# Use of CT X-ray in Gamma NDA Measurements: Reducing Matrix Uncertainty in Waste Characterization


Xavier Ducoux

Mirion Technologies, Montigny, France; Correspondence to: xducoux@mirion.com



## Abstract

Gamma NDA systems, such as Far-field spectroscopy systems, are widely used for the radiological characterization of waste drums, but their accuracy is often limited by unknowns in matrix composition and source distribution. This work explores the integration of X-ray Computed Tomography (CT) with gamma spectrometry to reduce Total Measurement Uncertainty (TMU). By generating high-resolution voxel-based density maps and incorporating them into SuperISOCS modeling, we can demonstrate improved accuracy and reduced reliance on transmission sources. Results from a test drum and simulation show that this approach can significantly enhance NDA performance and operational safety.


## Introduction

Traditional NDA systems (such as Far-field spectroscopy) rely on assumptions about the internal distribution of materials and radioactivity within waste drums. These assumptions often lead to conservative estimates and over-declaration of activity, especially when Acceptable Knowledge (AK) is limited. More advanced systems, such as SGS and TGS systems, usually require radioactive transmission sources to improve the drum content information (averaged layer attenuation for SGS ; more localized attenuation and source distribution in the case of the TGS). The use of radioactive sources greatly increases performance but also brings additional constraints (source administrative management, source replacement, HP zoning, …), making it worthwhile to explore alternatives.

Real-Time Radiography (RTR) is commonly used for visual inspection but lacks quantitative density data. X-ray CT offers a promising solution by providing high-resolution, three-dimensional density maps that can be directly integrated into gamma spectrometry modeling tools like SuperISOCS. This integration allows for more accurate efficiency calibration and activity quantification, particularly in heterogeneous or legacy waste scenarios.

## Materials and Methods

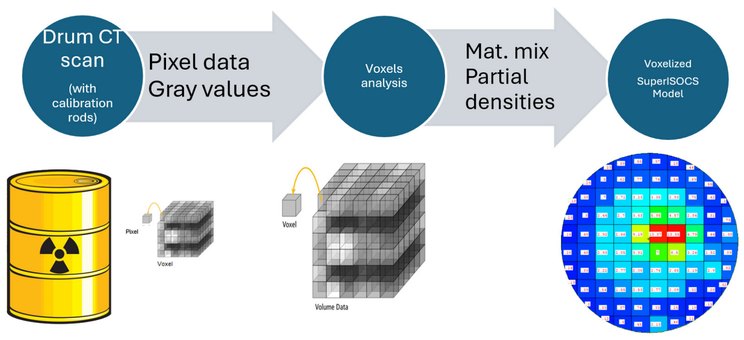
A 200L test drum, constructed by loading known materials of varying density to simulate realistic waste configurations, was scanned using a VJ Technologies X-ray CT system and then measured with a Far-Field system.

### Test drum Creation & Scan

Rod sources of known materials (aluminum, copper, etc.) were positioned around the test drum for the X-ray scans in order to provide a base reference for the density evaluation process.

Radioactive point sources and line sources were positioned at various positions in the drum to reproduce multiple configurations during the gamma spectroscopy measurements. Two measurement results are presented in this poster:

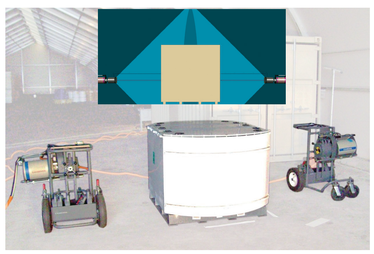
- Measurement 1: one line source positioned in hole C
- Measurement 2: three line sources of similar activities positioned at 3 radii (A-B-C holes in picture below) to simulate source homogeneity.

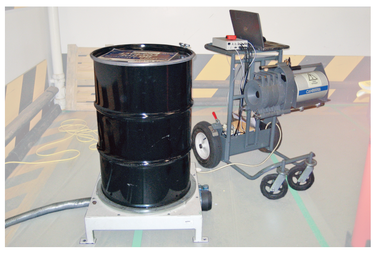



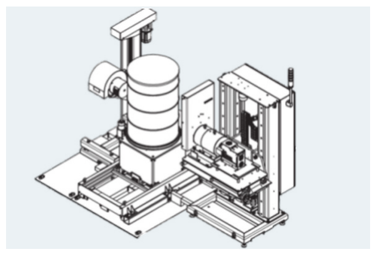

A 3D density map was then generated from the CT scan, integrated in a SuperISOCS template and used to simulate the detection efficiencies of the spectroscopy measurement.

A comparative analysis was conducted between a traditional homogeneous model and the CT-informed model.

## NDA Systems

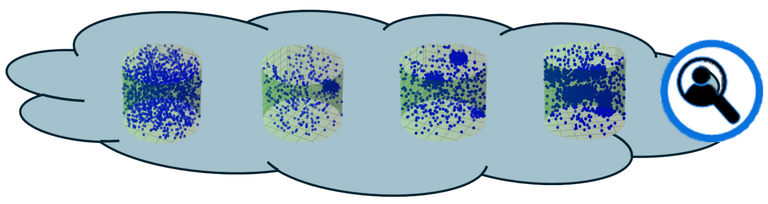


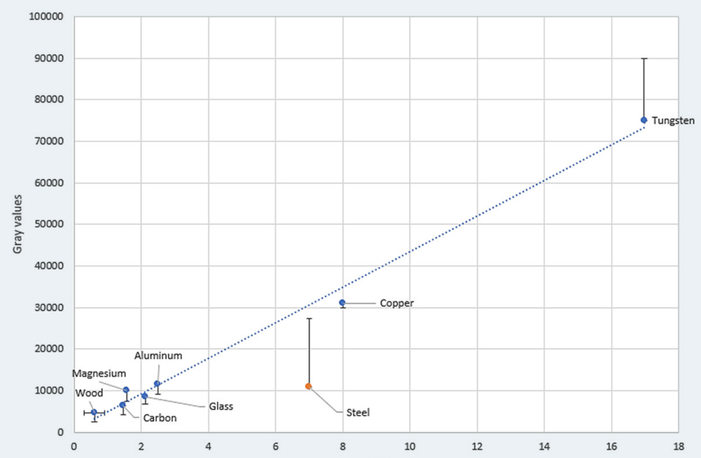


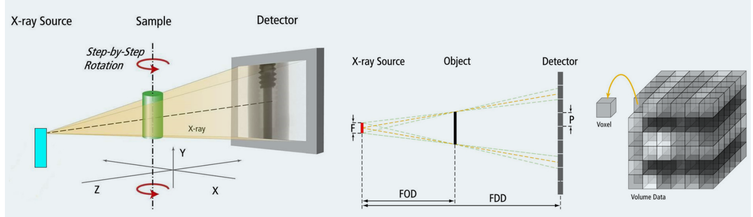
## TMU (Total Measurement Uncertainty)

Source and/or matrix distribution illustrations:



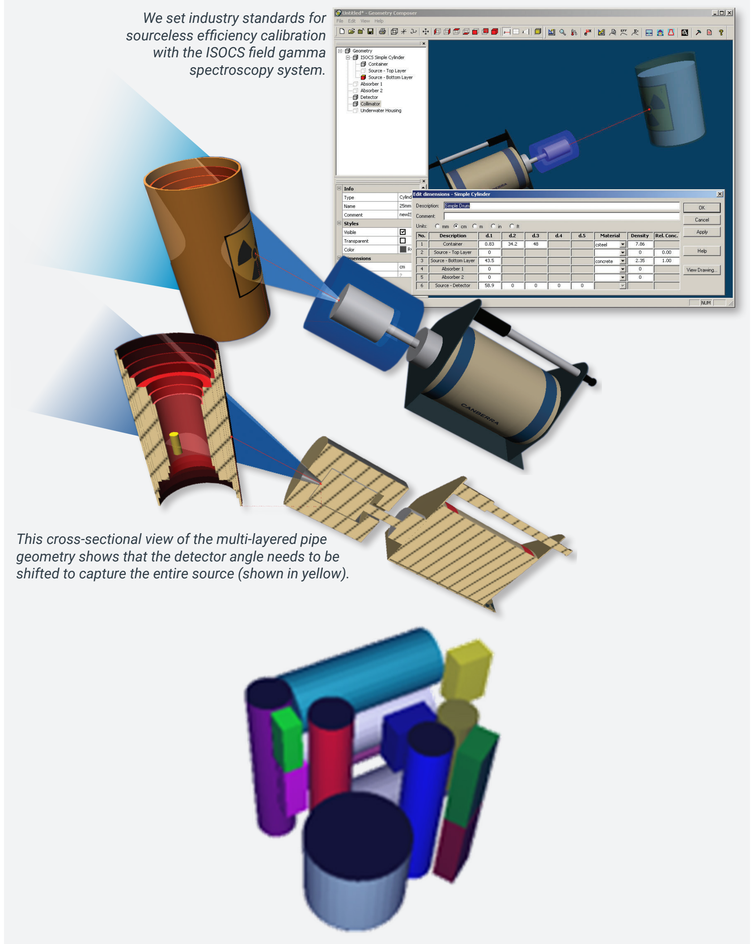
### X-Ray CT – density evaluation




### ISOCS/SuperISOCS

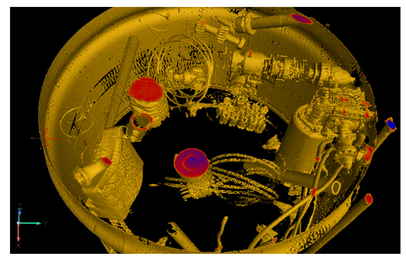
*We set industry standards for sourceless efficiency calibration with the ISOCS field gamma spectroscopy system.*

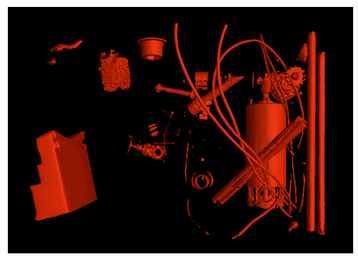


*This cross-sectional view of the multi-layered pipe geometry shows that the detector angle needs to be shifted to capture the entire source (shown in yellow).*



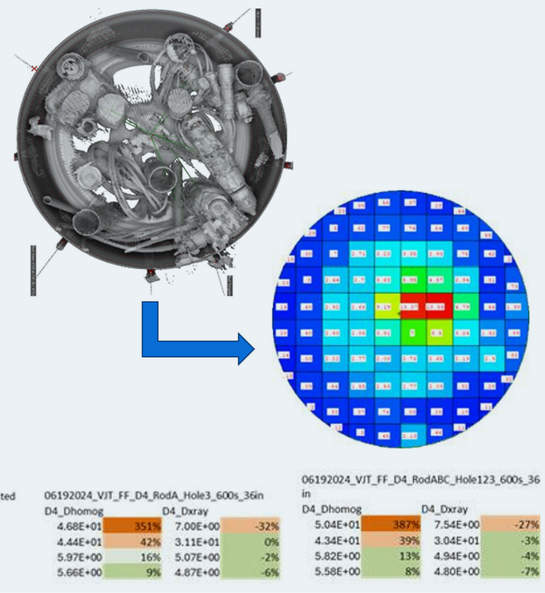
## 200L Results





| Voxel | Material | Av. density |
|---|---|---|
| 25 | mat007 | 0.1998 |
| 26 | mat009 | 4.6694 |
| 27 | mat010 | 1.5189 |
| 28 | mat011 | 0.2007 |
| 29 | mat012 | 0.2121 |
| 30 | mat013 | 0.2008 |
| 31 | mat014 | 3.4089 |
| 32 | mat015 | 1.6478 |
| 33 | mat006 | 0.2 |
| 34 | mat016 | 0.4066 |
| 35 | mat017 | 0.3316 |
| 36 | mat018 | 1.0139 |
| 37 | mat019 | 1.0484 |
| 38 | mat006 | 0.2 |
| 39 | mat006 | 0.2 |
| 40 | mat020 | 0.4629 |

| Material number | Wgt composition |
|---|---|
| mat006 = | matrix:100% |
| mat009 = | lead:97.56%<br>matrix:2.44% |
| mat010 = | lead:88.53%<br>matrix:11.47% |
| mat012 = | dryair:0.28%<br>copper:5.75%<br>matrix:93.97% |



| | Corrected | 06192024_VJT_FF_D4_RodA_Hole3_600s_36in | | | 06192024_VJT_FF_D4_RodABC_Hole123_600s_36 in | | |
|---|---|---|---|---|---|---|---|
| | | D4_Dhomog | | D4_Dxray | D4_Dhomog | | D4_Dxray |
| Am241 | 10.36 µCi | 4.68E+01 | 351% | 7.00E+00 -32% | 5.04E+01 | 387% | 7.54E+00 -27% |
| Ba133 | 31.22 µCi | 4.44E+01 | 42% | 3.11E+01 0% | 4.34E+01 | 39% | 3.04E+01 -3% |
| Cs137 | 5.152 µCi | 5.97E+00 | 16% | 5.07E+00 -2% | 5.82E+00 | 13% | 4.94E+00 -4% |
| Co60 | 5.184 µCi | 5.66E+00 | 9% | 4.87E+00 -6% | 5.58E+00 | 8% | 4.80E+00 -7% |

In the studied scenarios, the CT-informed SuperISOCS model significantly improved the accuracy of activity estimates, demonstrating the potential for matrix heterogeneity uncertainty reduction (to below 10% for $^{133}$Ba, $^{137}$Cs, $^{60}$Co) and TMU improvement.

## Discussion

The integration of X-ray CT with gamma NDA systems represents a significant advancement in waste characterization. By providing detailed spatial density information, CT scans eliminate the need for conservative assumptions and reduce reliance on transmission sources. This not only improves measurement accuracy but also enhances operational safety and efficiency. The approach is particularly valuable for complex or poorly characterized waste streams, where traditional methods fall short. Furthermore, the ability to automate voxel extraction and modeling opens the door to high-throughput, operator-independent analysis.

Ongoing steps are the performance validation of the technique over a broader range of configurations and the deployment at a test customer site.

Additionally, the feasibility of integrating CT voxel data into TGS algorithms is currently explored, aiming to reduce the need for high-activity transmission sources.

## Conclusions

X-ray CT, when combined with SuperISOCS and NDA systems, offers a powerful toolset for improving the accuracy and reliability of gamma NDA measurements. The methodology has been preliminarily tested through both experimental and simulated studies, showing substantial reductions in uncertainty and potential cost savings in waste classification.

Future work focus on full automation of the CT-to-modeling pipeline and broader deployment in customer environments.

### References


1. ISOCS-Based Extended In Situ Gamma Spectrometry Services Tool SuperISOCS for waste Measurements, L. Leong, P. Chard, S. Philips, J. Beaujoin, D. Sullivan, C. Binnersley, M. Rushby, P. Couturier, Proceedings of the Waste Management Symposium, Phoenix, Arizona, 8 – 12 March 2021.
2. Integration of X-Ray Computer Tomography with Gamma Spectroscopy: Applications and savings for complex waster management challenges, P. Chard, L. Leong, A. Baldwin, S. Halliwell, R. Maziuk and S. Philips, Poster presented at the Waste Management Symposium, Phoenix, Arizona, 26 February - 2 March, 2023.


VJTechnologies

MIRION TECHNOLOGIES

www.mirion.com