Transportable Assay System for Reclassifying Transuranic Waste to Low Level Waste - 25549

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ABSTRACT

This paper describes a transportable variant of the ANTECH UDASS (Universal Drum Assay and Segregation System) which has been developed and optimised for use in measuring Transuranic Waste (TRU) in the United States. It is based on the use of a single high efficiency high purity germanium (HPGe) detector for measuring radioactive waste in drums. It is becoming clear that over a period of years, much of the Transuranic Waste (TRU) generated in the US has been misclassified (overclassified). In part this is due to the conservative assumptions associated with measurements of TRU. It is also due to the often-inappropriate use of Open Detector (OD) geometry based assay systems that require the assumptions that the radioactive waste is homogeneous in both density and activity distribution. These assumptions are seldom appropriate. The OD measurement approach often leads to large errors and a consequent over estimation (overclassification) of waste activity. The UDASS was designed to overcome this difficulty. It combines three waste measurement methods including Dynamic Open Detector (DOD), Wide Range Segmented Gamma Scanner (WR-SGS) and Tomographic Gamma Scanner (TGS) used in transmission mode. These enhanced characterisation methods have evolved from traditional assay methods which have been in use for some time. All three assay techniques or methods are implemented in the single UDASS platform. In order to determine the optimum approach to the assay of a given waste drum, emission and transmission pre-scan measurements are performed using the WR-SGS method. If a drum is sufficiently homogeneous then a DOD emission measurement is performed. If the drum is assessed to be heterogeneous in either density or activity distribution, then a WR-SGS emission measurement is performed. The results of the pre-scan transmission measurement are used to perform a transmission correction to adjust the results for matrix attenuation for either DOD or WR-SGS emission scans and produce a preliminary assay result. If a WR-SGS assay result falls close to a radiological classification boundary, then a TGS transmission measurement may be undertaken to improve the attenuation correction, extending the measurement time. A trial of the UDASS has been conducted by N3B at the Los Alamos National Laboratory (LANL) sponsored by the DOE. Technical support has been provided by NUVISION ENGINEERING and ANTECH. ANTECH previously conducted successful characterisation measurements with a prototype UDASS at the Low Level Waste Repository (LLWR), operated by the Nuclear Decommissioning Authority at Drigg in the UK. At LANL, characterisation measurements have been undertaken of 373 legacy drums available at TA-54. A throughput of between 7 to 11 drums per day has been achieved with a typical measurement time of 30 minutes per drum. Although the UDASS measurements were undertaken as a blind trial without knowledge of the density or activity range of the target drums, previous Open Detector measurements employing the SNAP measurement and analysis code, have indicated that the drum activity ranged from between 80 and more than 900 nanocuries per gram (nCi/g) of alpha activity. The drums were also assumed be relatively homogeneous. Despite the UDASS having a more robust error analysis and using the more sophisticated WR-SGS attenuation corrected analysis for heterogenous waste drums, broad agreement exists between the two sets of results. This agreement confirms the assumption of homogeneity of the drum matrix. More sensitive UDASS measurements would have resulted had the DOD measurement method been employed. The advantages of the UDASS become more important for more challenging waste drums such as heterogenous higher density drums.

INTRODUCTION

As part of joint project initiative by the US Department of Energy Office of Environmental Management (DOE-EM) and the UK Nuclear Decommissioning Authority (NDA), a task was initiated to demonstrate the performance of the UDASS in the US. A successful legacy waste reclassification project employing the UDASS in the UK [1, 2, 3, 4] had previously been conducted by the NDA at the Low Level Waste Repository (LLWR).

The US project was funded by DOE-EM and undertaken through the Cooperative Agreement on International Technology Transfer and Demonstration (DE-EM0005297) on a contract with NuVision Engineering (NVE). The demonstration project was implemented at LANL and involved the Environmental Management-Field Office (EM-LA), NVE, ANTECH and Newport News Nuclear BWXT (N3B) Los Alamos, the site contractor, all working closely together. The on-site implementation of the demonstration project is described elsewhere [5].

The UDASS was developed by A. N. Technology Ltd., (ANTECH) in the UK. The aim of the design was to address the problem of over classification of radioactive waste in that LLW is often incorrectly sentenced as ILW PCM (plutonium contaminated material) in the UK or TRU in the USA. This problem has arisen due to measurement inaccuracy largely due to the use of Open Detector measurements technologies applied to inhomogeneous waste. A failure to consider both the distribution of activity in the waste matrix and more seriously the distribution of density (causing variable gamma ray attenuation) leads to over estimation of drum activity and hence waste overclassification.

In order to address this problem, the UDASS design incorporates a number of features and multiple measurement modes. These include a high efficiency (>50%) High Purity Germanium (HPGe) detector with a 2-inch lead shielding around the circumference of the detector. The transmission source is a 370 MBq (10mCi) Eu-152 source with a tungsten source holder assembly. When in safe (home) position, the transmission source is shielded further by a lead shield within the frame of the system. The system also contains a Cd-109 dead time source located on the barrel of the detector within the lead shield assembly.

The UDASS is designed to measure radioactive waste in a range of different drum sizes up to 400 litres, although reclassification measurements are optimised for 55 US gallon (200 litre) drums. It is therefore able to accommodate 85 US gallon (340 litre) overpack drums, often used to contain legacy waste.

The UDASS incorporates three proven and established measurement technologies in a single instrument platform. These are enhanced Open Detector (designated Dynamic Open Detector - DOD), Wide Range Segmented Gamma Scanner (WR-SGS) and Tomographic Gamma Scanning (TGS) transmission measurements. In order to select which measurement method is most appropriate for a particular drum, the UDASS first performs two per-scan short measurements. The first is a transmission pre-scan to establish the density (or attenuation) profile of the candidate drum. The second is an emission pre-scan to establish the variation of source distribution in the drum and to locate any source concentrations (point sources or higher activity regions commonly known as hot spots).

Following the pre-scans and the subsequent assay measurement, whether DOD or WR-SGS depending on the results of the pre-scan, a determination of the status of the waste drum is made, either transuranic (TRU) or Low-Level Waste (LLW). In the UK further waste categories below LLW exist (Low Activity LLW – LALLW and Very LLW – VLLW) to which the UDASS is able to consign drums. If, following the assay measurement, the data suggests that further analysis is appropriate (for example if the measured drum activity lies close to the TRU – LLW boundary of 100 nCi/g (3,700 Bq/g)), further measurements may be made to refine the result. These measurements may include a WR-SGS transmission scan of a drum initially measured by the Dynamic Open Detector method or a TGS Transmission measurement of the drum to improve the transmission correction applied to a drum measured by the WR-SGS method. The multiple measurement methods incorporated into the UDASS optimize the probability of reclassifying drums to the lowest appropriate radiological category and provide the best opportunity to reclassify TRU to LLW, with resulting significant cost savings. (In the UK, the segregation measurement is between ILW PCM (Intermediate Level Waste Plutonium Contaminated Material) and LLW and the equivalent ILW PCM/LLW boundary is 4,000 Bq/g). The measurement methods are described in detail elsewhere [2].

UDASS DEPLOYMENT AND MEASUREMENTS

As a result of the experience of the previous UK deployment to LLWR and legacy waste measurement campaign as well as the extensive UK testing, a number of improvements and modifications were implemented in the UDASS destined for deployment to the US. These modifications included improvements in both in hardware and software. Some of these were specific for the US such as employing US electrical wiring conventions and UL testing. The most significant of these was to house the UDASS in a 20 ft ISO shipping container in preparation for in-field use at LANL. The testing, deployment and measurement campaign is described in the following sections.

UDASS Validation and Testing

Prior to shipping from the ANTECH UK factory, the UDASS underwent extensive calibration, testing and verification to confirm the correct and accurate functionality of the instrument. The UDASS HPGe detector was calibrated using a point source calibration for DOD analysis. Calibrations were performed over the height of the drum for selected fill heights for the WR-SGS measurement, including both the 55 Gallon and 85 Gallon container sizes and for every combination of collimator aperture and filter. Multiple measurements were performed for validation and verification across a range of different drum densities and drum sizes. These verification measurements employed a set of test drums designed for both homogenous activity and density distribution. These test measurements confirmed the validity of the calibration measurements over a range of drum sizes and drum matrices.

Further testing was completed using a customised and reconfigurable heterogeneous test drum matrix constructed of components so that the density distribution could be made non uniform, and the activity (source distribution) could be varied by placing or removing point sources and rod sources from positions within the reconfigurable drum matrix. The heterogenous test drum was constructed to validate the correct operation and assessments made by the pre-scan and WR-SGS main scan, for a range of different source activities and density distributions.

Once delivered on site, a sample verification of the validity of the testing was carried out. This included testing the weigh scale calibration and using the existing factory quality assurance data of the full width and half maximum, centroid position and net peak counts of the Eu-152 transmission source to confirm the detector alignment and efficiency. In addition to the successful testing in both the UK and the US in preparation for the demonstration tests at LANL, the UDASS has recently been accredited by the UK Government Accreditation Service to the ISO/IEC17025:2017 laboratory measurement standard [6] for in-field laboratory quality measurements.

Deployment of the UDASS Mobile Assay Laboratory to the Los Alamos Site

To facilitate in-field operation as well as for ease of transport and deployment of the system to site, the UDASS was installed inside of a customised ISO shipping container, to create a UDASS Mobile Assay Laboratory (U-MAL). This approach dramatically simplified both the process of shipping the unit from the UK to LANL and simplified the installation and commissioning process following arrival. As a self-contained laboratory, the only service required from the site operators is a single phase, 110Vac mains supply, which was provided by N3B for the NuVision/ANTECH joint project operation team. The ISO shipping container mounted UDASS U-MAL is shown in Figure 1.

The UDASS is housed in a high cube standard configuration ISO container. This configuration has dimensions of length, 20ft (6.06m), width 8ft (2.44m) and height 9.5ft (2.89m) with standard cargo doors at one end (control room) and reinforced side opening with foldable doors on one side. This arrangement facilitates drum loading operations as well as providing easy access for maintenance. On deployment onto site, the functional checks, and re-assembly typical of system in-field installation were mitigated by delivering the unit as a mobile lab housed within the ISO container. This approach reduced the administrative burden on N3B of setting the system to work, allowing them to focus on the challenge of staging drums, delivering them to the system and handling them in accordance with site procedures and requirements [5].

The UDASS Mobile Assay Laboratory divides the ISO container into two separate areas; an operator control room and an assay area, where the UDASS is located. The internal areas were lined and sub-divided with insulating panels designed for use in containers, to provide environmental protection and temperature stability throughout the measurement campaign. Within the operator control room, an UDASS operator can control, monitor and carry out measurements on the UDASS, as well as monitor the loading and unloading process being carried out by the N3B site operators, through two windows in the control room wall. An interlinked safety circuit enabled both the operator and the site team to halt the measurement process at any time through multiple emergency stop push buttons. The operator control room featured a desk, operator control console onto which the control and analysis software was loaded, an uninterruptible power supply (UPS) to hold up the UDASS critical supply voltage, and an HVAC unit (air conditioning) for operator comfort. To ensure the stability of the operating conditions of the UDASS instrument, the HVAC could be applied through the office wall to the UDASS assay area via a ventilation fan in order to heat/cool the assay area as necessary.

Fig. 1. UDASS mounted in an ISO shipping container. The operator control room is shown on the left. The photograph shows the UDASS mobile lab with a drum in the measurement position and the foldable side doors open.

The UDASS incorporates a horizontal loading axis of motion which positions the drum rotation platform at the threshold of the side-opening doors of the container to enable a drum to be easily loaded onto the drum rotation platform. Typically, a drum to be measured is placed on the drum rotation platform by a forklift, when the drum rotation platform is in the load position. Separating the drum loading position from the measurement position of the UDASS reduces the risk of damage to the detector and sensitive electronics during the drum loading process. Once loaded onto the drum rotation platform in the drum loading position, the drum and rotation platform are automatically moved to the drum measurement or assay position. This operation is reversed once the measurement is complete. Once returned to the load position, the drum can be unloaded by a forklift. The side-opening container doors can be left open or closed during the measurement period (typically 30 minutes) to minimise the likelihood of operational downtime due to adverse weather conditions.

Through the use of a standard configuration, externally unmodified ISO container, the UDASS Mobile Assay Laboratory was able to be shipped as a standard container unit both over-seas and by road. Shipment restrictions and constraints applicable to externally modified or non-standard ISO shipping containers were avoided. This allowed the relatively rapid deployment of the UDASS assay system to the LANL site by both sea and road.

The UDASS was deployed to TA-54, Area G at LANL. TA-54 is the legacy waste management area at LANL and Area G is a site within TA-54 that contains legacy radioactive waste disposal areas and above ground TRU waste storage and handling facilities. This is the area where LANL's legacy TRU and LLW are stored and characterized. The TA-54 site is operated by N3B Los Alamos as a contractor under the DOE-EM.

UDASS Drum Measurements Demonstration Project

During the period from 18 March to 28 June 2024, the UDASS measured between 4 and 11 drums per day. The drums were loaded onto the drum rotation platform in the load position of the UDASS using a forklift operated by the N3B site team. After automated transfer to the measurement position of the instrument, the UDASS drum measurements were performed by the NVE operators, with advice were necessary from ANTECH. Once each drum measurement was complete the drum was repositioned to the load position from where it was removed by forklift and then return to storage. Figure 2 shows a waste drum being loaded into the UDASS.

Fig. 2. The UDASS in operation in Area G of TA-54 at LANL. The photograph shows a TRU waste drum being loaded into the UDASS for measurement.

The demonstration project analysed more than 300 drums of radioactive waste, estimated to be in the range from 80 to 400 nCi/g (nanoCuries/gram). Drums had been selected for analysis from the EM inventory located in Area G by N3B. The drums included in the demonstration had all been previously measured either by the Central Characterization Project (CCP) or the LANL M&O contractor using gamma assay technology employing mostly open detector SNAP assay instruments.

Most of the drums were 85-gallon overpack drums. They were divided by N3B into 4 batches of approximately 100 drums each. In batches 1 and 2, the majority of drums contained waste with activity levels in the range of 100 to 400 nCi/g. With the UDASS more accurate and sensitive measurement technology, drums with this activity range were more likely to be suitable to demonstrate the concept of reclassification from TRU to LLW. In batches 3 and 4, most of the drums were in the activity range of 400 to 800 nCi/g, making them very unlikely candidates for drum re-dispositioning.

MEASUREMENT RESULTS AND ANALYSIS OF LANL TRU DRUMS

The UDASS measurements of TRU drums at LANL were conducted as a blind test, without a knowledge of the results of the earlier measurements conducted by both CCP and the LANL site M & O contractor. The ANTECH personnel responsible for data analysis were only given at most the same information available to the team who performed the original drum assay and analysis.

The typical UDASS data analysis process involves a review of the measurement data by a suitably qualified and experienced subject matter expert (SME). The SME review is carried out to ensure that there are no issues with the measurement and includes, where necessary, an in-depth review to rule out false-positive reporting of radionuclides detected in the gamma ray spectra. The typical post-measurement analysis process involves copying the raw measurement data, which is saved with each measurement record, into a review spreadsheet template which allows the SME to carry out a comprehensive review. Depending on the measurement, this process can be done in an expedient manner by an experienced SME gamma ray spectroscopist for most drums in 10 to 15 minutes per drum. Only drums of a more challenging nature, as highlighted in the data review, may take extended time to complete the review process.

In high resolution gamma spectroscopy (HRGS) measurements of radioactive waste, a library of typical or expected radionuclides from the waste stream or other guidance is often provided the owner of the waste. These library files are used to specify, as a minimum, what peaks in the gamma ray spectrum are reported and processed by the analysis software. Whilst the library file does not limit which peaks are analysed, with any others gamma ray peaks being reported throughout the process as ‘unidentified peaks’, it is a common approach to ensure crucial radionuclides are not missed in the analysis process.

For the demonstration project, in the absence of nuclide library files, configuration data or other guidance about the nature of the waste, the initial measurements employed the same nuclide library files that were used in the earlier measurement campaign of radioactive waste at LLWR in the UK.

However, once a couple of weeks of measurement data was available, the UDASS team carried out an iterative process of repeating analyses on a number of drums in order to establish which radionuclides should be included as typically present. To ensure a suitable analysis process, the library files established were conservative in nature, with multiple peaks of radionuclides included to ensure the contents of the drum were suitably captured. As a result, the analysis process for UDASS measured data was more likely to result in double-counting and as such, the review process required a closer scrutiny of the radionuclide data.

In the UDASS measurement campaign at LLWR in the UK, a nuclide vector or nuclide ‘fingerprint’ was employed in the analysis to extend the measurement capabilities of the instrument. A nuclide vector is typically generated by sampling, combined with small sample high efficiency gamma spectroscopy or other radionuclide identification techniques, where it can be assumed that the sampled radionuclide distribution is representative of the radionuclide distribution in a large group of drums of similar origin. The use of nuclide vectors or fingerprints facilitates (by means of ratios) the identification and quantification of other nuclides which are hard to measure by conventional HRGS means or those which do not have a measurable gamma ray signature. As no nuclide vectors were available for use in the UDASS demonstration measurements at LANL, this capability of the UDASS was not employed. The absence of nuclide vectors and the iterative process to establish a workable radionuclide library diminished the effectiveness of the UDASS in the demonstration project.

In order to compare UDASS measurements with the earlier Open Detector measurements made of the same drums in the past, a further post measurement analysis of the UDASS measurement data was necessary. This was so that a like-for-like a comparison of the two measured data sets could be achieved. The general treatment of measurement errors for the SNAP measurement and analysis process was compared with the equivalent process for the UDASS. This comparison was made more complex as SNAP is an Open Detector measurement technology whereas the UDASS employed the WR-SGS measurement technology.

As a result of the review, it became apparent that the treatment of Minimum Detectable Activities (MDAs) in the UDASS was more pessimistic than the approach employed in SNAP. The treatment of MDAs within the UDASS WR-SGS analysis was based on collaboration with the Sellafield physicists who oversaw the UK demonstration measurements at LLWR. The MDA treatment in the UDASS was modified and the data was re-analysed so that the like-for-like comparison could be achieved of the two measurement data sets. This final post-measurement analysis phase of the demonstration at LANL was a multi-staged process, involving end user engagement, cooperation and collaboration of all parties to produce a set of results suitable for a direct comparison.

Using the revised UDASS measurement data, the results of the comparison of the two measurement data sets leads to the following conclusions:

- 15% of the TRU drums from the original measurements in drum batches 1 and 2 are eligible for reconsignment to LLW as they have an alpha activity of <100nCi/g.

  NOTE: Of the four separate batches, batches 3 and 4 offered very few candidates for reconsignment. However, when batches 3 and 4 are included, there were still 13% of drums from the total demonstration eligible for reconsignment.

- 98% of the drums from the original measurements showed an improved uncertainty value which can result in more efficient packing at WIPP

- 75% of the drums from the original measurements showed a reduced alpha activity

- 88% of the drums from the original measurements showed a reduction in total activity

Figure 3 below is a plot of the two measurement result data sets with lines joining the measured data points. Plotted along the horizontal axis is the drum identification number in increasing order of drum ID. The measured drum activity including measurement uncertainty is plotted on the vertical axis in units of nCi/g. The TRU – LLW threshold at 100 nCi/g is shown with a dashed line on the plot.

Figure 3 serves more as a visual guide to the overall performance of the two measurement systems. Generally, the UDASS results are of lower activity with more data points falling below the 100nCi/g threshold than the previous SNAP measurements. This is also shown in the numbers above, reflecting reduced alpha activity, reduced uncertainty, reduced total activity and increased number of drums reclassified as LLW as a result of the UDASS measurements.

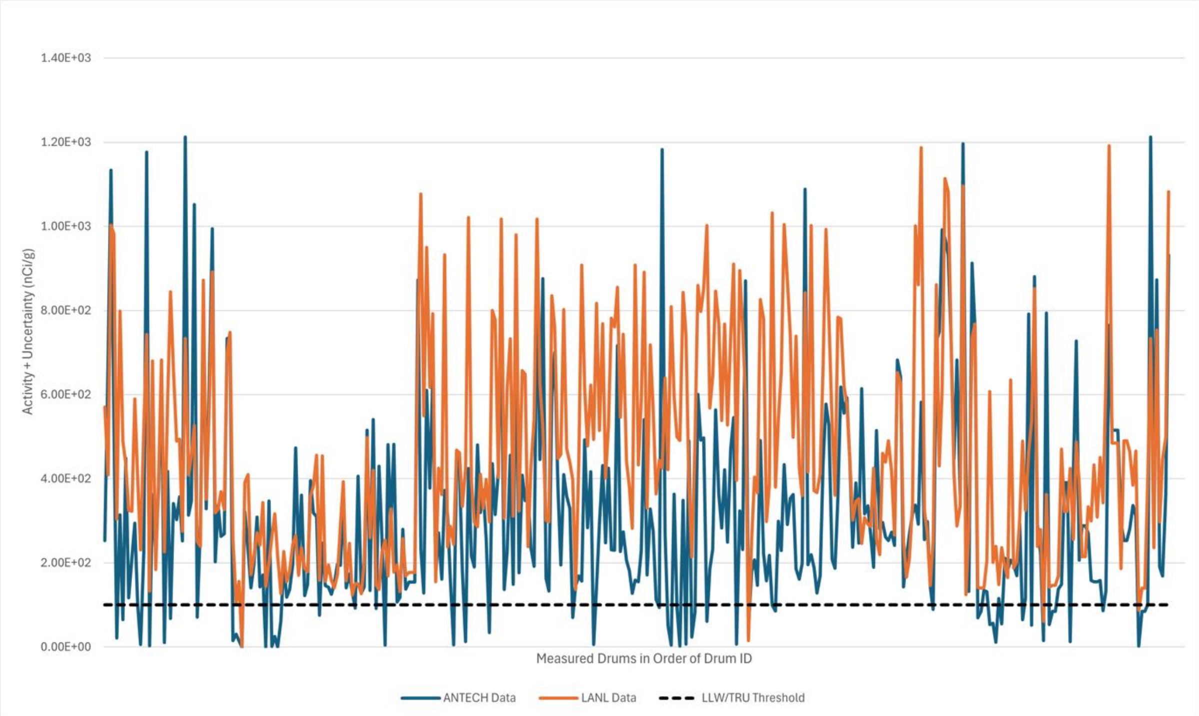

Fig. 3. Comparison plot of the same waste drums measured earlier at LANL using (mostly) SNAP measurement instruments and measured subsequently by the UDASS.

A significant benefit of the UDASS is that it assesses the degree of homogeneity of each waste drum using the pre-scan process. For most of the drums in the trial, both the matrix and the activity distribution proved to be homogeneous, and therefore suitable for measurement by Open Detector assay technology such as SNAP. Open Detector measurement technology must assume drum homogeneity, whereas the UDASS removes the need for this assumption. Note that the SNAP measurement analysis has the capability of employing differential attenuation by measuring multiple photopeaks arising from a single radionuclide, to assess drum density variations, although this feature does not appear to have been used in measuring the LANL drums. For the heterogeneous drums encountered in the measurement campaign, the SNAP Open Detector assay technology would, in general, over-estimate drum activity.

Unfortunately, although a large proportion of the waste drums in the demonstration were homogeneous, the Dynamic Open Detector (DOD) measurement method incorporated into the UDASS for such cases, was not employed. This was due to the configuration and setups of containers for the campaign, specifically with relevance to the 85-gallon overpack drums. In future, it will be possible to configure the UDASS to use DOD measurement for homogeneous 85-gallon drums. Had the DOD measurement been used for relevant homogeneous drums it would have reduced uncertainty and improved counting statistics potentially leading to greater drum reclassification. Due to this configuration problem, the DOD measurement method was not demonstrated during the LANL measurement campaign.

CONCLUSIONS

The UDASS performed as anticipated. It identified that a significant fraction of the trial drum population was overclassified waste - TRU that was actually LLW. For the remaining TRU waste drums, the UDASS measurements demonstrated that the activity was not as great as had been declared as a result of the earlier measurements performed by other measurement techniques. As the trial drum population was selected to be representative of typical TRU waste, the UDASS measurement performance can reasonably be extrapolated to other TRU drum populations at LANL and elsewhere in the DOE complex.

A major benefit of the UDASS is that, as far as possible, the assumptions made about the drum matrix and activity distribution are removed. These assumptions, if incorrect, can lead to large measurement errors. The UDASS avoid the limitations of measurements using Open Detector technology which very often leads to over estimation of drum activity and resulting waste over classification.

Aside from successful measurement trial results in both the UK and the US, the UDASS is accredited by independent assessors as an in-field laboratory instrument under ISO/IEC17025:2017 in the UK. Similar laboratory accreditation could be obtained for UDASS deployment to DOE sites in the US. Also, although this paper has focused on the capability of the UDASS for TRU/LLW reclassification and segregation at relatively low activity, with a variable aperture collimator and tungsten filters, the UDASS has the additional capability for measuring high activity and high dose rate TRU waste.

The UDASS will improve the efficiency of TRU/LLW drum segregation and generate substantial savings for the DOE by diverting a significant amount of waste that is really LLW, (with alpha activity below 100nCi/g), away from WIPP to lower-cost, alternative disposal sites. Waste volumes going to WIPP will be optimised and waste shipments of LLW accelerated which will assist DOE to meet state regulatory targets. Deployment of the UDASS would help accelerate and increase cost-effectiveness of the legacy waste cleanup effort across the entire DOE complex.

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