INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0433

Position-Sensitive Radiation Monitoring (Surface Contamination Monitor)

Deactivation and Decommissioning Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

June 1999

DISCLAIMER

INNOVATIVE TECHNOLOGY
Summary Report

Position-Sensitive Radiation Monitoring (Surface Contamination Monitor)

OST Reference #1942

Deactivation and Decommissioning Focus Area

Demonstrated at
Hanford Site
Richland, Washington

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this Document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available online at http://OST.em.doe.gov under "Publications."

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SECTION 1

EXECUTIVE SUMMARY

The Shonka Research Associates, Inc. Position-Sensitive Radiation Monitor both detects surface radiation and prepares electronic survey map/survey report of surveyed area automatically. The electronically recorded map can be downloaded to a personal computer for review and a map/report can be generated for inclusion in work packages. Switching from beta-gamma detection to alpha detection is relatively simple and entails moving a switch position to alpha and adjusting the voltage level to an alpha detection level. No field calibration is required when switching from beta-gamma to alpha detection. The system can be used for free-release surveys because it meets the federal detection level sensitivity limits required for surface survey instrumentation. This technology is superior to traditionally-used floor contamination monitor (FCM) and hand-held survey instrumentation because it can precisely register locations of radioactivity and accurately correlate contamination levels to specific locations. Additionally, it can collect and store continuous radiological data in database format, which can be used to produce real-time imagery as well as automated graphics of survey data. Its flexible design can accommodate a variety of detectors. The cost of the innovative technology is 13% to 57% lower than traditional methods.

• Technology Summary

This section summarizes the demonstration of an innovative technology developed by Shonka Research Associates, Inc. (SRA), Marietta, Georgia, which is a beta/gamma and alpha radiological contamination detection system, with an electronic data logger mounted on a self-propelled cart. The technology is equipped with a software package to facilitate electronic mapping.

Problem Addressed

The innovative technology can be used in any application where radiological surveys of flat surfaces must be documented. The technology eliminates the necessity to hand record data or develop manually generated surface contamination maps. The instrumentation can detect both alpha and beta/gamma contamination. The system is consistent in detecting radiological contamination and recording radiological intensity and location in an electronic database. The data can be downloaded to a personal computer (PC) for generating radiological contamination area maps. The radiological contamination monitor is superior to traditional baseline detection systems, because it is less costly to run, yet produces more consistent, reliable radiological contamination maps. It is more efficient and more precise than the baseline technology (hand recording and manual mapping and/or laser-assisted ranging and data system [LARADS] mapping). This technology is suited for radiological surveys of flat surfaces at U.S. Department of Energy (DOE) nuclear facility decontamination and decommissioning (D&D) sites or similar public or commercial sites. The technology is too sensitive suitable for use in high-radiation areas.

Features and Configuration

The system consists of a cart-mounted surface contamination monitor (SCM), (see photograph above), and a software package, the Survey Information Management System (SIMS). The SCM/SIMS has the following attributes:

- A position-sensitive detection system that precisely registers locations of radioactivity
- Ability to accurately correlate contamination levels to specific locations
- Ability to collect and store continuous radiological data in a database format
- Ability to monitor for both beta/gamma and alpha contamination
- Provision of real-time imagery of the contamination as the surface is being surveyed
- Provision of clear, concise, easily understood graphics of survey data
- Flexible design that can accommodate a variety of detectors (e.g., sodium iodide for cesium-137 gamma or field instrument detection for low energy radiation (FIDLER) for transuranic gamma)
- Compatible with existing software to facilitate automatic mapping
- Efficient, automatic production of reports using standard word processing software coupled with two-dimensional color imagery of the area surveyed
- Cost effective.

The SRA position-sensitive SCM/SIMS consists of the following components:

- A segmented gas-filled proportional counter that is equivalent to numerous side-by-side detectors
- Controls for quickly switching between beta/gamma and alpha monitoring
- A motorized cart with controllable speed
- A wheel encoder that senses distance traveled, for automatic mapping
- A 12-volt DC lead-acid battery (the system can also be operated using 110 VAC)
- An on-board computer for data collection/processing
- An on-board video camera
- SIMS software package used to generate floor maps that show locations and radiation levels of hot spots.

Potential Markets

The SRA technology consists of a beta-gamma/alpha radiological contamination detection system, electronic data logger, self-propelled cart, and mapping software that are useful at DOE, U.S. Environmental Protection Agency (EPA), or Nuclear Regulatory Commission (NRC) sites where there is a necessity to survey and log specific levels and locations of contamination.

Advantages of the Innovative Technology

The following table summarizes the advantages of the innovative technology against the baseline in key areas:

Category	Comments
Cost	The cost of the innovative technology is 13% to 57% lower than the baseline. A cost breakdown is given in the tabulation in Section 5.
Performance	The production rate per unit area for the innovative technology is five times better than the baseline for beta/gamma and two times better than the baseline alpha survey. The electronic data logging, the downloading of data to a PC, and mapping capability of the innovative technology provide consistent and reliable maps. The electronic data and maps can be shared without losing clarity, whereas the hand-drawn baseline maps are barely adequate and are subject to human error.
Implementation	Setup time for the technology is about the same as for the baseline, however, switching from beta/gamma detection to alpha detection is accomplished in minutes by moving a selector switch and adjusting a voltage level. This transition typically takes 3 hours with the baseline. The new technology does not require frequent instrument calibration and field source checks, which is required by the baseline.
Secondary Waste	No secondary waste is generated by either the innovative or the baseline technologies.
ALARA/Safety	Neither the innovative or the baseline technologies cause significant safety hazards.

A summary of costs and production rates is as follows:

Innovative Technology				Baseline Technologies		
Cost Element	Production Rate	Unit Cost		Cost Element	Production Rate	Unit Cost
		Purchase	Rent			
Beta/Gamma Survey				**Beta/Gamma Survey**		
Unobstructed Floor	446 m^2/hr (4,800 ft^2/hr)	\$0.22/m^2 (\$0.02/ft^2)	\$0.32/m^2 (\$0.03/ft^2)	Unobstructed Floor	Same as for Normal Floor	\$3.67/m^2 (\$0.34/ft^2)
Normal Floor	117 m^2/hr (1,260 ft^2/hr)	\$0.65/m^2 (\$0.06/ft^2)	\$1.10/m^2 (\$0.10/ft^2)	Normal Floor	15.61 m^2/hr (168 ft^2/hr)	\$3.67/m^2 (\$0.34/ft^2)
Obstructed Floor	61 m^2/hr	\$1.20/m^2	\$2.00/m^2	Obstructed Floor	Same as for Normal Floor	\$3.67/m^2 (\$0.34/ft^2)
Alpha Survey				**Alpha Survey**		
Normal Floor	100 m^2/hr (1080 ft^2/hr)	\$0.75/m^2 (\$0.07/ft^2)	\$1.20/m^2 (\$0.11/ft^2)	Normal Floor	43 m^2/hr (465 ft^2/hr)	\$1.40/m^2 (\$0.13/ft^2)

Limitations/Operator Concerns

The innovative technology is not recommended for use in high-radiation/contamination areas, due to the sensitivity of electronic components and circuits. Also, the system demonstrated cannot be used for contamination detection on walls and ceilings (but the technology could be adapted to do so).

Skills/Training

Training of field technicians is minimal (less than 1 day), provided that the trainees are proficient in standard radiological survey practices. The setup and use of the system requires technician training. In addition, PC-based knowledge is necessary to produce enhanced-quality floor maps.

• Demonstration Summary

Under the Large-Scale Technology Demonstration, at least twenty innovative and baseline technologies will be demonstrated and assessed for applicability and potential deployment throughout the DOE complex. The SCM/SIMS technology was demonstrated for applicability at the C Reactor Interim Safe Storage (ISS) Project at DOE's Hanford Facility in southeastern Washington. The ISS Project is part of a nuclear facility decommissioning program in which portions of or entire facilities must be characterized in order to plan work or certify for free release. Part of the characterization work involves beta/gamma and alpha radiological surveys of indoor and outdoor surfaces of the facility. This has traditionally been accomplished using survey instrumentation with no capability for automated data logging. The demonstration compared the innovative technology to a baseline that consisted of four separate plastic scintillator detectors arranged side by side. With the baseline, traditional survey methods, although the signals from the detectors are displayed via an on-board computer, they are collected and logged manually for beta/gamma measurements. The alpha survey required a level of detection that could not be achieved by the floor contamination monitor that is currently owned. Current planning for alpha surveys at the F Reactor (these plans form the basis of the baseline estimate for the alpha survey costs) rely on purchasing of a floor monitor that is suitable for the required detection limit and linking the monitor to the LARADS (to record the position and radiologic data). Subsequently, reports are generated. After the demonstration at C Reactor, surveys were conducted at the F Reactor area. The total area surveyed at the two facilities was 2,300 m^2 (25,000 ft^2). The surveys at C Reactor and the F Reactor areas were the first large-scale application of the SCM for alpha detection as well as beta/gamma at a DOE facility.

Site Description

At its former weapons production sites, the DOE is conducting an evaluation of innovative technologies that might prove valuable for facility D&D. As part of the Hanford Site Large-Scale Technology Demonstration (LSTD) at the C Reactor Interim Safe Storage (ISS) Project, at least 20 technologies will be tested and assessed against baseline technologies currently in use. DOE's Office of Science & Technology/Deactivation & Decommissioning Focus Area, in collaboration with the Environmental Restoration Program, is undertaking a major effort of demonstrating improved and innovative technologies at its sites nationwide, and if successfully demonstrated at the Hanford Site, these innovative technologies could be implemented at other DOE sites and similar government or commercial facilities.

Various rooms (i.e., sample rooms), and areas (i.e., C Reactor front face work area) at the C Reactor building and various areas (i.e., Building 108 F) at F Reactor were surveyed using the innovative technology radiation detection system.

Applicability

The DOE's Richland Operations Office (DOE-RL), located in Richland, Washington, has successfully completed a demonstration to verify the capabilities of the SCM/SIMS. The system represents an innovative technology that can be used where there is a need to perform beta/gamma and alpha radiological surveys. This innovative technology is well suited to surveys of large, open areas and smooth surfaces, and is particularly useful for environmental and free-release surveys. The system can be configured with large detectors on mobile platforms for surveying outdoors or large wall, ceiling, and floor surfaces. This system is in use at a laundry that cleans contaminated protective clothing. The innovative technology is not applicable for areas with high levels of radioactive contamination/radeation. The precision and quality of the survey documents resulting from the use of this technology support regulatory reviews.

Key Demonstration Results

This innovative system was successfully demonstrated at the C Reactor ISS Project with the following key results:

- Accurately correlated contamination levels to specific locations as evidenced by hot spot verification using the baseline
- Acquired and stored continuous radiological data in database format
- Provided clear, concise, comprehensible graphics of survey data
- Demonstrated the flexibility to use a variety of detectors (e.g., sodium iodide for cesium-137 gamma or FIDLER for transuranic gamma) because of the cart construction and compatibility with the existing software
- Costs using the innovative technology were less than baseline costs
- Because the SCM detector is highly sensitive to alpha radiation, confirmatory measurements of alpha detections with a hand-held probe may be needed.

Regulatory Issues

The SCM/SIMS system is an investigation tool for characterizing contaminated surfaces; therefore, no special regulatory permits are required for its use. The detection level of the SCM/SIMS system meets the requirements of 10 CFR Parts 20 and 835, and proposed Part 834, which makes this system appropriate for free-release surveys.

Technology Availability

The SCM/SIMS system is commercially available from SRA on either a rental or purchase basis. The system is past the demonstration stage and has been deployed in a variety of situations. Marketplace opportunities exist for the innovative technology at potentially radiologically contaminated sites in which remediation, D&D, or release activities are planned.

Technology Limitations/Needs for Future Development

Due to physical size and geometry of the SCM, near-corner and wall measurements could not be obtained in one pass; a secondary pass perpendicular to the first was needed. Near-corner and wall measurements may also be accomplished by changing to a detector with a right angle. At the present time, there is no need to modify the system demonstrated at the Hanford Site C Reactor.

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Other

All published Innovative Technology Summary Reports are available at http://em-50.doe.gov. The Technology Management System, also available through the EM-50 Web site, provides information about OST programs, technologies, and problems. The OST Reference # for the Position-Sensitive Radiation Monitoring (Surface Contamination Monitor) is 1942.

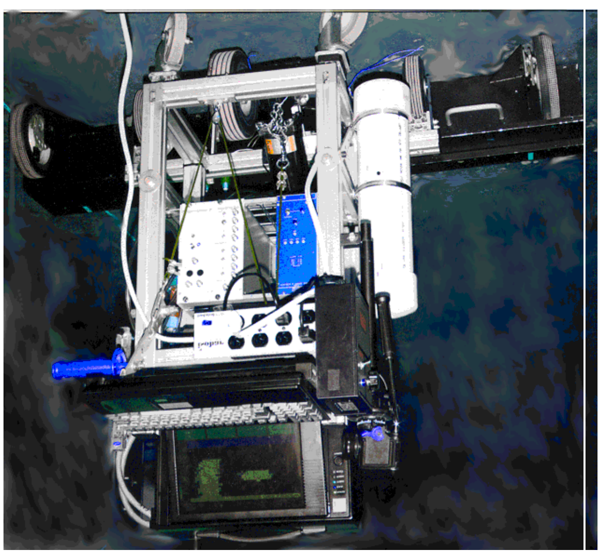
SECTION 2

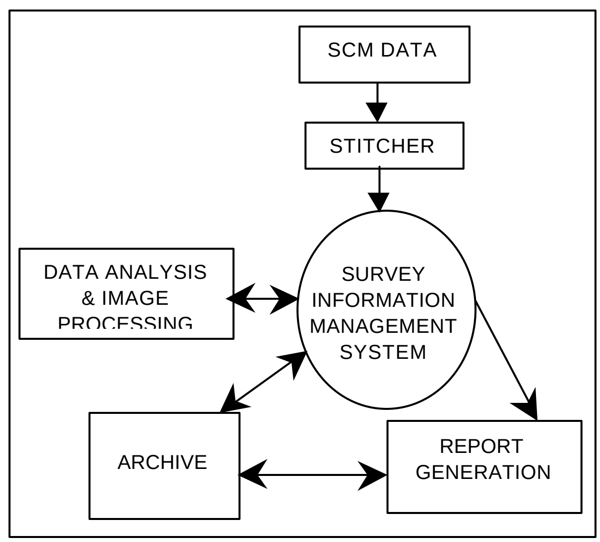
TECHNOLOGY DESCRIPTION

• Overall Process Definition

The SCM (Figure 1) and the associated SIMS are two distinct elements of this innovative technology that permit a radiation survey to be performed. The radiation detector is a gas-filled proportional counter. Four hundred measurements are taken and recorded per square meter of surface area scanned (each measurement corresponds to an area of 25 cm^2 [~4 $in.^2$], which is about the area of the commonly used pancake Geiger-Mueller [GM] probe). An image of the contamination is generated and shown to the operator in real time while the monitor scans over the surface. The system description presented follows SRA documentation on the SCM/SIMS technology (Reference 1).

The schematic for the SCM/SIMS system is shown in Figure 2. The SIMS can log data from the SCM, and the SIMS software can analyze data from a variety of detector systems for use with any data that are spatially oriented. Digital imaging tools are included with the SIMS and allow for detailed studies to analyze for the presence of contamination. The SIMS allows import and export of data to various formats, including spreadsheets. These surveys are assembled into matrices of data using STITCHER©, a graphical code that permits the user to lay out and/or assemble strips graphically in the pattern in which they were run.





The SCM consists of a computerized position-sensitive proportional counter (PSPC) deployed on a cart with a direct-current gear-motor drive. The system includes a video recorder for recording surveys. The recorded video images are correlated with data collection. The detector differs from the conventional proportional counter used for surveying surface contamination in that the location of an event is measured in the counter. The detector is filled with P-10 gas (10% methane/90% argon).

The detector is a specialized type of proportional counter that includes an anode wire that collects gas ions. Proportional counters are radiation counters in which the initial charge created in the counter gas is multiplied by factors of up to a million or more through a process known as a Townsend discharge. The amount of charge that is collected by the anode wire is proportional to the initial ionization. Because air is a poor counting gas, argon is used as a counting gas, with 10% methane added to improve the performance by stabilizing the discharge, preventing large gain excursions. In a normal proportional counter, the anode wire is connected to a circuit that provides the high voltage needed to initiate the discharge and also provides a preamplifier circuit that increases the electronic gain over the initial gas multiplication. This is further connected to a circuit that counts the pulses that occur that are larger than some discriminator value. If a count occurs, the user knows that an alpha or beta particle has entered the counter through the thin aluminized mylar entrance window. A more sophisticated electronic circuit is used to determine if it was either an alpha or a beta particle, since the amount of ionization (and hence the proportional electronic pulse height) differs by a factor of approximately 10. PSPCs are a specialized type of proportional counter where each end of the anode wire is connected to its own preamplifier electronics. When the pulse of charge is collected on the anode wire, the charge divides and migrates down the anode wire to each preamplifier. If the initial charge is deposited in the middle of the counter, one half of the charge will travel to each end of the counter. The pulse height at each end of the anode wire is measured for each pulse that occurs, and the location of the event is automatically calculated from the relative pulse heights.

Notable Capabilities

<u>SCM/PSPC</u>

- The PSPC detector can detect both alpha and beta/gamma radiation separately in the field without re-calibrating the system.
- The system also can support a GM detector for monitoring the general area radiation, a sodium iodide detector for gamma radiation (i.e., cesium-137, cobalt-60) and a FIDLER for transuranic gamma radiation, all with automatic mapping.
- The PSPC detector is adaptable to surveying walls, ceilings, or flat articles (e.g., laundry, sheetrock, and plywood), and for use as a portal monitor.
- Reports are automatically generated using a standard word processing program and include a two-dimensional color image of the contamination divided into a grid of 1-m^2 blocks. A table beneath the image shows the minimum, maximum, average, and standard deviation of the average values for each block. Values for any block that exceed release limits are displayed in bold font.
- The existing software and cart construction are flexible in that a variety of PSPC configurations and detectors can be used (see Figures 3 and 4).

<u>SIMS</u>

The SIMS embeds an analysis system called VISUSPECT© for studying the data. VISUSPECT© provides most of the mathematical treatments that the National Aeronautics and Space Administration developed for studying earth-imaging data sets. The SIMS also provides for segregating the survey data into square-meter blocks, with all relevant data reported for each block. This report provides a three-dimensional view of the data set and two-dimensional views that are split into blocks with a table indicating minimum, maximum, average, and standard deviations for the 400 measurements taken per square meter.

The SIMS can also provide output for other systems such as CAD and geographic information systems (GIS).

- A database electronic file is provided that includes every reading obtained with the date, time, file identification, reading(s), and coordinate information. The default coordinate system used is based on the local coordinate system for each survey with the origins at some arbitrary, identifiable location in the survey area, such as a corner.

- The direct-current gear motor, computer, and electronics can be powered from a 12-volt battery or normal wall plate (110 VAC), and the system has been operated from a portable generator.

• System Operation

SCM Operation

The SCM is computer controlled and executes under the Microsoft disk-operating system. When the software is launched, the survey technician enters basic information such as the building and room name. This information is stored in a database associated with the survey. At this point, the SCM can be operated as a scanning machine. The survey technician decides on a set of straight passes (called strips) that cover the area of interest. A crude drawing of the strips is made as a reminder. The computer logs the data in 5-cm by 5-cm (2-in. by 2-in.) increments as the system moves forward. The recorder is started by the computer. At the end of the strip, the technician stops recording and relocates to the next strip.

The SCM does not need a collimator and can image the contamination in the same manner as a contact photograph because the detector is held in close proximity to the surface. The monitor software permits recording the data in a computer file that can be played back or can be used by SIMS. A Hanford Site radiological control technician (RCT) successfully operated the system with less than 2 hours of instruction and no prior information on the system.

SIMS Operation

The SIMS operation was demonstrated using the same computer that was used for the SCM, where the software is embedded in Microsoft Windows, 3.1™, and is written in C programming language. The SIMS can be loaded on a workstation that includes color printing, backup (either locally or through a local area network), a video player with time indexing, and a video capture board (to permit capturing useful video images into reports).

The survey is assembled into a pattern that reflects the pattern that the SCM used, by using STITCHER©. Using a computer mouse and the monitor screen, the user simply "grabs" strips, pulls them into location, and points them in the direction that they were taken.

After a survey has been stitched, another Windows® application, VISUSPECT© (which stands for visual inspection) is run. The operator can automatically generate a report without having to transcribe numbers manually.

SECTION 3

PERFORMANCE

• Demonstration Plan

Site Description

The demonstration was conducted at the DOE's Hanford Site by Bechtel Hanford, Inc. (BHI) along with representatives from SRA. BHI is the RL's Environmental Restoration Contractor, and is responsible for the D&D program at Hanford. The purpose of the demonstration is to show how to use commercially available technologies to place Hanford's C Reactor into an interim storage mode for up to 75 years, or until the final disposal of the reactor's core is completed. The C Reactor ISS Project objectives include placing the reactor in a condition that will not preclude or increase future decommissioning costs; minimizing the potential for releases to the environment; and reducing the frequency of inspections, thereby reducing potential risk to workers.

As part of the interim storage process, large surface areas must be surveyed to detect alpha and beta/gamma radiological contamination. The resulting survey information is used to make decisions about whether to decontaminate, demolish, or free-release areas of the reactor facility. In March, October, and November of 1997, the demonstration of the SCM/SIMS and PSPC technology was conducted at various floor areas at the C Reactor Building and F Reactor area.

Performance Objectives

The objective of the demonstration was to determine if there are viable alternatives to traditional radiation survey methodologies and to compare the performance of the innovative technology to the baseline, which was the floor contamination monitor with plastic scintillator detectors. The specific performance objectives for the innovative SCM/SIMS and PSPC technology to be evaluated during the demonstration included the following:

A. System must be self-contained with no umbilical or remote operations.

B. Sensitivity must be capable of detecting the equivalent of 1,000 disintegrations per minute (dpm)/100 cm^2 for strontium-90, 3,000 dpm/ 100 cm^2 for cesium-137, 5,000 dpm/100 cm^2 for technetium-99; and 100 dpm/100 cm^2 for any alpha contamination; detection limits may be averaged over the detector surface area if greater than 100 cm^2 (15.5 $in.^2$) and not exceeding three times the above-stated limits for the entire detector surface area (as indicated in 10 CFR 835).

C. System must be capable of producing a real-time radiation map of a floor (to scale), including coordinates.

D. Cross-talk from beta to alpha channel must be less than 1%.

E. Cross-talk from alpha to beta channel must be less than 10%.

F. System must simultaneously count alpha and beta radiation.

G. System must display alpha and beta contamination separately (in dpm for each).

H. System must provide audible and visible indicators when contamination limits are exceeded.

I. System must be able to operate effectively in an ambient temperature environment from 3EC to 40EC (37.4EF to 104EF).

J. System must have a data-logging capability to download survey information in dpm values per position to a commercially available PC program. Computer and software must be supplied with the system.

K. Components must be easy to decontaminate using conventional equipment.

L. Detector must be capable of achieving desired sensitivity in a background field of 20 x 10^{-8} Sv/hr (20 microrem/hr).

Specific Technology Demonstration Instructions

SRA submitted a specific procedure for completing the survey for the demonstration at the Hanford Site C Reactor ISS Project. The following summarizes the main steps in the demonstration and later provides a detailed description of the specific surveys that were performed using the innovative and baseline technologies:

<u>Demonstration Summary</u>

- The instrument was calibrated offsite by SRA.

- Two types of surveys (beta and alpha) were conducted in a series of strips that could be automatically assembled for report purposes with SIMS to provide complete documentation of the surveys without requiring manual transfer of data.

- The total area surveyed with the PSPC for both alpha and beta/gamma radiation consisted of 2,300 m^2 (25,000 ft^2). With the SCM the same area was surveyed twice, once for beta/gamma and once for alpha contamination.

- To accomplish a survey, a technician first made a crude sketch of the area and indicated the direction and start point of each strip. A survey file name was recorded on the sketch, and a reference coordinate for a corner of each strip area was noted. The surface was cordoned into strips 1.2-m (4-ft) wide using a chalk line.

- To prepare the instrument for surveying the next strip, the survey technician needed only to change the file name for each new strip.

- To perform an alpha survey, the PSPC was set at the alpha plateau, which rejects beta to the maximum extent.

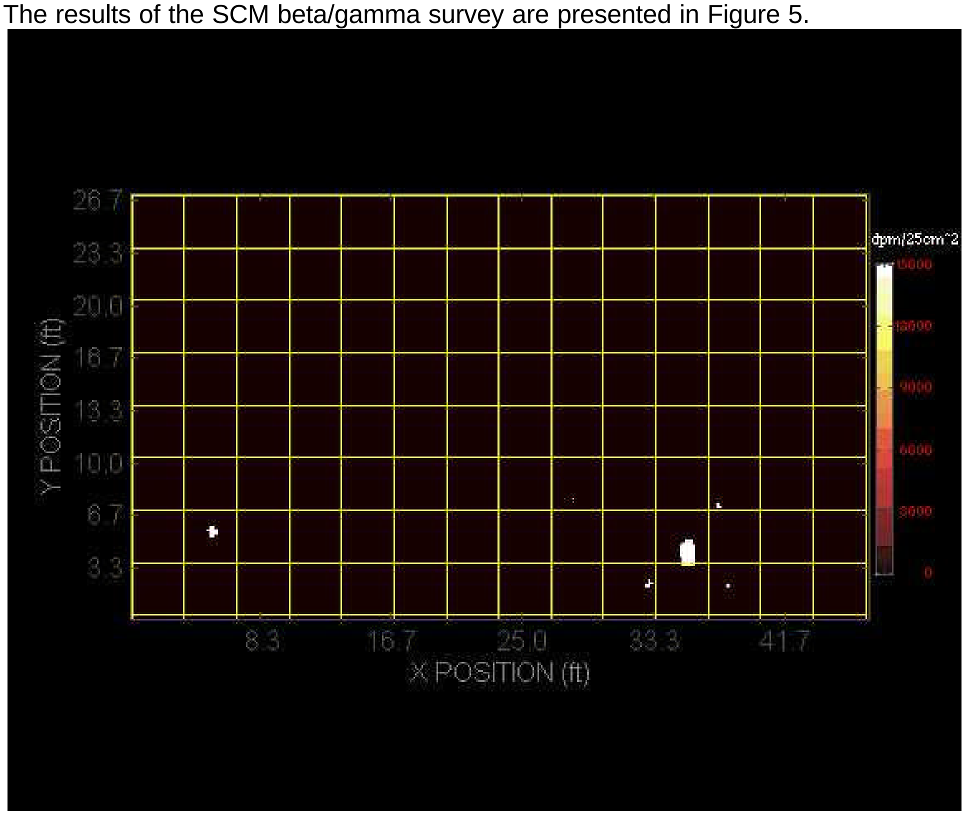
<u>Pre-Survey Preparation</u>

The SCM was assembled and tested by two SRA staff prior to moving the system to the Hanford Site C Reactor area. The assembly and test took 6 hours, which included mounting and connecting detectors and the video camera and conducting dry runs with the computer. The work was preceded by calibrations performed at the vendor's facility for alpha and at the Oak Ridge Institute of Science and Education (ORISE) for beta/gamma. The calibrations take approximately 15 minutes each, and are normally performed once per year. The SCM was then disassembled into major components suitable for shipping. The SCM was assembled in the field at the area adjacent to the reactor building using quick-disconnect fittings for the electrical and gas connections. Following a 5-minute gas purge, the system was again ready for operation. A field source check was performed by placing two different sources on the floor and then passing the monitor over the sources. Approximately 1 hour total was required for field setup. The cart was moved into the reactor building to the front face floor. Background beta/gamma and alpha radiation were each measured with the SCM placed over temporary thin floor covers.

<u>Beta Survey</u>

It should be noted that, for comparison purposes, both the innovative and baseline technologies were used to survey the same surface areas.

The floor contamination survey for beta contamination was performed by a Hanford RCT. After the RCT was instructed in the use of the system, the system was moved to the front face work area and set up for a beta surface contamination survey. During the survey, SRA staff observed and provided any needed guidance on proper use. Before commencing the survey, the scanning speeds were checked, the wheel encoder was calibrated, background radiation was measured, and a source check was completed. The setup procedure took 15 minutes (including source checks), and the beta survey was completed in 16 minutes for a 55.7-m^2 (600-ft^2) area at a scan speed of 5 cm (~2 in.) per second. (Using the baseline technology, only about one-half of the same area was completed in that time.) The SCM survey completed the baseline study area first, then returned to finish the remainder of the area. A microrem/hour exposure rate measurement was also logged simultaneously with a high-sensitivity, energy-compensated GM tube, and this survey is reported separately. The results of the SCM beta/gamma survey are presented in Figure 5.



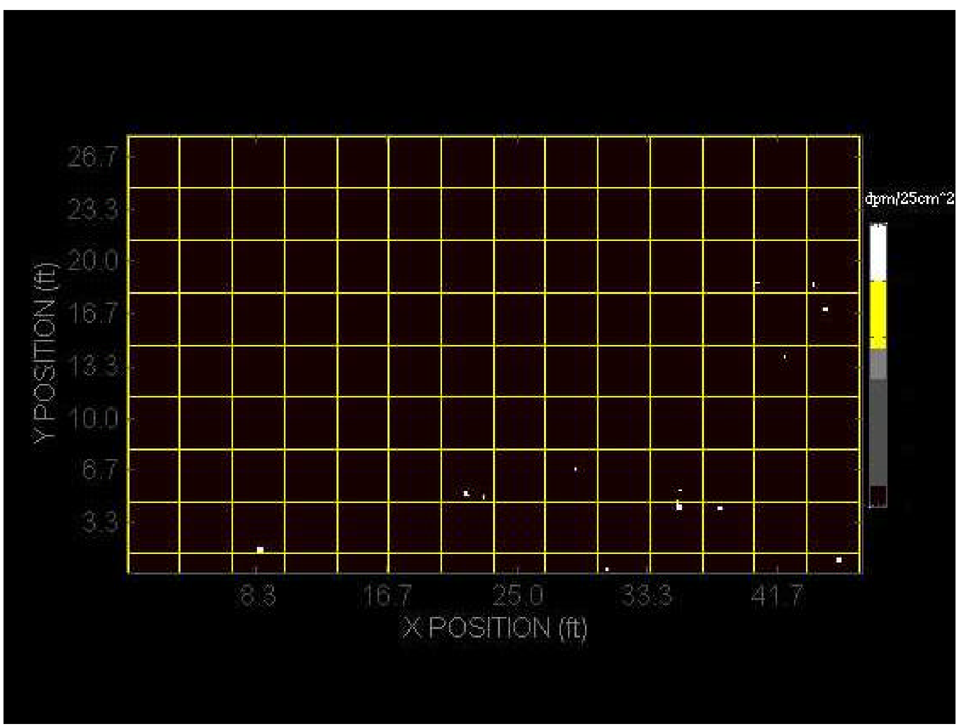
Following the beta/gamma survey, the SCM was re-deployed to another area (the lunchroom) in the C Reactor complex to demonstrate remobilization time. This required the RCT to change the detector from the survey mount to the transport mount (approximately 1 minute). Next, the equipment was easily rolled to the lunchroom area, set up for a survey, then returned to the front face test area. Significant effort was not required to re-deploy the SCM.

<u>Alpha Survey</u>

Following the beta survey, the instrument was set up for an alpha radiation survey. The following steps were taken to transition the system from the beta/gamma mode to the alpha mode:

- The detector was lowered to increase the alpha efficiency.
- The protective screen was removed (which was not needed on the smooth concrete floor).
- The high voltage was lowered to an alpha-only plateau (which rejected counts from beta radiation by 10,000:1).
- The scan speed was reduced from 5 cm (2 in.) per second to 2.54 cm (1 in.) per second.

The setup time for the alpha phase of the survey took about 15 minutes, the majority of which was spent removing the protective screen. The actual survey took an additional 29 minutes. The alpha survey report created by SIMS showed some areas above 300 dpm/100 cm^2. The results of the survey are presented in Figure 6. The highlighted areas shown in the figure were also observed as alarms on the SCM. Background has not been subtracted from these data (the background was quite low), so these areas may not have been true alpha hot spots. The areas are believed to be either statistical fluctuations or are manifestations of the natural flux of alpha particles from the concrete. One of the areas where an alarm occurred was the small beta contamination area that was nearly one million dpm. Even with the beta rejection ratio of 10,000:1, some of the beta particles were counted, causing the area to appear as slightly contaminated with alpha radiation. Proper disposition of these areas would require re-examination, perhaps by using the SCM's multichannel analyzer in a static mode.



Alpha surveys with conventional scanning methods are costly because they must be performed at extremely slow rates (well under 2.5 cm [1 in.] per second). Conventional measurements can take several minutes for each point that is measured. However, the SCM technology combines scanning and recording at the same time, which was set at a speed of 2.5 cm (1 in.) per second. This scanning speed, when combined with a wide (1.3 m [4.3 ft]) detector, provided a significant increase in survey speed over conventional systems.

Release limits for alpha are 100 dpm/100 cm^2 when averaged over 1m^2 with no more than 300 dpm/100 cm^2 in a localized 100-cm^2 (15.5-$in.^2$) area. With software set to monitor with 90% confidence level, which is acceptable to the regulators, several false positive alarms were observed on the SCM. The survey indicated a few localized alpha hot spots above 300 dpm/100 cm^2. The number of hot spots is consistent with statistically expected false positives. Thus, given that the average contamination is not measurable and is less than 10 dpm/100 cm^2 (when background is accounted for) and that the few isolated 100-cm^2 (15.5-$in.^2$) areas are consistent with the false alarm rate, an assertion of no reasonable surface alpha contamination is reasonable.

Detector Edge Effect

The response to a source near the edge of the detector is indicative of how close the detector can be positioned to a wall or similar obstacles. As with all detectors, the response of the SCM to a point source drops to somewhat less than one-half of the response as the point source is moved to the edge of the Mylar window (and the detector cavity).

As part of the demonstration, an experiment was performed with the SCM technology. While the SCM was moving, a point source was placed in the detector path at 2.54-cm (1-in.) increments, beginning 15.3 cm (6 in.) from the right edge until the end of the detector housing was reached. A measurement with the source 5.1 cm (2 in.) outside of the detector housing was also recorded. As expected, the detector experiences roll-off when responding to a point source located off of the Mylar window (the detector's response ranged from 100% at 15.2 cm [6 in.] from the detector's edge to 9% at 5.1 cm [2 in.] from the detector's edge). SRA's survey practice is to provide for 122-cm (48-in.) survey strips, overlapping 11.4 cm (4.5 in.) of the 145-cm (57-in.) detector housing on each strip. Thus, SRA avoids using the edge for surveys.

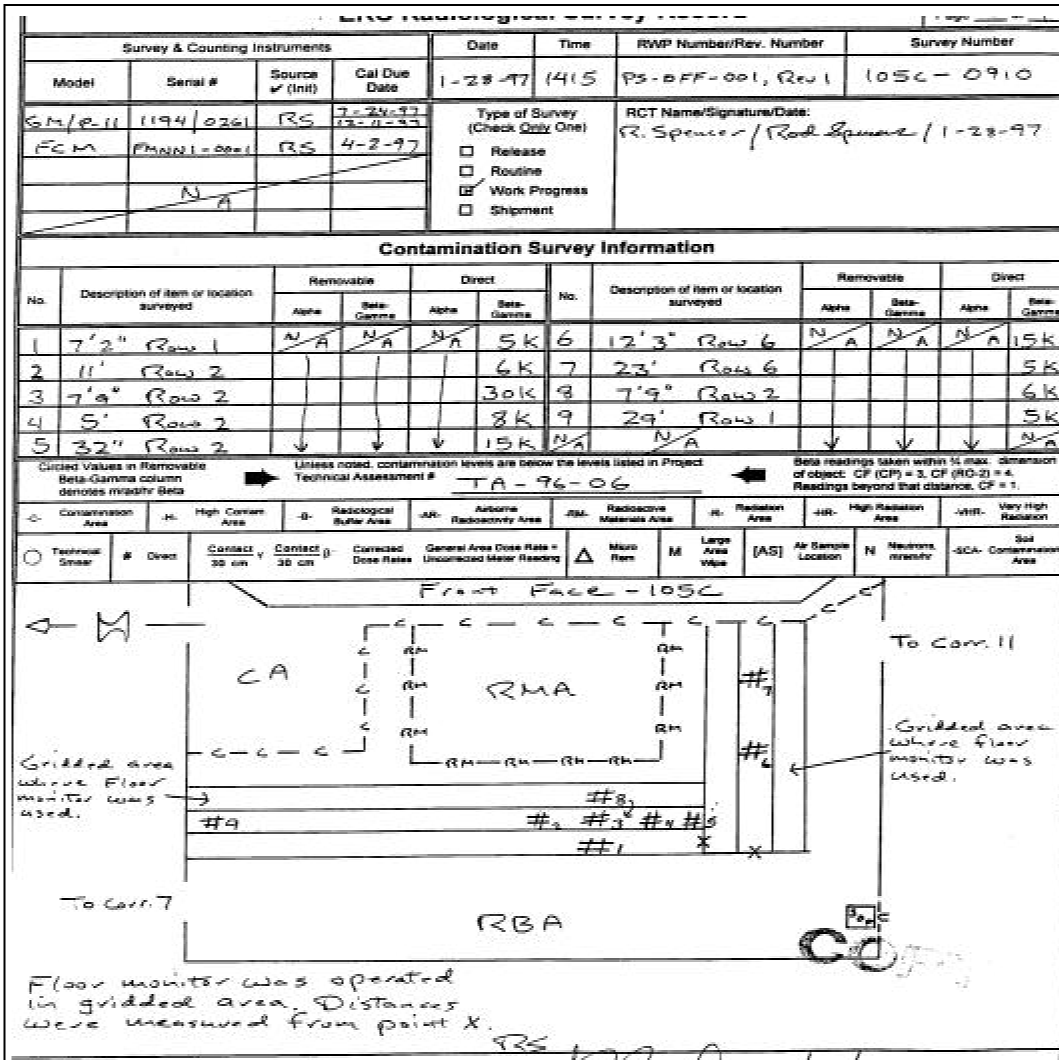
Post-Survey Source-Check

The post-survey source-check of the innovative system showed all data within 10%. The test consisted of comparing the count rate in counts per minute (cpm) from SRA s check sources with the measurements obtained during the pretest calibration conducted prior to shipping to the Hanford Site. The largest deviation was 9% for the center channel for the alpha source.

• Technology Demonstration Results

Successes

Measurement performance details described in this section follow the SRA documentation on this demonstration (Reference 1). The demonstration indicated that radiation surveys could be performed for large areas at rates much faster than with conventional technology. Survey reports have improved completeness and quality compared to conventional survey documentation and are generated with much less effort. The system does not require a skilled operator and does not have the embedded costs associated with other surveying systems that have a higher degree of automation (e.g., incorporating robotics or radio-telemetry systems). A detailed report can be generated within minutes with minimal operator interaction.



ERC Radiological Survey Report

Survey & Counting Instruments				Date	Time	RWP Number/Rev. Number	Survey Number
Model	Serial #	Source ✔ (Init)	Cal Due Date	1-28-97	1415	PS-DFF-001, Rev 1	105C-0910
GM/P-11	1194/0261	RS	~~7-24-97~~ 12-11-97	Type of Survey (Check Only One): ☐ Release ☐ Routine ☑ Work Progress ☐ Shipment		RCT Name/Signature/Date: R. Spencer / Rod Spencer / 1-28-97	
FCM	FMNN1-0001	RS	4-2-97				
N/A							

Contamination Survey Information

No.	Description of item or location surveyed	Removable Alpha	Removable Beta-Gamma	Direct Alpha	Direct Beta-Gamma	No.	Description of item or location surveyed	Removable Alpha	Removable Beta-Gamma	Direct Alpha	Direct Beta-Gamma
1	7'2" Row 1	N/A	N/A	N/A	5K	6	12'3" Row 6	N/A	N/A	N/A	15K
2	11' Row 2	↓	↓	↓	6K	7	23' Row 6	↓	↓	↓	5K
3	7'9" Row 2	↓	↓	↓	30K	8	7'9" Row 2	↓	↓	↓	6K
4	5' Row 2	↓	↓	↓	8K	9	29' Row 1	↓	↓	↓	5K
5	32" Row 2	↓	↓	↓	15K	N/A	N/A	↓	↓	↓	N/A

Circled Values in Removable Beta-Gamma column denotes mrad/hr Beta ➡ Unless noted, contamination levels are below the levels listed in Project Technical Assessment # TA-96-06 ⬅ Beta readings taken within ½ max. dimension of object: CF (CP) = 3, CF (RO-2) = 4. Readings beyond that distance, CF = 1.

-C- Contamination Area; -H- High Contam Area; -B- Radiological Buffer Area; -AR- Airborne Radioactivity Area; -RM- Radioactive Materials Area; -R- Radiation Area; -HR- High Radiation Area; -VHR- Very High Radiation

○ Technical Smear; # Direct; Contact/30 cm γ; Contact/30 cm β; Corrected Dose Rates; General Area Dose Rate = Uncorrected Meter Reading; △ Micro Rem; M Large Area Wipe; [AS] Air Sample Location; N Neutrons mrem/hr; -SCA- Soil Contamination Area

Shortfalls

The innovative technology is not recommended for use in high-radiation areas, due to the sensitivity of electronic components and circuits. Also, the system demonstrated cannot be used for contamination detection on walls and ceilings (but the technology could be adapted to do so). Because of the physical geometry of the instrumentation, it was difficult to obtain near-wall and near-corner survey readings.

• Comparison of Innovative Technology to Baseline

Table 1 summarizes performance and operation of the innovative technology in comparison with the baseline technology. Table 2 summarizes variable conditions that can be used for estimating site-specific costs.

Table 1. Performance and operation summary of the innovative technology

Activity or Feature		Baseline	Technology Demonstration
Source and system check		0.2 hr	0.5 hr
Scanning speed	alpha	Hand probe	2.54 cm/sec (1 in./sec)
	beta/gamma[a]	2.3 cm/sec (0.9 in. /sec)	5.1 cm/sec (2 in./sec)
Survey time	alpha	2.0 hr	0.6 hr
	beta/gamma[a]	3.5 hr	0.5 hr
Number of RCTs		2 - mark lines	2 - mark lines
		1 - run system	1 - run system
Survey report generation		30 min.	3 min.
Sensitivity		acceptable	better than baseline
Flexibility		acceptable	better than baseline
Precision, accuracy, representativeness, completeness		good	better than baseline
Safety		same	same
Durability		note b	note b
Data interpretation		note c	note c
Ease of operation		note d	note d
Waste generation		same	same
Utility requirements		same	same

[a] The innovative detector is twice the width of the baseline detector and does not have to be stopped for verification of hot spots with a hand-held detector. These factors, as well as scanning speed, affect survey time.

[b] For durability comparison, both technologies are comparable in ruggedness for field work.

[c] For data interpretation, the innovative unit can give more false-positive readings for alpha but produces beta/gamma maps that are easily interpreted.

[d] For ease of operation, the innovative unit requires slightly more training because it has computerized mapping capability as an option, but the PSPC is much easier to change between beta/gamma and alpha monitoring.

Baseline Survey

For the baseline survey, a floor contamination monitor (FCM) equipped with four separate plastic scintillator detectors arranged side by side was used. The signal from each detector is displayed (in cpm) separately using an on-board computer. Prior to the survey, the system was calibrated for beta/gamma by Pacific Northwest National Laboratory. Although this model of monitor can be calibrated for alpha, switching between beta/gamma and alpha scan mode is time consuming, so the unit is not routinely used for alpha measurements.

A Hanford Site RCT made a hand-drawn sketch of the floor area of the room. The survey area was divided into a grid of four 0.6-m (2-ft) wide strips. The survey was conducted within the boundary of the two strips using a normal survey speed (approximately 2.3 cm [0.9 in.] per second to achieve the required sensitivity). A survey area of 26 m^2 (280 ft^2) was surveyed in its entirety for beta/gamma-emitter contamination.

When hot spot areas were noted, the areas were re-surveyed manually using a pancake GM detector to pinpoint more accurately the hot spot locations. The alpha survey required a level of detection that could not be achieved by the floor contamination monitor that is currently owned. Current planning for alpha surveys at the F Reactor (these plans form the basis of the baseline estimate for the alpha survey costs) rely on purchasing of a floor monitor that is suitable for the required detection limit and linking the monitor to the LARADS (to record the position and radiologic data).

A hand-written report (Figure 7) was prepared, and the sketch of the surveyed area was attached to indicate hot spots. Only beta/gamma hot spots were reported.

Innovative/Improved Technology

Meeting Performance Objectives

The objectives listed in the demonstration overview section were met with a few exceptions. For example, item B (sensitivity levels) was not tested specifically, but prior work by SRA indicates that these sensitivity requirements can be met. Item C (real-time mapping) was not entirely met, but maps produced within a few minutes of completing surveys are adequate. Item F (simultaneous alpha and beta surveys) was not performed, but surveys are so rapid that sequential surveys are acceptable. Item L (working in a higher radiation background environment) cannot be met because the system is useful in detecting hot spots only in areas where the background level is not elevated.

Other System Capabilities

<u>Capability for Battery Operation</u>

One of the new elements tested for the SCM included battery-power operation. Previous versions of the system were powered from conventional wall outlet power (110 VAC) or using gasoline-powered portable generators. Evaluating whether the system could be operated using battery power was necessary because the baseline technology (FCM) was battery-operated. Additionally, facilities at the Hanford Site that are undergoing D&D have often had normal power services removed, making battery or generator power a key implementation consideration.

<u>Capability for Automatic Alignment and Calibration</u>

The PSPC technology is capable of automatic electronic alignment and continuous calibration using internal collimated check sources. Because the PSPC acts as multiple small counters, collimated alpha sources can be placed inside of the detector volume to provide fixed peaks in both the position and energy spectra. Process software continuously looks for these alpha peaks located at the physical ends of each detector and compares the peak heights (counts per second), along with the energy spectra obtained from the peak locations, to continuously adjust, source check, and calibrate the system.

<u>Compatibility with Other Hanford Site Technologies</u>

The SCM and SIMS combination is compatible with several systems that have been tested by BHI craftworkers and are undergoing extended evaluation. One such system is STREAM© (System for Tracking Remediation, Exposure, Activities, and Materials), a visually oriented database for saving and displaying information about the decommissioning project. Discussions were held with STREAM staff who indicated that any of the formats for SIMS output data can be used by STREAM, including the various figures and reports.

Another system that can be integrated with SRA's SCM and SIMS in two different ways is the Laser-Assisted Ranging and Data System (LARADS), which was demonstrated for the LSTD for mapping contaminated surfaces. With LARADS, an auto-tracking civil surveyor's total station is used to determine the location of a target prism placed on a survey instrument. Computer logging of the location and instrument reading permits data collection in electronic form. The SCM uses a low-cost wheel encoder to measure the location of the SCM along a survey strip. Conversion to use a civil engineering total station would require a modest change in the data-logging software, should logging of the data in a similar fashion be desired. The two systems are compatible in that the SIMS data management system is capable of processing data from the LARADS.

In general, the SCM/SIMS can generate output files in delimited ASCII-coded format for data and image files for video information. Therefore, any document management system that can handle a large amount of data in these formats can be adopted and interfaced with the SCM/SIMS system.

Skills/Training

Training of field technicians is minimal (less than one day), provided that the trainees are proficient in standard radiological survey practices. The setup and use of the system requires technician training. In addition, PC-based knowledge is necessary to produce enhanced-quality floor maps.

Operational Concerns

Due to physical size and geometry of the SCM, near-corner and wall measurements could not be obtained in one pass; a secondary pass perpendicular to the first was needed. Near-corner and wall measurements may also be accomplished by using a detector with a right angle. The technology should not be used in high radiation areas since this will affect the sensitivity of the instrumentation.

Table 2. Summary of variable conditions

Variable	Innovative Technology	Baseline Technology
Scope of Work		
Quantity and type of material surveyed in test areas	A total of 2,300 m^2 (25,000 ft^2) of concrete floor area was surveyed, of which 1,500 m^2 (16,269 ft^2) had data for cost analysis, including 54 rooms at various elevations.	26 m^2 (280 ft^2) of concrete floor was surveyed. For cost comparisons the same area as for the innovative technology was assumed.
Location of test area	C Reactor Building, front face floor area.	C Reactor Building, front face floor area.
Nature of survey work	Floor areas were characterized for beta/gamma and alpha contamination at the C Reactor and at the F Reactor Area. The required alpha detector detection limit was 100 dpm.	26 m^2 (280 ft^2) of floor area was characterized for beta/gamma and alpha contamination at C Reactor. The required alpha detector detection limit was 100 dpm.
Work Environment		
Level of floor contamination in the test areas	The demonstration area is not a radiation area. Any contamination that might be present is fixed.	The demonstration area is not a radiation area. Any contamination that might be present is fixed.
Level of floor obstructions in test areas	For beta/gamma: • Obstructed 151 m^2 (549 ft^2) • Normal 803 m^2 (8,645 ft^2) • Unobstructed 487 m^2 (5,240 ft^2) For alpha: • Normal 217 m^2 (2,335 ft^2)	Unobstructed.
Work Performance		
Technology acquisition means	Two scenarios cost estimated: • Equipment is assumed to be purchased by the Hanford Site for use by site RCTs, as in the demonstration. • Rented equipment, with vendor technicians	Equipment is assumed to be site owned for use by Site RCTs.
Compliance requirements	Compliance is necessary to meet the requirements for a release survey: • For beta/gamma 5,000 dpm/100 cm^2 averaged over 1 m^2 • For alpha, 100 dpm/100 cm^2 averaged over 1 m^2	Compliance is necessary to meet the requirements for a release survey.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

• Technology Applicability

- This technology can be used to provide well-documented release or characterization surveys of contaminated or potentially contaminated floors, buildings, and structures before and after D&D.

- The system may be used on both interior and exterior surfaces. The system is particularly suited to smooth surfaces since a protective window is needed on rough surfaces, which can result in reduced detector sensitivity.

- The precision and quality of the survey documents resulting from use of this technology support regulatory reviews.

- The system can be configured with large detectors on mobile platforms for surveying large wall, ceiling, and floor surfaces.

- The innovative software and cart construction are flexible for using any detector (e.g., sodium iodide for cesium-137 gamma or FIDLER for transuranic gamma), making it adaptable to surveying a variety of surfaces such as walls, ceilings, or flat articles (e.g., laundry, sheetrock, and plywood).

• Competing Technologies

- The sensitivity of the PSPC technology provides a method for determining whether contamination levels are below action levels, which is required for DOE to certify facilities for release. The result of this feature allows the technology to compete with the cost of removing the soil, brick or concrete walls, floors, and ceilings that could not otherwise be certified for release. Because the technology is efficient at surveying large surface areas, it is useful for projects with short schedules and where reducing remediation costs is an objective.

- Alternative methods to this technology are conventional hand-held instruments, conventional floor monitors (such as baseline), or the indoor ultrasonic ranging and data system (USRADS). Generation of reports from the demonstrated system requires less effort than with competing technologies and the resulting product is more complete, accurate, and timely.

- The SCM also competes with segmented detectors, but these systems have a lower survey speed and are more difficult to transition between alpha and beta/gamma detection modes. Also, calibration of the segmented detector system is more difficult.

• Patents/Commercialization/Sponsors

- The PSPC technology is commercially available for beta, gamma, alpha, and transuranic surveys of surfaces.

- Two patents have been granted to SRA for this technology, as well as two NUREG reports. Patents and NUREG reports are listed in Appendix A.

- The PSPC technology is past the demonstration stage. BHI radiological contamination control engineers have used the technology for radiological contamination surveys in the 108-F Reactor facilities.

Technology Status

To date, the demonstration at Hanford's C Reactor ISS Project was the first to include both beta/gamma and alpha monitoring at a DOE facility. However, following additional applications have also been performed using this technology:

- ***CP-5 Reactor's Argonne National Laboratory*** - In December 1996, the SCM/SIMS was used to survey a truck dock area for beta/gamma radiation to determine the level of cesium-137 contamination caused by a spill in the area, December 96.
- ***EPA, Montgomery, Alabama*** - Beta and alpha surveys were performed in September 1995 to provide a better understanding of contamination and to help resolve disputes with the remediation contractor.
- ***ETI*** - Several demonstrations of beta surveys, alpha surveys, and GM surveys were performed for a multiple-technology deployment site in August 1994, February 1996, August 1996, November 1996, and February and May 1997.
- ***Oak Ridge K-25*** - Beta surveys were performed on a wide range of indoor and outdoor sites in August 1995.
- ***Oak Ridge Institute of Science and Education (ORISE)*** - Beta surveys, alpha surveys, NaI surveys, GM surveys, and FIDLER (a thin sodium iodide detector with a large surface area) surveys were performed, primarily for standardization measurements against accepted survey instrumentation and methodologies used for formerly authorized sites and NRC license terminations. As a result of these surveys, ORISE will be using the SCM/SIMS to assist with independent verification measurements for both DOE and NRC. The surveys took place in April 1995, August 1995, December 1996, and February 1997.
- ***Oak Ridge Y-12*** - In September 1995, beta surveys were performed with an emphasis on large outdoor areas and the need to establish the mobility of historic contamination.

Key Results of Demonstrations

This PSPC system was successfully demonstrated at the C Reactor ISS Project with the following key results:

- Accurately correlated contamination levels to specific locations as evidenced by hot spot verification using the baseline
- Acquired and stored continuous radiological data in database format
- Provided clear, concise, comprehensible graphics of survey data
- Demonstrated flexibility to use a variety of detectors (e.g., sodium iodide for cesium-137 gamma or FIDLER for transuranic gamma) because of the cart construction and compatibility with the existing software
- Costs using the innovative technology were less than baseline costs.

SECTION 5

COST

• Introduction/Methodology

This cost analysis compares the innovative SRA position-sensitive SCM technology, used to survey for beta/gamma floor contamination and also alpha floor contamination, to baseline technologies used for radiological surveying at the Hanford Site. The innovative technology was deployed for use in surveying 2,300 m^2 (25,000 ft^2) of concrete floor surface in various rooms and areas at the C Reactors building and at the F Reactor Area. The innovative technology costs are based on the observed durations and production rates observed for 1,500 m^2 (16,269 ft^2) of that 2,300 m^2 (25,000 ft^2) (not all the work was recorded).

Costs for the beta/gamma baseline technology are derived from the production rates observed during the demonstration on 26 m^2 (280 ft^2) of concrete floor located at the front face work area of the C Reactor. The alpha baseline was not demonstrated or observed. Production rates for the alpha baseline were generated based on the past experience and judgement of the RCTs who were involved with radiological surveys at the C Reactor building and the F Reactor area. The production rates for the beta/gamma and for the alpha baselines were used to compute baseline costs by assuming the same quantity of survey work as the quantity for the innovative technology. The innovative SRA technology saves 57% over the baseline for the site purchase option and 13% for the rental option.

The cost analysis considers two options for the innovative technology: 1) purchase and use by site labor; and 2) rental and use by site labor. The analysis includes mobilization, survey activities, demobilization, and data processing and reporting. The mobilization includes set up of the equipment at the C Reactor, and the innovative technology adds the cost for training on use of the equipment and its shipment (shipping for the equipment rental option only). The survey activity costs include survey of 54 rooms and areas at the C Reactor building and at the F Reactor area of which 1,300 m^2 (13,934 ft^2) areas were surveyed for beta. The baseline assumes survey of the entire 1,300 m^2 (13,934 ft^2) using a floor contamination monitor, and the hot spots identified are then delineated using a hand-held meter. The alpha survey required a level of detection that could not be achieved by the floor contamination monitor that is currently owned. Current planning for alpha surveys at the F Reactor (these plans form the basis of the baseline estimate for the alpha survey costs) rely on purchasing of a floor monitor that is suitable for the required detection limit and linking the monitor to the LARADS (to record the position and radiologic data). Demobilization includes decontamination of the equipment and shipping for the innovative technology rental option.

• Cost Analysis

The innovative technology is available from the vendor in the forms and at the rates indicated in Table 3:

The unit costs and production rates shown in Table 4 do not include mobilization, other losses associated with non-productive portions of the work (such as suit-up, breaks, etc.), or stopping to delineate hot spots (in the case of the baseline technology). The intention of Table 4 is to show unit costs at their elemental level that are free of site-specific factors (such as work culture or work environment influences on productivity loss factors). Consequently, the unit cost for the"Beta Gamma Survey - Unobstructed Floor" is the unit cost shown for the Beta Gamma Survey - Unobstructed line item of Table C-1 and Table C-1.1 of Appendix C. Tables C-1 and C-2 can be used to compute site-specific costs by inserting quantities and adjusting the units for conditions of an individual D&D job.

Table 3. Innovative technology acquisition costs

Acquisition Option	Item	Cost [1]
Equipment Purchase	C SRA Model 1 Surface Contamination Monitor Includes: - PSPC electronics cart - 2-ft and 4-ft PSPC detectors - 486 PC - wheel encoder - DC gear motor and controller - 3 cylinders of P10 gas C SIMS computer software	$50,000.00 $10,000.00 **Total System: $60,000.00**
Vendor Provided Service	C Vendor technician (daily rate)[2] C Per diem (lodging, meals, and trans.)[3] C SRA equipment (daily rate)	$520.00 $170.00 $613.00 **Total Daily Rate:$1,303.00**
Equipment Rental	C SRA monthly rental rate for the SRA SCM Model 1P and SIMS software	**$12,250.00** (or $76.56/hr based on (4) 40-hour work weeks per month)

(1) All costs are based on 1997 pricing data made available by Shonka Research Associates, Inc.
(2) Based on $65.00/hr for a Shonka Research Associates technician and an 8-hour work day.
(3) Based on per diem allowance for work at the Hanford Site.

Observed unit costs and production rates for principal components of the demonstrations for both the innovative and baseline technologies are presented in Table 4 below:

Table 4. Summary of unit costs and production rates

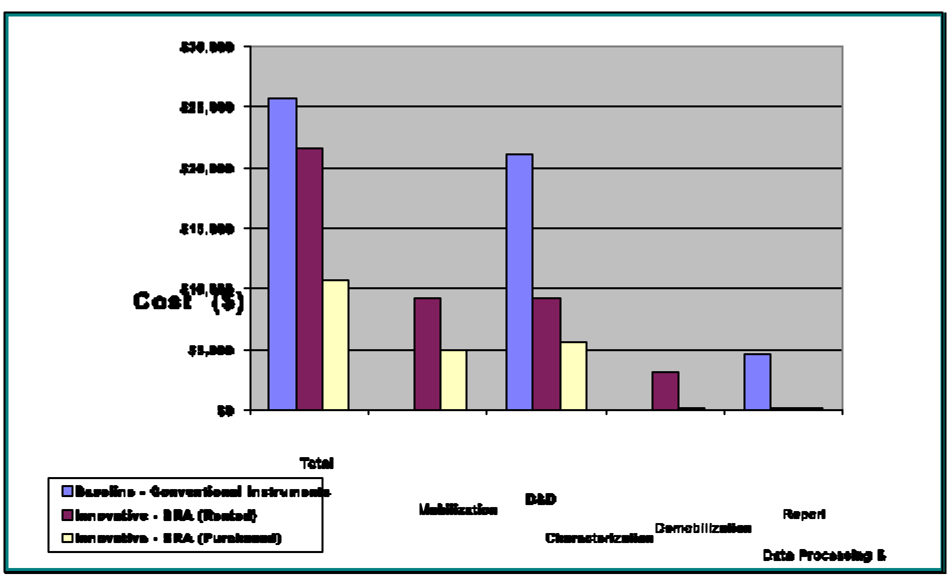
Innovative Technology				Baseline Technologies		
Cost Element	Production Rate	Unit Cost		Cost Element	Production Rate	Unit Cost
		Purchase	Rent			
Beta/Gamma Survey				**Beta/Gamma Survey**		
Unobstructed Floor	446 m^2/hr (4,800 ft^2/hr)	\$0.22/m^2 (\$0.02/ft^2)	\$0.32/m^2 (\$0.03/ft^2)	Unobstructed Floor	Same as for Normal Floor	\$3.67/m^2 (\$0.34/ft^2)
Normal Floor	117 m^2/hr (1,260 ft^2/hr)	\$0.65/m^2 (\$0.06/ft^2)	\$1.10/m^2 (\$0.10/ft^2)	Normal Floor	15.61 m^2/hr (168 ft^2/hr)	\$3.67/m^2 (\$0.34/ft^2)
Obstructed Floor	61 m^2/hr	\$1.20/m^2	\$2.00/m^2	Obstructed Floor	Same as for Normal Floor	\$3.67/m^2 (\$0.34/ft^2)
Alpha Survey				**Alpha Survey**		
Normal Floor	100 m^2/hr (1080 ft^2/hr)	\$0.75/m^2 (\$0.07/ft^2)	\$1.20/m^2 (\$0.11/ft^2)	Normal Floor	43 m^2/hr (465 ft^2/hr)	\$1.40/m^2 (\$0.13/ft^2)

Some features of the demonstration are unique and affect cost. Consequently, the specific conditions at other sites will result in different costs due to the variation in these features. The following site-specific conditions for this demonstration are judged to be the principal factors affecting costs:

- Floor area surveyed divided into 54 rooms, which included surveys on different floor levels.
- Detection limit for alpha contamination is 100 dpm (for the baseline this prevented using the floor monitor used for the beta/gamma survey).
- The quantity of hot spots requiring delineation with a hand-held meter is assumed to be 201 locations and 56 m^2 (603 ft^2) for the beta/gamma baseline technology.
- Beta/gamma surveys included 4% of the total area being relatively obstructed areas, 58% being normal floor areas, 38% being relatively unobstructed floor areas, and the alpha surveys were conducted on relatively normal areas.
- The lost time for issue resolution, coordination with other ongoing work, project/safety meetings was approximately 3.5 times the duration of the actual work.

• Cost Conclusions

Figure 8 is a comparison of costs for both the innovative and baseline technologies. The innovative technology has been separated into options addressing different means of equipment acquisition. One option is based on renting the innovative technology equipment from the vendor and was the actual method of acquisition used for deployment of the innovative technology at the C Reactor and F Reactor areas. The other option is based on acquiring the innovative technology from the vendor by direct purchase. See Table 3 for vendor-supplied pricing data for both options. Refer to Appendix C of this report for detailed cost tables on each of the options.



Note: Chart created using Excel 97.

The innovative technology has higher productivity rates than the baseline technology (4 to 28 times faster for the beta/gamma survey and 2 times faster for alpha), but equipment costs are 10 times more expensive for the rental option and 3 times more expensive for the purchase option. This higher equipment cost with the added costs for shipping (for the rental option) and training (considered to be necessary for proper operation and data interpretation) result in the purchase option for the innovative being 57% less expensive and the rental option being 13% less expensive than the baseline.

The innovative costs include training costs (vendor travel to the site and training of site RCTs), which would not apply once the site personnel are adequately trained. If the training costs are excluded from the cost analysis, the innovative purchase option saves 73% and the rent option saves 33% over the baseline.

The major cost drivers are production rate, training, shipping, moving from room to room, non-productive time, and data processing. The production rates for the innovative technology were observed. The production rates for the baseline are from observed work for 26 m^2 (280 ft^2). The baseline costs for beta/gamma surveys are extrapolated to the 1,500 m^2 (16,269 ft^2) for this analysis, while the alpha survey costs are based on judgement and are not as certain as costs based on directly observed production rates. The costs for the innovative technology are very sensitive to the degree of obstruction of the floor area (production rates were observed to vary from 705 m^2/hr [126 ft^2/min] to 2.4 m^2/hr [0.4 ft^2/min] depending upon the degree of obstruction and size of room. It is assumed that the alpha baseline is unaffected by these factors, because the meter is moved by hand in increments over the floor area. The baseline costs for the beta/gamma surveys are sensitive to the quantity of delineation of hot spots using a hand-held meter. Since the time required for this hot spot delineation work was not directly observed, those costs were extrapolated based on quantities determined from the survey results from the innovative technology (amount of area identified as exceeding the release limits). The time required to move from one room to the next varies to a large degree, with moving to adjacent rooms requiring less than 1 minute and moving to different floors requiring more than 1 hour in some cases. The baseline costs were assumed to be the same as the innovative technology for moving the monitor. The time lost from performing surveys due to resolving issues, waiting on other work in progress in the survey areas, meetings, etc., was a large factor in the observed innovative costs. This analysis assumes 5 hours lost for each day worked for both the innovative and the baseline technologies. This item impacts the baseline costs five times more than the innovative cost (because the slower production rate for the baseline results in more days of work) and is the single largest line item cost in the costs for the innovative and the baseline. Significant variations in this item could easily change the cost conclusions. This is a site-specific factor that varies over a wide range.

The innovative technology can provide substantial savings, particularly for circumstances where the area is unobstructed and the data reporting requirements are intensive. If the work areas are unobstructed and many hot spots require delineation, then the savings could be much greater. The tables in Appendix C allow readers to make an estimate for their job by inserting their site's quantities into the cost estimate tables.

SECTION 6

REGULATORY/POLICY ISSUES

• Regulatory Considerations

- The SCM/SIMS system is an investigation tool for characterizing contaminated surfaces; therefore, no special regulatory permits are required for its use.
- The detection level of the SCM/SIMS system meets the requirements of 10 CFR Parts 20, 835, and proposed Part 834, which make this system appropriate for free-release surveys.
- Although the demonstration took place at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, no CERCLA requirements apply to the surveys conducted.

• Safety, Risk, Benefits, and Community Reaction

Worker Safety

- Normal radiation protection worker safety procedures used at the facility would apply.
- Technology users should implement contamination control practices.
- Since the PSPC uses P-10 gas supplied by an on-board, small pressurized cylinder, precautions for airborne contamination should be considered when the instrument is used in areas with loose surface contamination.
- Normal electrical grounding requirements should be met when using 110-VAC power.
- Normal precautions with lead-acid storage batteries apply.

Community Safety

- There is no adverse impact on community safety.

• Environmental Impact

- It is not anticipated that implementation of this innovative technology would present any adverse impacts to the environment.

• Socioeconomic Impacts and Community Perception

- No socioeconomic impacts would be expected in association with use of this technology.
- Public perception of this technology should be positive as it enhances the quality of information available upon which regulators and the public base cleanup decisions.

SECTION 7

LESSONS LEARNED

• Implementation Considerations

- To effectively perform a survey, objects and obstacles should be cleared from the floor area or minimized to the extent possible. Even though the system can be maneuvered around the obstacles by using a smaller detector size, the main benefit of using the larger length detectors is that overall survey time is reduced.
- Additional caution is required when the system is operated over rough surfaces (e.g., gravels or outdoor surfaces), particularly with alpha measurements. In these situations, the PSPC window could easily be damaged.
- The system demonstrated at the C Reactor ISS Project is well-suited for large open areas.
- The system is not suitable for high-contamination/radiation areas because of its sensitivity and size. The best use is for environmental and release surveys.
- Considering the sensitivity of the system, alpha detections may need confirmatory measurements with a hand-held detector (e.g., PAM).

• Technology Limitations/Needs for Future Development

- Due to physical size and geometry of the PSPC, near-corner and wall measurements could not be obtained in one pass; a secondary pass perpendicular to the first was needed. Near-corner and wall measurements may also be accomplished by changing to a detector with a right angle.
- At the present time, there is no need to modify the system demonstrated at the Hanford Site C Reactor.

• Technology Selection Considerations

- The technology is suitable for DOE nuclear facility D&D sites or any other sites requiring surface characterization. It is particularly useful for property transfer or site release where DOE desires to turn the site over to the private sector without restrictions.
- The technology is useful for site characterization in support of D&D engineering design, as well as during and post-D&D activities.
- The technology has the ability to capture both alpha and beta/gamma information with one detector for all surfaces surveyed. This detector is equivalent to an assembly of many baseline detectors, providing more accuracy and completeness at higher scanning speeds than the baseline; however, the alpha scanning speed is still slower than the beta/gamma scanning speed for this technology.
- Reports can be generated automatically that provide a clear, concise, and understandable representation of the exact locations and concentrations of contamination. The data can be used for job planning and decontamination activities, as well as input to dose assessment software packages. Obtaining the data is quicker than the baseline, and the resulting data set is more accurate, complete, and reproducible than the baseline technology.
- All information acquired with the system is scientifically derived and is left subject to subjective observations. The data are electronically logged and are not recorded manually, reducing the propensity for error.

APPENDIX A

REFERENCES

• Related Publications

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Experiments

C Experiment 97-02-004, Calibration of an ESP-II energy window for measuring Cs-137 with 3x3 NaI detector

C Experiment 97-03-001, Calibration of the PSPC for Sr/Y-90

C Experiment 97-03-002, Calibration of the PSPC for Tl-204

C Experiment 97-03-003, Measurement of the alpha plateau for SCM

C Experiment 97-03-004, Calibration of the PSPC for Tc-99

C Experiment 97-03-005, Calibration of the PSPC for Th-230

C Experiment 97-03-006, Determination of calibration parameters for LND 7807 GM tube when coupled to ESP-II

C Experiment 97-03-007, Determination of calibration parameters for 3x3 NaI crystal installed in collimation assembly

C Experiment 97-03-008, Calibration of the PSPC for Cs-137

C Experiment 97-03-009, Calibration of the PSPC for Th-232

C Experiment 97-03-010, Determination of calibration parameters for Bicron G5 FIDLER

C Experiment 97-03-011, Post survey confirmation of SCM calibration in support of operations at Hanford

C Experiment 97-03-012, Characterization of source response near the ends of the detector

APPENDIX B

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
BHI	Bechtel Hanford, Inc.
CFR	*Code of Federal Regulations*
cpm	counts per minute
D&D	decontamination and decommissioning
DC	direct current
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EPA	U.S. Environmental Protection Agency
ETI	Eastern Technology, Inc.
FIDLER	field instrumentation detection for low energy radiation
FCM	floor contamination monitor
GIS	geographic information system(s)
GM	Geiger-Mueller
HTRW	Hazardous, Toxic, Radioactive Waste
ISS	Interim Safe Storage (project)
LARADS	Laser-Assisted Ranging and Data System
LSTD	Large-Scale Technology Demonstration (project)
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute of Science and Education
PAM	portable alpha meter
PC	personal computer
PSPC	position-sensitive proportional counter
RA	remedial action
RCT	Radiological Control Technician
RL	U.S. Department of Energy, Richland Operations Office
SCM	surface contamination monitor
SF	square foot (feet)
SIMS	Survey Information Management System
SRA	Shonka Research Associates, Inc.
STREAM	System for Tracking Remediation, Exposure, Activities,

Acronym/Abbreviation	Description
	and Materials
TC	total cost
TQ	total quantity
UC	unit cost
USACE	U.S. Army Corps of Engineers
VAC	volts, alternating current
WBS	work breakdown structure

APPENDIX C

TECHNOLOGY COST COMPARISON

• Introduction

The analysis in this appendix strives to develop realistic estimates to compare costs between the innovative SRA position-sensitive surface contamination monitor and a baseline technology consisting of conventional methodologies and equipment currently used for radiological surveying of floor surfaces at the Hanford Site.

The cost of performing and documenting a floor radiation survey with conventional radiation monitoring equipment is considerable and depends on the complexity and size of the room or area to be surveyed, the level and type of contamination in the room or area, and the analysis requirements imposed on the survey end results, such as whether the survey is being conducted for characterization or for free release.

The selected basic activities being analyzed come from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS), USACE, 1996. The HTRW RA WBS, developed by an interagency group, was used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for the individual site. The overhead and general and administrative (G&A) markup costs for the site contractor managing the demonstration are omitted from this analysis. Overhead and G&A 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 Hanford Site.

The following assumptions were used as the basis of the innovative cost analysis:

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.
- The procurement cost of 7.5% was applied to applied to all purchased equipment costs to account for costs of administering the purchase (this cost is included in the hourly rate).
- The equipment hourly rates for the innovative and baseline equipment (except for LARADS, which has a standard site rate), represent the Government's ownership, and are based on general guidance contained in Office of Management and Budget (OMB) circular No. A-94 for Cost Effectiveness Analysis.
- The standard labor rates established by the Hanford Site for estimating D&D work are used in this analysis for the portions of the work performed by local crafts.
- The analysis uses an eight hour work day.
- Additionally, an anticipated life of 10 years and an average usage of 500 hr/year are used in the calculation of hourly rate for the innovative and baseline equipment.

MOBILIZATION (WBS 331.01)

Ship Equipment from Marietta, GA to Hanford Site: This cost element is based on the actual cost to ship the equipment via UPS ground carrier. The cost item was submitted by Shonka Research Associates and is measured as one each. This item is not included in the cost calculation for the purchase option for the innovative. Costs for shipping equipment under this option are included in the purchase price of the equipment, which is then used to establish an amortized hourly rate for the equipment. (See the Computation of Hourly Rate for Government ownership calculations in the cost backup data.)

Set Up, Check, & Calibrate Equipment for Use: This cost element provides for assembling the equipment components and running self-diagnostics and source-checks on the equipment before it is used. The activity cost is measured as one each for the entire deployment.

Vendor Supplied On-Site Training: This cost item accounts for two full days of on-site hands-on training on the equipment given by a vendor technical representative to a Hanford Site RCT. The activity is measured as a one each cost.

Vendor Travel & Per Diem: This cost element is based on allowable rates for government travel, lodging, meals, and local transportation (car rental) for the vendor technician. It is applied to the time the technician needed to spend on the site.

D&D CHARACTERIZATION (WBS 331.17)

Survey for Beta/Gamma: For the innovative technology, this cost element includes setting up the grid patten and strip path the monitor will follow, running the device to conduct the beta/gamma survey, automatically logging data (measurements), adjusting the path the device follows as required, and ensuring that the device's encoder wheel stays on the strips for data logging purposes. Cost also includes delays for moving unfixed floor obstructions, working around fixed floor obstructions, moving the equipment from one room or area to another, partially disassembling the equipment to move it up stairs, and dealing with abnormal equipment readings or software glitches. The activity uses the observed survey productivity rate to calculate costs on a per square foot of area surveyed basis. Production rates used in the analysis are based on the observed production rates for the innovative and on extrapolations for the baseline. The baseline uses an NNC floor monitor to survey the entire surface. This survey production rate was observed for 280 ft^2. Any hot spots identified by the floor monitor are delineated using the Eberline HP-360. The production rate for the delineation is based on the scan rate for the instrument with added costs for assumed durations for painting the location, adding the location to a drawing, and moving the floor monitor out of the way of the delineation work. The quantity of area requiring delineation is based on the innovative technology survey results (areas that were identified by the survey to exceed the release limit were assumed to be the area delineated in a baseline survey).

Alpha Survey: This activity includes setting up the grid pattern, detaching and reattaching the probe as needed to move from room to room, etc., for the innovative alternative. The production rate used in the analysis is based on the average production rate observed. The baseline survey for alpha contamination consists of moving a Bicron FLP-3A across the entire surface of the floor. The production rate is based on the scan rate for that equipment (not based on observed). The equipment costs for the baseline include costs for LARADS to record the radiologic data and the position.

Move from Room to Room: The time required for the innovative technology equipment to move from room to room for 54 rooms was observed. That duration is assumed to be the same for the baseline case.

Set Up LARADS: The LARADS equipment must be repositioned and the software registration reset for the room geometry for each room surveyed for the baseline alpha surveys. The duration used is based on previously observed demonstration work for this technology.

Move and Set Up at F Reactor: The deployment of the innovative technology began at the C Reactor and eventually required a move to the F Reactor. The effort to move is included in this item and is assumed to be the same for the innovative and the baseline.

Non Productive Time: The overall duration of the innovative technology deployment was observed to include substantial amounts of time with no survey production and amounted to 64% of the work day on average (for an 8-hour work day this results in 5 hours of lost time per day). The specific nature of the down time was not recorded, but includes time to resolve work methodology issues, radiologic entry issues, schedule conflicts with other work in the same area, donning and doffing protective clothing, etc. The observed “down time” 5 hours per day lost time is assumed to be the same for both innovative cases as well as for the baseline.

DEMOBILIZATION (WBS 331.21)

Exit Survey Equipment: This cost element provides for radiological survey of the equipment by a site RCT to ensure that contaminated equipment does not leave the site and includes costs for decontamination. Costs include equipment stand-by time plus RCT labor.

Disassemble & Package the Device for Shipping: For the innovative technology, this cost element includes breaking apart the equipment and repacking it for shipment back to the vendor. It is measured as a one each activity.

Ship Equipment Back to Marietta, GA: This element is based on the actual cost to ship the innovative technology equipment via UPS ground carrier. As with the item on shipping the equipment to the Hanford Site, it is included only in the rental option.

D&D DATA ASSEMBLY & DOCUMENTATION (WBS 331.17)

Data Transfer: For the innovative technology, this cost element includes taking data logged during the survey and utilizing the SIMS graphical interface program to create computer files that are then manipulated in Windows© software. Observed duration were used for the innovative technology costs.

Final Report Compilation: For the innovative technology, the transferred data is converted to graphical reports within Windows© via software called VISUSPECT©. The activity cost is measured as one each for the entire deployment.

The details of the cost analysis for the two innovative options and the baseline are summarized in Tables C-1, C-1.1, and C-2.

Table C-1. Cost Summary - Innovative Technology (Rental Option)

Work Breakdown Structure (WBS)	Unit Cost (UC)						Total Quantity (TQ)	Unit of Measure	Total Cost (TC)	Crew	Comments
	Labor		Equipment		Other	Total UC					
	HRS	Rate	HRS	Rate							
Mobilization (WBS 331.01)								**Subtotal**	**$9,161**		
Ship Equipment			32	$76.56	$605	$3054.92	1	each	$3,055		Via UPS ground carrier from Marietta, Ga. to Hanford (includes equipment standby time during shipping)
Set Up, Check, & Calibrate Equipment for Use	8	$114.95	8	$76.56		$1,532.08	1	each	$1,532	1 Vendor 1 RCT	
Vendor Supplied On-Site Training	16	$114.95	16	$76.56		$3,064.16	1	each	$3,064	same crew	
Vendor Travel & Per Diem					$1,510	$1,510	1	each	$1,510	1 Vendor	Assumes $1,000 for round trip air fare and $170/day for per diem for 3 days
D&D CHARACTERIZATION (WBS 331.17)								**Subtotal**	**$9,197**		
Beta Survey - Obstructed	0.0015	$49.95	0.0015	$76.56		$0.19	549	square feet (Ft²)	$104	1 RCT	Production rate 11 ft²/minute (min)
Beta survey - Normal	0.0008	$49.95	0.0008	$76.56		0.10	8,145	Ft²	$814	same	Production rate 21 ft²/min
Beta survey - Unobstructed	0.0002	$49.95	0.0002	$76.56		0.03	5,240	Ft²	$133	same	Production rate 80 ft²/min
Change Setup for Alpha	0.22	$49.95	0.22	$76.56		$27.83	1	each	$28	same	
Alpha Survey - Normal	0.0009	$49.95	0.0009	$76.56		$0.11	2,335	Ft²	$266	same	Production rate 18 ft²/min
Move From Room to Room	13.15	$49.95	13.15	$76.56		$1,663	1	Lump Sum	$1,664	same	Includes travel to adjacent rooms as well as to different floors
Move and Set Up at F	4	$49.95	4	$76.56		$506.04	1	each	$506	same	Move from C Reactor to F Reactor and set up
Non Productive Time	44.92	$49.95	44.92	$76.56		$5,683	1	Lump Sum	$5,683	same	Includes don & doff protective clothing, issue interruptions, & breaks
DEMOBILIZATION (WBS 331.21)								**Subtotal**	**$3,093**		
Exit Survey Equipment	0.5	$49.95	0.5	$76.56		$63.26	1	each	$63	1 RCT	Equipment standby time included
Disassemble & Package the SRA Equipment for Shipping	3	$49.95	3	$76.56		$379.53	1	each	$380	same	
Ship Equipment	4	$49.95	32	$76.56		$2,649.72	1	each	$2,650	same	Return to Marietta, GA.
Characterization Data Assembly & Documentation (WBS 331.17)								**Subtotal**	**$797**		
Data Transfer	0.02	$49.95	0.02	$76.56		$2.11	54	rooms	$114	1 RCT	Stitch time (average per room)
final Report Compilation	0.1	$49.95	0.1	$76.56		$12.65	54	rooms	$683	same	
								TOTAL:	**$22,248**		

Table C-1.1. Cost Summary - Innovative Technology (Purchase Option)

Work Breakdown Structure (WBS)	Unit Cost (UC)						Total Quantity (TQ)	Unit of Measure	Total Cost (TC)	Crew	Comments
	Labor		Equipment		Other	Total UC					
	HRS	Rate	HRS	Rate							
Mobilization (WBS 331.01)								**Subtotal**	**$4,899**		
Set Up, Check, & Calibrate Equipment for Use	8	$114.95	8	$26.26		$1,129.70	1	each	$1,130	1 Vendor 1 RCT	
Vendor Supplied On-Site Training	16	$114.95	16	$26.26		$2,259.41	1	each	$2,259	same crew	
Vendor Travel & Per Diem					$1,510	$1,510	1	each	$1,510	1 Vendor	Assumes $1,000 for round trip air fare and $170/day for per diem for 3 days
D&D CHARACTERIZATION (WBS 331.17)								**Subtotal**	**$5,541**		
Beta Survey - Obstructed	0.0015	$49.95	0.0015	$26.26		$0.11	549	square feet (Ft²)	$63	1 RCT	Production rate 11 ft²/min
Beta survey - Normal	0.0008	$49.95	0.0008	$26.26		0.06	8,145	Ft²	$490	same	Production rate 21 ft²/min
Beta survey - Unobstructed	0.0002	$49.95	0.0002	$26.26		0.02	5,240	Ft²	$80	same	Production rate 80 ft²/min
Change Setup for Alpha	0.22	$49.95	0.22	$26.26		$16.77	1	each	$17	same	
Alpha Survey - Normal	0.0009	$49.95	0.0009	$26.26		$0.07	2,335	Ft²	$160	same	Production rate 18 ft²/min
Move From Room to Room	13.15	$49.95	13.15	$26.26		$1,002	1	Lump Sum	$1,002	same	Includes travel to adjacent rooms as well as to different floors
Move and Set Up at F	4	$49.95	4	$26.26		$304.85	1	each	$305	same	Move from C Reactor to F Reactor and set up
Non Productive Time	44.92	$49.95	44.92	$26.26		$3,424	1	Lump Sum	$3,424	same	Includes don & doff protective clothing, issue interruptions, & breaks
DEMOBILIZATION (WBS 331.21)								**Subtotal**	**$114**		
Exit Survey Equipment	0.5	$49.95	0.5	$26.26		$38.116	1	each	$38	1 RCT	Equipment standby time included
Break Down Equipment	1	$49.95	1	$26.26		$76.21	1	each	$76	same	
Characterization Data Assembly & Documentation (WBS 331.17)								**Subtotal**	**$480**		
Data Transfer	0.02	$49.95	0.02	$26.26		$1.27	54	rooms	$69	1 RCT	Stitch time (average per room)
final Report Compilation	0.1	$49.95	0.1	$26.26		$7.62	54	rooms	$412	same	
								TOTAL:	**$11,034**		

Table C-2. Cost Summary - Baseline Technology

Work Breakdown Structure (WBS)	Unit Cost (UC)						Total Quantity (TQ)	Unit of Measure	Total Cost (TC)	Crew	Comments
	Labor		Equipment								
	HRS	Rate	HRS	Rate	Other	Total UC					
Mobilization (WBS 331.01)								**Subtotal**	**$6,711**		
Set Up, Check, & Calibrate Equipment for Use	8	$114.95	8	$26.26		$1,339.81	1	each	$1,340	1 RCT, Eberline E-600, Eberline HP-360, NNC-FCM	
D&D CHARACTERIZATION (WBS 331.17)								**Subtotal**	**$21,079**		
Beta Survey Screen Entire Floor	0.006	$49.95	0.006	$7.26		$0.34	13,934	square feet (Ft²)	$4,783	same	Production rate 2.8 ft²/ minute (min)
Delineate Hot Spots *Each Location* *Scan Area*	0.033 0.0167	$49.95 $49.95	0.033 0.0167	$7.26 $7.26		$1.91 $0.96	201 603	each location Ft²	$383 $576	same same	Move floor monitor out of path, paint area, add to drawing, and replace floor monitor (scan rate 1 ft²/min)
Alpha Survey Set Up LARADS Survey Floors	0.25 0.0022	$49.95 $49.95	0.25 0.0022	$9.40 $9.40		$14.84 $0.13	54 2,335	rooms Ft²	$801 $305	1 RCT, LARADS, Eberline E-600, Bicron FLP-3A	Includes repositioning for each room and reset of coordinates (registration) Production rate 7.75 ft²/min
Move from Room to Room	13.15	$49.95	13.15	$8.33		$766.40	1	Lump Sum	$766	see comment	Assume same duration as innovative, and the equipment rate is avg, Of beta and alpha
Move and Set Up at F	4	$49.95	4	$9.40		$237.41	1	each	$237	same as alpha survey	Assume same duration as innovative
Non Productive Time	227	$49.95	227	$8.33		$13,226	1	Lump Sum	$13,226	see comment	Assume same duration as innovative, and the equipment rate is avg. Of beta and alpha
DEMOBILIZATION (WBS 331.21)								**Subtotal**	**$17**		
Exit Survey Equipment	0.25	$49.95	0.5	$16,09		$16.51	1	each	$17	1 RCT, LARADS, Eberline E-600, Bicron FLP-3A, Eberline HP-360, NNC-FCM	Equipment standby time included
Characterization Data Assembly & Documentation (WBS 331.17)								**Subtotal**	**$2,200**		
Interpret Collected Data	1	$49.95				$49.95	22	day	$1,100	1 RCT	
Create Survey Report	1	$49.95				$49.95	22	day	$1,100	same	

TOTAL: $25,658