C-2. Baseline technology cost summary.

Unit/ Fixed Cost	Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost: Prod Rate (unit/hr)	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
	Facility Deactivation, Decommissioning, & Dismantlement											Total Cost =	$12,183.51
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURE SAMPLES (WBS 4.07.14)											Subtotal =	$10,376.28
Fixed	Pickup-Check Equipment	ls	21.26	1	$ 21.26	2	0.50	1RCT	39.45	P,L2A,NaI	3.07		
Unit	Travel to Area	ea day	59.14	8	$ 473.12	2	4.00	2RCT,1/2JS,1/4IH	115.45	P	2.84		
Unit	Prejob Briefing	ea day	29.58	8	$ 236.64	4	2.00	2RCT,1/2JS,1/4IH	115.45	P,L2A,NaI	2.87		
Unit	Equipment Checks	ea day	10.59	8	$ 84.72	4	2.00	1RCT	39.45	L2A,NaI	2.89		
Unit	Don PPE	ea	39.45	15	$ 591.75	2	7.50	2RCT	78.90			216.16	$13.51/PPE × 2 RCT × 8 DA = $216.16
Unit	Mark Grids	Rm-sf	0.99	120	$ 118.80	120	1.00	2RCT,1/2JS,1/4IH	115.45	P,L2A,NaI	2.87		
Unit	Hand Survey Room	Rm-sf	39.92	120	$ 4,790.40	3	40.00	2RCT,1/2JS,1/4IH	115.45	P,L2A,NaI	4.31		
Unit	Hand Survey Contents	ea	997.98	3	$ 2,993.94	0.12	25.00	2RCT,1/2JS,1/4IH	115.45	P,L2A,NaI	4.31		
Unit	Doff PPE and Exit	ea	19.73	15	$ 295.95	4	3.75	2RCT	78.90				
Unit	Travel Back	ea day	59.14	8	$ 473.12	2	4.00	2RCT,1/2JS,1/4IH	115.45	P	2.84		
Fixed	Postjob Briefing	ls	59.16	1	$ 59.16	2	0.50	2RCT,1/2JS,1/4IH	115.45	P,L2A,NaI	2.87		
Fixed	Return Equipment to Storage	ls	21.26	1	$ 21.26	2	0.50	1RCT	39.45	P,L2A,NaI	3.07		
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)											Subtotal =	$ 223.23
Unit	Solid Waste Transport	ls	223.23	1	$ 223.23		2.50	TD, LB, 1/4 EO	75.97	FB, 1/4FL	13.33		
	DISPOSAL FACILITY, DISPOSAL FEES, AND TAXES (WBS 4.13)											Subtotal =	$ 1,584.00
Unit	Disposal Fees & Taxes	cf	150.00	10.56	$ 1,584.00							150.00	0.66 cf/day × 8 day × 2

Labor and Equipment Rates Used to Compute Unit Cost

Crew Item	Rate $/hr	Abbreviation	Crew Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbreviation
Sampling Technician	39.15	ST	Equipment Operator	37.10	EO						
Radiation Control Tech	39.45	RCT	Truck Driver	34.35	TD	Pickup	1.62	P			
Job Supervisor	55.94	JS	Laborer	32.34	LB	Flat-Bed Truck	12.50	FB			
Industrial Hygienist	34.32	IH				Survey Meter	0.31	SM			

						Fork Lift	3.30	FL			

Notes:

1. Unit cost = (labor + equipment rate) × duration + other costs, or = (labor + equipment rate)/production rate + other costs.
2. Abbreviations for units: ls = lump sum, ea = each, cf = cubic feet, Rm-sf = room square feet.
3. Other abbreviations: PPE = personal protective equipment, Decon = decontaminate, Loc = location, Equip = equipment, Tech = technician, Prod = production.

Table C-3. Innovative technology cost summary.

Fixed/ Unit Costs	**Work Breakdown Structure**	**Unit**	**Unit Cost $/Unit**	**Quantity**	**Total Cost**	**Computation of Unit Cost** Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	**Comments**
									Total Cost =				**$ 3,455.34**
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURE SAMPLES (WBS 4.07.14)										Subtotal =		$ 2,836.34
Fixed	Pickup & Calibrate ISOCS	ls	29.53	1	$ 29.53	2	0.50	1RCT	39.45	P,IS0CS,GE	24.28		
Unit	Travel to Work Area	Ea day	68.14	2	$ 136.28	2	1.00	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	24.28		
Unit	Prejob Briefing	Ea day	33.71	2	$ 67.42	4	0.50	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	18.29		
Unit	Equipment Checks	Ea day	18.86	2	$ 37.72	4	0.50	1RCT	39.45	IS0CS,GE	45.31		
Unit	Don PPE	ea	39.45	3	$ 118.35	2	1.50	2RCT	78.90			54.04	$13.51/PPE × 2 RCT
Unit	Set ISOCS	ea	33.71	2	$ 67.42	4	0.50	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	46.73		× 2 DAY = $54.04
Unit	Scan Walls	sf	3.32	440	$ 1,460.80	12	36.67	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	46.73		
Unit	Scan Ceiling	sf	0.42	120	$ 50.40	12	10.00	2RCT, 1/2JS, 1/4IH	39.45	P,IS0CS,GE	46.73		
Unit	Scan Contents (equip)	ea	50.95	3	$ 152.85	3	1.00	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	46.73		
Unit	Remove ISOCS	ea	33.71	2	$ 67.42	4	0.50	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	46.73		
Unit	Decon Equipment	ea	150.84	2	$ 301.68	0.5	4.00	2RCT, 1/2JS, 1/4IH	135.61	IS0CS,GE	46.73		
Unit	Doff PPE	ea	19.73	3	$ 59.19	4	0.75	2RCT	78.90				
Unit	Travel Back	Ea day	68.14	2	$ 136.28	2	1.00	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	24.28		
Fixed	Postjob Briefing	ea	67.43	1	$ 67.43	2	0.50	2RCT, 1/2JS, 1/4IH	135.61	P,IS0CS,GE	18.29		
Fixed	Return Equip. to Storage	ea	29.53	1	$ 29.53	2	0.50	1RCT	39.45	P,IS0CS,GE	24.28		
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)										Subtotal =		$ 223.00
Unit	Solid Waste Transport	ls	223.00	1	$ 223.00		2.50	TD, LB, 1/4 EO	83.08	FB, 1/4FL	13.33		
	DISPOSAL FACILITY, DISPOSAL FEES, AND TAXES (WBS 4.13)										Subtotal =		$ 396.00
Unit	Disposal Fees & Taxes	cf	150.00	2.64	$ 396.00							150	0.66 cf/day × 2 days × 3

Labor and Equipment Rates Used to Compute Unit Cost											
Crew Item	**Rate $/hr**	**Abbre-viation**	**Crew Item**	**Rate $/hr**	**Abbrev-iation**	**Equipment Item**	**Rate $/hr**	**Abbrev-iation**	**Equipment Item**	**Rate $/hr**	**Abbreviation**
Industrial Hygienist	34.32	IH	Equipment Operator	37.10	EO	Pickup	1.62	P			
Radiation Control Tech	39.45	RCT	Truck Driver	34.35	TD	ISOCS	28.74	IS			
Job Supervisor	55.94	JS				Ge Detector	16.57	SM			
						Flat-Bed Truck	12.50	FB			

					Fork Lift	3.30	FL			

Notes:

1. Unit cost = (labor + equipment rate) × duration + other costs, or = (labor + equipment rate)/production rate + other costs.
2. Abbreviations for units: ls = lump sum; ea = each; loc = location; cf = cubic feet; sf = square feet.
3. Other abbreviations: PPE = personal protective equipment, Decon = decontaminate, Loc = location, Equip = equipment, Prod = production, Tech = technician.

APPENDIX D
ACRONYMS AND ABBREVIATIONS

Bq	Becquerel (disintegration/s)
CFA	Central Facilities Area
CFR	Code of Federal Regulations
Co	cobalt
Cs	cesium
D&D	decontamination and decommissioning
DOE	Department of Energy
ESP	Environmental Surveillance Program
Eu	europium
Ge	germanium
HPS	Health Physics Society
IFR	ISOCS for Free Release
INEEL	Idaho National Engineering and Environmental Laboratory
ISOCS	In Situ Object Counting System
MCP	Management Control Procedure
NaI	sodium iodide
OMB	Office of Management and Budget
OST	Office of Science and Technology
PPE	personal protective equipment
RCT	radiation control technician
STD	standard
WBS	Work Breakdown Structure