REMOTE SYSTEMS FOR HAZARDOUS WASTE SITE REMEDIATION AND CHARACTERIZATION

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ABSTRACT

This paper describes the integrated system proposed for in-situ characterization and removal of transuranic (TRU) waste from the 618-10 and 618-11 burial grounds at the U.S. Department of Energy (DOE) Hanford site. Developed through experience with components of the system and examination of additional innovative technologies, the approach is designed for worker and environmental safety and expedited excavation rates. Components of the integrated system approach are being implemented on the three-phase demonstration project. Although the complete integrated system approach was proposed, Phase II activities only include delineation and in-situ characterization. The retrieval component is currently out of scope in Phase II due to budget limitations. Originally funded by the DOE Office of Science and Technology, the project was designed to identify and demonstrate innovative robotic and remote retrieval and characterization technologies for TRU waste that could be used on other burial grounds and landfills across the DOE complex.

This paper presents a brief description of the technologies chosen for demonstration in the integrated system, the approach for the Hanford project, and a discussion of the previous use of these technologies for high-hazard remediation projects.

INTRODUCTION

This paper describes a fully integrated system of technologies to be used to remediate burial grounds contaminated with radioactive and chemical wastes. The approach includes effective in-situ characterization, remedial design, and conventional and remote excavation techniques.

This integrated remediation system is being developed and demonstrated at the U.S. Department of Energy (DOE) Hanford site in Washington state. Originally funded by the DOE Office of Science and Technology, the Hanford 618-10 618-11 remediation project is directed at in-situ and ex-situ characterization and removal of transuranic (TRU) waste from these two burial grounds near the Columbia River. The project is structured in three phases. Phase I tasks included identification of innovative technologies potentially useful for the project, evaluation of the technologies, selection of those that made up an integrated system for remediation, and preparation of an approach and preliminary work plans to implement the project. Phase II of the project includes finalizing the work plans and demonstrating components of the integrated system at both a cold site and a selected “warm” burial ground (containing radionuclides). Although the complete integrated system approach was proposed for demonstration in Phase II, only delineation and in-situ characterization components will be demonstrated. The retrieval component is currently out of scope in Phase II due to budget limitations. Once the system has been tested during Phase II, the system will be refined to complete removal of the TRU waste from the Hanford 618-10 and 618-ll burial grounds in Phase III. If successful, the approach and integrated system could be used on additional hazardous burial grounds elsewhere in the DOE complex.

The approach for the integrated system is shown in Figure 1. Characterization and remedial design efforts are used to structure the retrieval process, prepare for and mobilize ex-situ characterization technologies, and deliver a stream of waste material that is designed to pass into site waste management activities, resulting in characterized and packaged waste material ready for disposal.

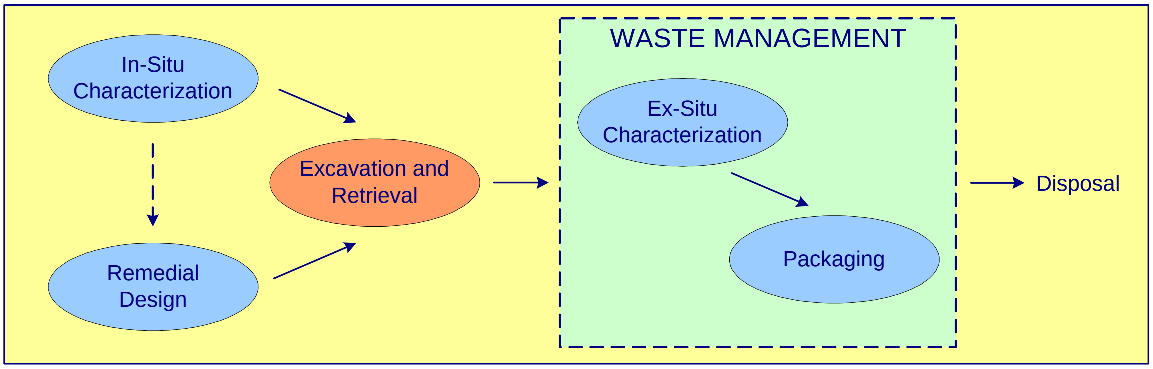

Fig. 1. Burial ground remediation process flow.

In-situ and real-time characterization data are used to design and manage the retrieval process, which then can deliver a stream of characterized waste material ready for disposal.

Remote and robotic systems increase safety and cost effectiveness in cleaning up waste sites where exposure of personnel to hazardous constituents, as well as physical hazards, is unacceptable. The remote systems developed for hazardous waste site remediation are mature, have been deployed on multiple full-scale remediation projects, and are exceptionally suited for remedial operations such as the retrieval of radioactively contaminated material from burial grounds. The use of on-board vehicle intelligence coupled with a real-time graphic operator interface creates systems that reduce operator fatigue, improve safety, and deliver advanced levels of controllability and dexterity.

This paper:

- Describes the component technologies of the integrated system including remote retrieval systems and in-situ characterization systems. The discussion includes successful use of the systems in various remediation projects.
- Discusses the approach planned for the Hanford 618-10 and 618-11 demonstration project.
- Projects the future use of these systems for difficult high-hazard projects at Hanford, the Idaho National Engineering and Environmental Laboratory (INEEL), and other DOE sites.

TECHNOLOGY DESCRIPTIONS

Remote systems have been designed to integrate robotic operation with data gathering that targets and characterizes hazardous materials. These systems can then remove the hazardous materials and package them appropriately for disposal. This approach centers on safe and effective excavation and retrieval activities, including the capability to transition from conventional to remote robotic excavation operations based on real-time characterization data. Operations as diverse as the careful retrieval of single objects to remote “hands-off” excavation have been accomplished using the systems described in this paper. When the robotic and remote systems are teamed with delineation and characterization technologies, the remediation activities can be completed safely, compliantly, and cost effectively. The following sections describe the robotic and remote system and the technologies used for characterization.

Remote Retrieval Systems

Robotic and remote excavation systems have been successfully applied to remediate burial grounds and landfills at many DOE sites, including Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL) [1,2,3,4]. The remote retrieval systems proved to be efficient and cost-effective alternatives to manual clean-up and reduced personnel hazards, remediation schedule, and overall clean-up costs. The use of on-board vehicle intelligence and real-time graphic operator interface created systems that reduced operator fatigue, improved safety, and delivered advanced levels of controllability and dexterity.

Material Disposal Area P (MDA-P) at LANL underwent clean closure under the Resource Conservation and Recovery Act (RCRA) and the New Mexico Environmental Department (NMED) regulations. MDA-P contained high explosives (HE), HE-contaminated equipment and material, barium nitrate, construction debris from Manhattan Project-era buildings, as well as trash, vehicles, empty drums, and miscellaneous containers. To mitigate the dangers of a detonation, the Hybrid rEmote Robotic Manipulation and Excavation System (HERMES), a computer-controlled, remotely operated, 25-metric ton (27.5-ton), hydraulic excavator coupled with a hydraulic manipulator, was developed and deployed to perform all initial excavation operations. The manipulator was mounted at the distal end of the excavator boom, directly behind and to the side of the bucket. This configuration allowed the excavator to remotely accomplish conventional excavation operations such as removal of overburden and debris in the MDA-P landfill. The versatility and dexterity of the robotic manipulator allowed HERMES to address any sensitive objects once they were uncovered, without placing personnel in direct contact with the hazard. The excavator was controlled from a remote operator console, which received and transmitted data to and from the system via multiple radio frequency communication channels. Multiple on-board cameras were used to facilitate remote operations including excavation and robot manipulation.

This system operated for 23 weeks with only 4 days of down time and removed a total of 24,465 cubic meters (32,000 cubic yards) of soil. The standard and robotic excavators (PC250) worked at a rate of 91.2 cubic meters (120 cubic yards) per hour and 76 cubic meters (100 cubic yards) per hour, respectively. Over 540 metric tons (600 tons) of contaminated debris and 540 kilograms (1,200 pounds) of explosives were removed from the landfill.

At SNL Technical Area II (TA-II) a robotic remote system was used for the remediation and clean closure of the Low-Level Radioactive Waste Landfill and the Classified Waste Landfill. The landfill contents were excavated using innovative remote systems attached to heavy excavation equipment; the hazardous chemical and radioactive constituents were analyzed onsite; all material and debris were segregated and staged; weapons shapes were declassified onsite; all programmatic aspects were implemented, including health and safety, National Emission Standards for Hazardous Air Pollutants (NESHAPS) air monitoring and modeling, and quality assurance. The estimated contents of the landfills were 333.3 cubic meters (11,110 cubic feet) of radioactive waste, with an activity of 2,847 curies, including irradiated and neutron-activated material (enriched uranium and debris contaminated with plutonium, uranium, cobalt-60, strontium-90, and cesium-137).

Due to the potential radiological, chemical, and high explosive contaminants associated with this project, project personnel built, demonstrated, and implemented innovative remote technologies for excavation and initial hazard screening. Using this technology, no personnel entered the landfill. In addition, robotics were implemented for staging remote handled waste using robotic manipulators to access the working face of the excavation. A cost-benefit analysis performed on the use of remote system before implementation showed a significant cost savings to the client. The use of these remote systems also provided the client with the ultimate benefit of safety by minimizing site worker exposure to radiation. Over 70,000 items were sorted using the camera on the robot to distinguish items that could immediately be disposed of versus those that required additional handling.

At Ft. McClellan in Anniston, Alabama, 32 test trenches were excavated during a trench study. A tele-robotic excavator and control trailer were deployed 2,576 kilometers (1,600 miles) to the project location. Work began within 48 hours of arrival as a result of the portable generators and the modular nature of the system. Trenches were remotely excavated in areas containing a variety of potential chemical agents. The excavated trenches were approximately 15 meters (50 feet) long and 3 meters (10 feet) deep. Excavation operations for the U.S. Department of Defense (DOD) client lasted for eight weeks with no down time and no accidents.

In-Situ Characterization Systems

The technologies used for delineation and in-situ characterization have been used successfully at numerous DOE and DOD hazardous material sites. This section summarizes the use of the following technologies to delineate and characterize waste in the subsurface:

- Geophysical survey coupled with global positioning system (GPS)
- Large-area survey monitor (LASM) coupled with GPS
- RadScan™ 800 4Pi Remote Gamma Imaging System

- Xenon isotope soil gas sampling (using cone penetrometer [CPT])
- Neutron activation with copper detectors (using CPT)
- Borehole neutron probe with helium-3 (using CPT)
- Helium isotope soil gas sampling (using CPT)
- Borehole gamma probe for radioactive material detection (using CPT)
- Volatile organics soil gas sampling (active/passive)

Cone penetrometers

The CPT is a fully mature direct-push technology for minimally invasive subsurface investigations. Deployment of soil-gas sampling for helium and xenon isotopes depends on the ability to sample gases from depths up to 12 meters (40 feet) below ground surface. Neutron detection systems must be accurately placed within approximately 0.5 meter (1.6 feet) of the source material. CPT has been used extensively at Hanford and at other sites.

Geophysical surveys

Geophysicists have performed magnetic and electromagnetic surveys for DOE and DOD clients for the past 18 years. Their experience in performing and managing large-scale geophysical programs at DOE sites includes the Rocky Flats Plant (Colorado), Pantex Plant (Amarillo, Texas), Savannah River Site (South Carolina), Hanford (Washington), and the INEEL. Using magnetic and electromagnetic methodologies, geophysicists have mapped and accurately identified trench boundaries, contaminant sources, and characteristics of individual items at burial sites that are very similar in character to the Hanford burial grounds.

At INEEL, the geophysical team accurately characterized burial patterns, contaminant sources, individual buried items, and the accurate location of the trench boundaries over the 39.2-hectare (98-acre) Subsurface Disposal Area (SDA) using ground-based state-of-the-art magnetic and electromagnetic (FDEM) techniques. The geophysical data are not consistent with the overall historical record of some of the trenches and burial patterns. Therefore, they provided an “as-built” that was used to determine sample locations that could be accurately positioned and decrease the likelihood of an unplanned release during sampling/remediation efforts.

The magnetic and EM methods used at INEEL were selected for the Hanford project based on their ability to meet the project objectives, as well as the synergistic approach that could be used in data interpretation. Each sensor provides unique information, and when interpreted collectively, provides the most comprehensive information on the source of the anomalous region.

Large area survey monitor (LASM)

The LASM, based on neutron detection technology, is designed to provide fast, accurate and efficient in-situ measurement of plutonium in soil, debris, and buried containers for critically control. The LASM is capable of measuring a volume with an area of approximately 2.5 x 2.5 meters (8.2 by 8.2 feet) at a depth of 1 meter (3.3 feet), and is capable of providing a three-dimensional image when operated in two orthogonal orientations [5]. The LASM is engineered for remote operation in contaminated, radioactive environments and is environmentally sealed for ease of decontamination and designed for rugged field applications.

The LASM technology was tested at a manufacturing facility in Los Alamos, New Mexico for all expected scenarios for the INEEL SDA program. Two instruments were built to address survey requirements of the SDA site, successfully demonstrated, and fully calibrated. A list of applicable documents, references, and website links is provided in Auchampaugh [5].

RadScan ™ 800: Remote 4Pi gamma imaging system

The RadScan®: 800 4pi Gamma Imager [6] remotely locates and characterizes gamma radiation hotspots in a wide variety of environments. Typical applications include survey of building surfaces, soils, hot cells, glove boxes, process vessels, and transport containers, including the cargo holds and surfaces of trucks, trains, or boats [7,8,9,10].

The RadScan®: 800 has been used as a planning tool to initiate cost savings and reduce dose uptake by supporting optioneering studies and reducing the requirements for manual area monitoring, particularly in unknown or high-dose radiation fields (OENHP #2002-33 Version A). This instrument has the potential to lower cost and dose uptake in any environment in which the spatial distribution, intensity, and isotopic identification of gamma emitting radioactive material is needed.

Soil-gas sampling for radioactive and stable xenon isotopes

The use of radioactive and stable xenon isotopes is a minimally invasive technique in-situ characterization of TRU wastes. Xenon is produced by spontaneous fission of plutonium and other TRU elements. The isotopes produced have very low background levels, and their presence in the subsurface is diagnostic for nearby sources of TRU. The low background means that large volume samples can be collected to increase the radius interrogated and to achieve low detection limits. Stable xenon isotopes are also produced during reactor nuclear fission. The isotopic ratios are distinct from atmospheric xenon and are indicative of certain waste forms (such as irradiated fuel).

A proof of concept demonstration was performed at Hanford in fiscal year 2003. Samples were collected from the 216-Z-1A tile field and outside the 618-10 and 618-11 burial grounds. Radioactive isotopes of interest were detected at levels up to 10,000 times the detection limit at the tile field, and stable fission isotopes were clearly detected outside the 618-11 burial ground near the caissons and vertical pipe units (VPUs).

Soil-gas sampling for helium isotopes

The use of helium isotopes is also a minimally invasive technique for in-situ characterization of tritium wastes. Helium-3 is produced by radioactive decay of tritium. Thus, tritium decay alters the helium-3/helium-4 isotopic ratio in soil gas around the waste. Helium has minimal interaction with the sediments and forms a conservative tracer for the presence of tritium.

Helium isotopes have been proven effective in locating groundwater tritium plumes at the Hanford 618-11 burial ground and in the 100-K Area. The 618-11 investigation also showed a strong response, interpreted as being from tritium in the wastes. Prior investigation has been restricted to measurements outside the burial grounds.

Neutron activation of copper detectors for location of TRU

Copper-63 in copper metal is activated by neutrons from sources such as TRU to copper-64, which has a 12.7-hour half-life. Neutrons are produced by spontaneous fission and by alpha-n reactions on light elements. Below ground level, the neutron background is extremely low. The positron emission decay branch of copper-64 is measured by gamma coincidence counting. The copper in the form of pipe, rods, or plates is emplaced below ground near the potential source through direct-push technologies. After an exposure of 24 hours, the detector is retrieved and counted.

This technology has been used to measure TRU in sediments and low-level environments (down to background levels). A variation of the technique using an active neutron source has been investigated for measurement of moisture in high-level waste tanks.

TRU detection via borehole neutron probe with helium-3 detector

Gas-filled (helium-3) neutron detectors are the conventional technology for detecting neutrons in boreholes. These detectors can be used in drilled holes or inside the push rods of CPTs. As the detectors traverse the length of the hole, the neutron-radiation profile is measured. A neutron count rate that is significantly above the natural background value indicates the presence of nearby TRU. The detector is sensitive to neutron sources within about 0.5 meter (1.6 feet) of the detector.

Neutron detectors have been used in boreholes for oil and mineral exploration. Typically they are used in combination with an internal neutron source in the probe to measure properties of the formation surrounding the borehole based on neutron scattering.

Moisture gauges are small probes used in some geologic applications with small-diameter holes. These gauges contain both a neutron detector and a neutron source. If the source is removed from the probe, then the detector can be used to measure the neutrons from external sources in the surrounding formation.

Radioactive material detection via borehole gamma probe

Gamma-ray detectors in borehole probes can be used to determine the location of buried waste that emits gamma rays. These detectors can be used in drilled holes or inside the push rods of CPTs.

Gamma-ray detectors are routinely used in boreholes for oil and mineral exploration. Gamma-ray detectors have also been used to locate areas of subsurface radioactive contamination. The simplest gamma-ray probes measure only the number of gamma rays, but not their individual energies. More advance probes include spectral measurements to determine the energy of the gamma rays and, thus, their emitting radionuclide. Sodium iodide (NaI) detectors are commonly used for these measurements. Even more advanced detectors use high-purity germanium, which must be cooled to cryogenic temperature, to provide enhanced spectral quality.

This technology has been deployed using a CPT at several DOE sites, including Hanford. At Hanford, 10 penetrations were used at the S tank farm in the 200-West Area to simultaneously collect inclinometer measurements due to the proximity of tanks. Spectral gamma measurements were collected when the gross gamma exceeded a pre-determined level. The tool has been calibrated using Hanford calibration models.

Active neutron borehole logging and conventional gamma borehole logging

The principal radioactive emissions of interest in borehole geophysics are gamma rays and neutrons. The simplest radioactive method in geophysical well logging is the natural gamma log. These logging tools record the level of naturally occurring gamma ray emissions from the rocks around a borehole and any radioactive wastes near the borehole.

A borehole geophysical logging tool used ~5 micrograms (μg) of Cf-522 for subsurface prompt gamma neutron activation analysis (PGNAA) investigation of the INEEL SDA. PGNAA measurements of elemental chlorine (from chlorinated solvents, salts, and organic compounds) were made using a high-purity germanium gamma detector in a cylindrical borehole probe, with the detector shielded from Cf-522 source neutrons and gamma rays by tungsten metal. The Cf-522 source was stored in a small, shielded container when not in use. The source was transferred to the lower end of the logging tool using a long source-handling tool to minimize personnel exposure. Twenty boreholes were drilled to a depth of ~4 meters (~13 feet). Although PGNAA measurements of hydrogen, silicon, calcium, iron, aluminum, and chlorine were obtained, only the chlorine measurements were calibrated, providing a minimum detection limit of 300 parts per million (ppm). Borehole concentrations of chlorine ranged from 1,000 to 30,000 ppm [11].

Active and passive soil-gas sampling

In general, there are two methods for soil-gas sampling -- active and passive. Active soil gas samples are collected by pumping gas from the subsurface into a gas-tight container or through a sorbent trap. Passive samples are taken by allowing barometric changes to move soil gas through a sorbent trap. The samples are analyzed for organic compounds by gas chromatography (GC) or GC/mass spectrometry (MS). The distribution of contaminants in the samples is used to locate potential sources in the subsurface.

HANFORD 618-10/11 DEMONSTRATION

The overall system proposed for 618-10/11 project is based on a fully integrated approach where delineation and in-situ characterization data would feed directly into the excavation approach to maintain a high level of productivity while ensuring worker safety. Figure 2 demonstrates the process flow of the overall approach. In Phase II, The Weston Team will demonstrate nonintrusive or minimally intrusive delineation and investigation technologies to characterize the soil in the burial ground around the VPUs, with an emphasis on TRU materials. Data collected will be used for excavation and vitrification tasks to be performed by other contractor teams working on the project.

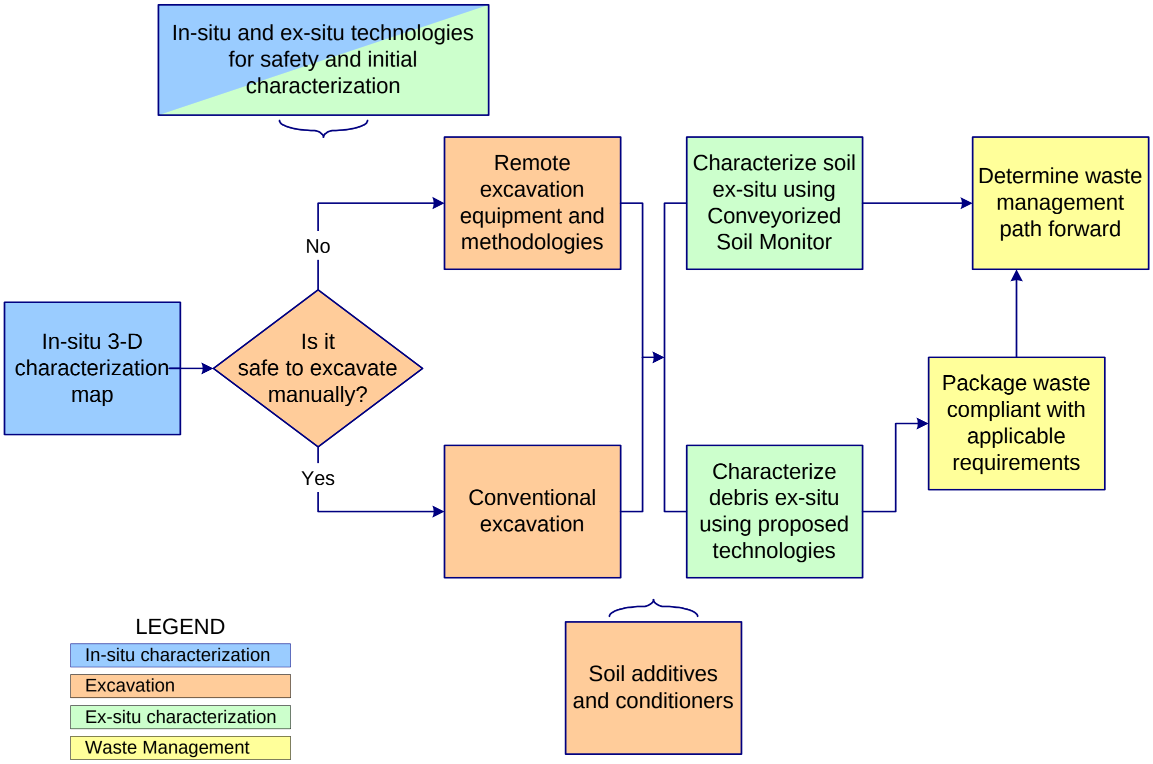

Fig. 2. Excavation process flow.

For the geophysical survey, four sensor technologies will be deployed: magnetic, time-domain electro-magnetic (TDEM), frequency-domain electromagnetic (FDEM), and ground penetrating radar (GPR). These technologies provide multiple data streams that can be digitally "synergized" to more completely define the target (shape, rudimentary composition, depth, relative size, etc.).

Using magnetic sensors in a vehicle towed, multiple sensor array (VTA), the passive method measures local distortions in earth's geomagnetic field, responds to magnetic properties of object/feature (detects ferrous metal), and produces complex target response patterns. The TDEM (VTA) is an active method that measures secondary magnetic field resulting from induced current in object via coils, responds to surface area (detects all types of metal), produces target response patterns that are more discrete than magnetic data, and detect metallic and non-metallic burial features and objects, in particular VPUs. The FDEM (carried by a worker) is an active method that uses transmitter/receiver coils separated by approximately 3.6 meters (12 feet). A larger footprint produces lower spatial resolution than magnetics, TDEM, or GPR. The FDEM responds to bulk conductivity and magnetic properties (detects metallic and non-metallic waste materials) and produces target response patterns that are generally more "nebulous" than magnetic and TDEM data. GPR responds to the conductive, magnetic, and dielectric properties of materials. GPR has genuine three-dimensional imaging capability at a higher resolution compared to the other methods; however, the penetration of the radar waves into the subsurface can be severely limited (<< 1 meter) in areas of elevated conductivity and increased soil magnetism. GPR waves do not penetrate through metal.

The LASM will provide in-situ measurement of plutonium in soil, delineate debris and buried containers, and provide criticality control The LASM can be skid/trailer mounted or easily maneuvered by crane or forklift. At the 218-W-4A low-level burial ground, the LASM will most likely be maneuvered using an all-terrain forklift. The LASM uses advanced imaging algorithms. Extensive modeling will be used to develop calibration and the modeling will be benchmarked before deployment. The LASM performs continuous instrument calibration between measurements, using an installed Cf-522 source.

The system will be deployed in conjunction with GPS, and the radiometric neutron data will be converted to grams of Pu-240 effective and plotted on site maps using GIS software. The data will be integrated with other radiological, geophysical and soil gas data. In addition, the LASM can be reconfigured in a vertical orientation for ex-situ characterization of an excavation dig face and unknown containers.

The project team will also employ minimally intrusive technologies to complete the delineation of the VPU and surrounding soil. As much as possible, these technologies were selected so that a common deployment platform could be used. With the exception of the passive soil gas monitoring, all of these technologies will use CPT penetrations. The CPT was chosen because it is:

- Proven method for accessing the subsurface to deploy a wide range of measurement techniques and sampling devices
- Minimally invasive; no drilling fluid is used, no cuttings returned to surface
- Proven to be easily decontaminated as rods are being withdrawn.

All sensor information will be gathered into a database, and multiple images will be created for interpretation (e.g., color-coded images of sensor information can be overlaid using transparent color schemes). Digital radiological and chemical data will be co-located with the geophysical sensor data and imaged geophysical anomalies. The data (geophysical, radiological, and chemical) will then be represented in a comprehensive three-dimensional map that will represent the radiological data relative to any geophysical anomalies. This three-dimensional map will be used to support removal or in-situ vitrification of a VPU.

THE FUTURE

Across the DOE complex many sites will benefit from an integrated approach that includes excavation defined by in-situ characterization. This approach improves production rates and maintains worker safety. The following section describes potential burial ground projects identified at DOE sites.

Hanford

Both areas of operation at the Hanford site (Central Plateau and River Corridor) contain multiple burial grounds that contain uncharacterized waste requiring methods to ensure worker and environmental safety while maintaining acceptable production levels. To understand the magnitude of sites that could benefit from the proposed system approach, the upcoming River Corridor procurement identifies 277 waste sites and 42 burial grounds in the 100, 300, 400, and 600 Areas that will require complete field remediation during the 5-year period of performance.

INEEL

The Radioactive Waste Management Complex (RWMC) in the southwest corner of the INEEL, covering 67.2 hectares (168 acres), is used to manage solid TRU and solid low-level radioactive waste. Between 1954 and 1970, radioactive and chemically hazardous waste was buried in the 39.2-hectare (98-acre) SDA of the RWMC. This site is being remediated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, Superfund). The SDA consists of 20 pits, 58 trenches, and 21 soil vault rows. Much of the TRU waste buried at the RWMC, which consists of both contact- and remote-handled waste, was shipped to the INEEL from the Rocky Flats Plant near Golden, Colorado, and was the product of Cold War nuclear weapons production. In 1954, Rocky Flats began shipping defense waste with TRU elements, and by 1957 the original 5.2 hectares (13 acres) were nearly filled. The RWMC was then expanded to 39.2 hectares (98 acres). The size of the RWMC remained the same until 1970.

LANL

Several areas within LANL have been identified as subsurface disposal areas that would benefit from the integrated system presented in this paper. Technical Area 21, which developed and executed weapon development operations that would later be moved to Rocky Flats, contains multiple material disposal areas (MDAs). The uncharacterized radioactive and chemical waste in the MDAs will require an approach to remediation that reduces the potential exposure to site workers. In addition, Technical Area 54 also contains several disposal sites that contain contact- and remote-handled waste. Over all, as many as 20 MDAs have been identified that could benefit from an integrated remediation system.

Paducah and Oak Ridge

At the Paducah Gaseous Diffusion Plant (PGDP), burial grounds that might require excavation, should they be determined to contribute to the groundwater contamination, are all capped, and include the C-404 mixed waste burial grounds and burial grounds at solid waste management units (SWMUs) 2, 3, 4 (classified burial ground), 5, 6, 7, 30, and 145. In addition, at Oak Ridge National Laboratory one unit suggested for potential remediation is the Engineered Test Facility, which is a research and development area consisting of nine trenches in Solid Waste Storage Area (SWSA) 6 that were used to investigate improved land burial technologies for low-level radioactive waste disposal in humid environments. The proposed remedial action is to excavate and dispose of waste and contaminated soils that are above the remediation level.

CONCLUSION

The successful implementation of this project approach is based on the intelligent application of innovative and proven technologies coupled with a skilled project team. In addition to the characterization and robotic excavation systems, a specialized team of technicians is required to excavate and sort the landfill materials. The team should include certified asbestos workers, a field chemist, radiological control technicians, explosives specialists, as well as heavy equipment operators, truck drivers, environmental laborers, and administrative personnel to excavate, sort, stage, sample, and ship all wastes. For some projects, landfill materials excavated by the remote system are then passed on to personnel for conventional sorting and packaging. All materials are visually inspected for safe handling, and conventional equipment with blast shields are used to transport materials for sorting and field screening. Administrative controls are implemented for all site personnel, and visitors are discouraged in the support areas. During robotic remote operations administrative controls can be relaxed, and still comply with safety requirements for hazardous waste site operations, due to the lack of personnel near the point of excavation.

Lessons learned from past project experience include:

- Characterization is the key to project planning. Using a wide variety of radiological and chemical techniques to identify areas of greatest concern is important for cost-effective and safe retrieval operations.
- Keep it simple. Elaborate processing facilities are far less effective than simpler methods of sorting.
- The robotic systems have performed much longer than originally estimated with only minor repairs and maintenance, which is counter to the popular opinion of many commercial robotic systems.
- Integration of robotics with traditional manual heavy equipment can be performed efficiently and cost effectively.
- The remote excavator can operate at approximately 80% efficiency of a manually operated unit.
- Schedule and production are controlled by the rate of sorting operations.

Benefits of the integrated system include:

- A high level of system integration
- Robotic vs. remote control
- Onboard intelligence
- Use of models and sensor feedback for error detection and correction
- Systems are designed to reduce operator fatigue
- Developed for real-world environments
- Seamless integration of multiple subsystems into a single project approach.

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