

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

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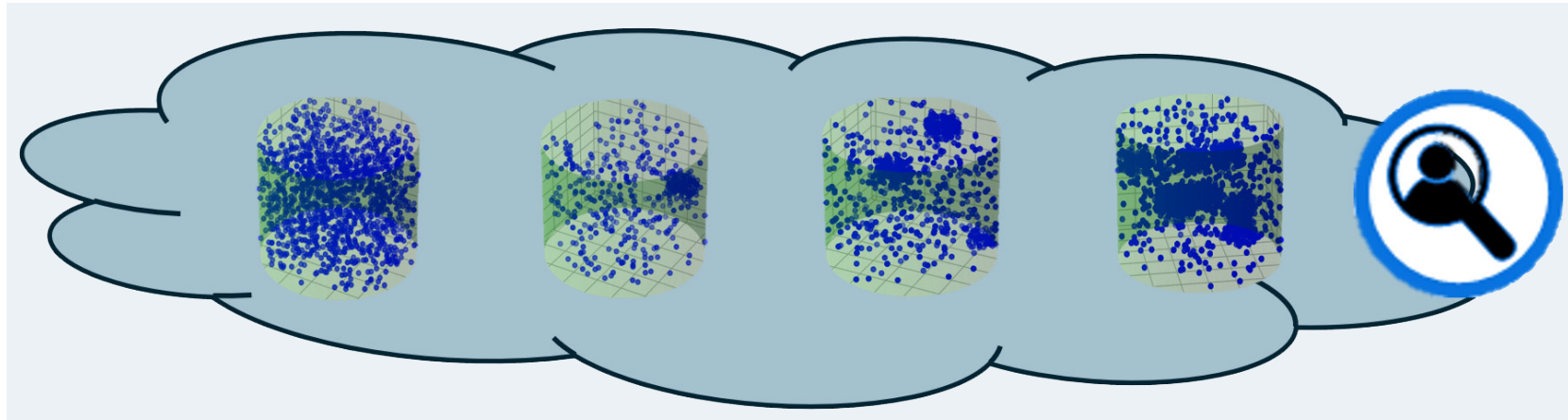
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Abstract

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.



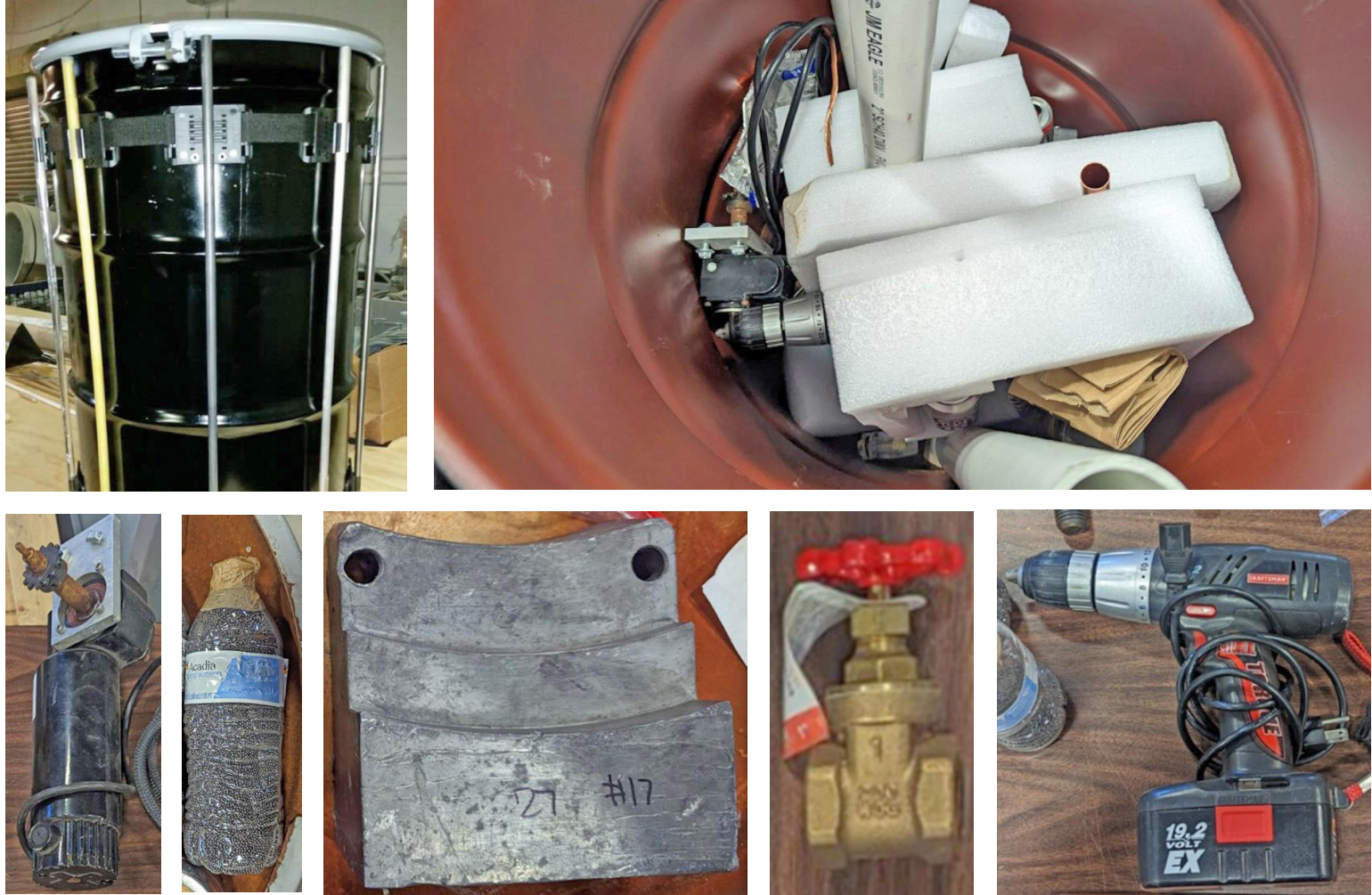
These assumptions often lead to conservative estimates and over-declaration of activity, especially when Acceptable Knowledge (AK) is limited. More advanced systems, such as SGS and TGS systems, usually require radioactive transmission sources to improve the drum content information (averaged layer attenuation 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 6MeV system and then measured with a Far-Field system.

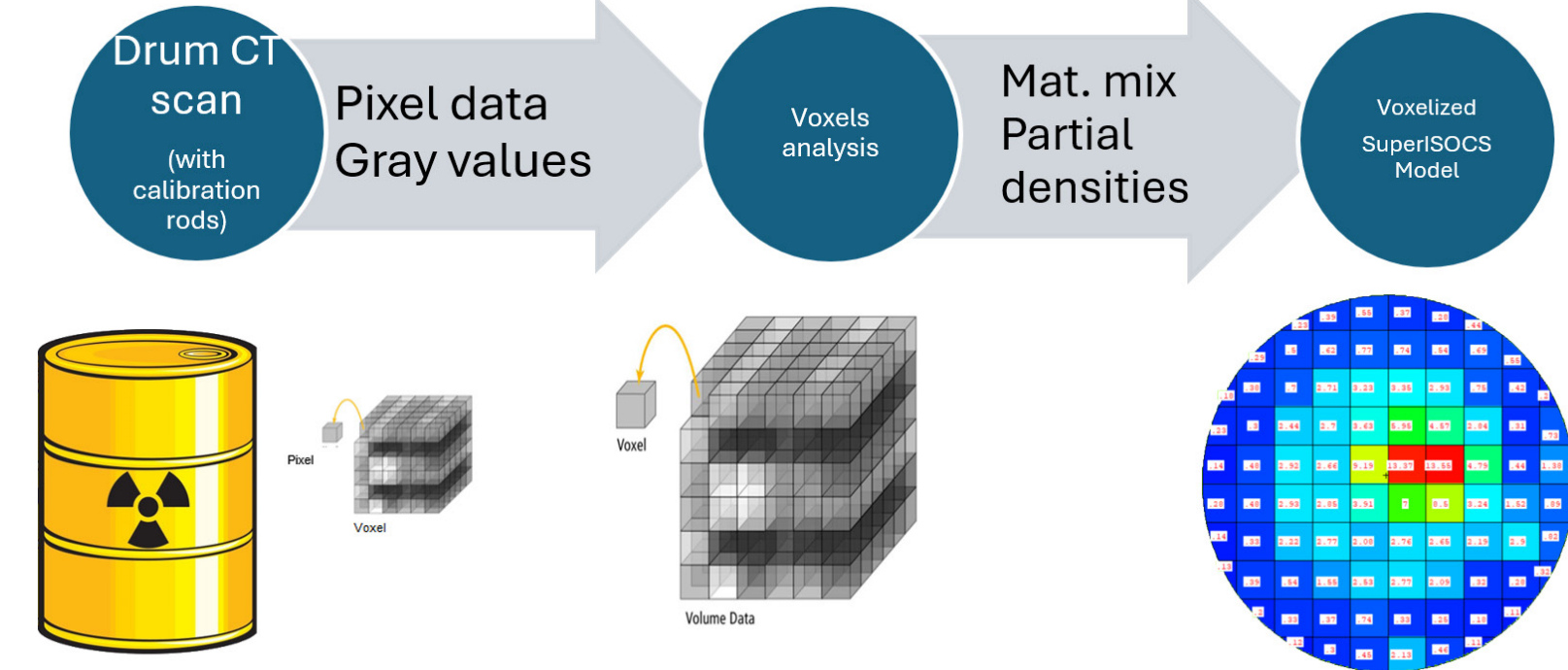
Test drum Creation & Scan



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.

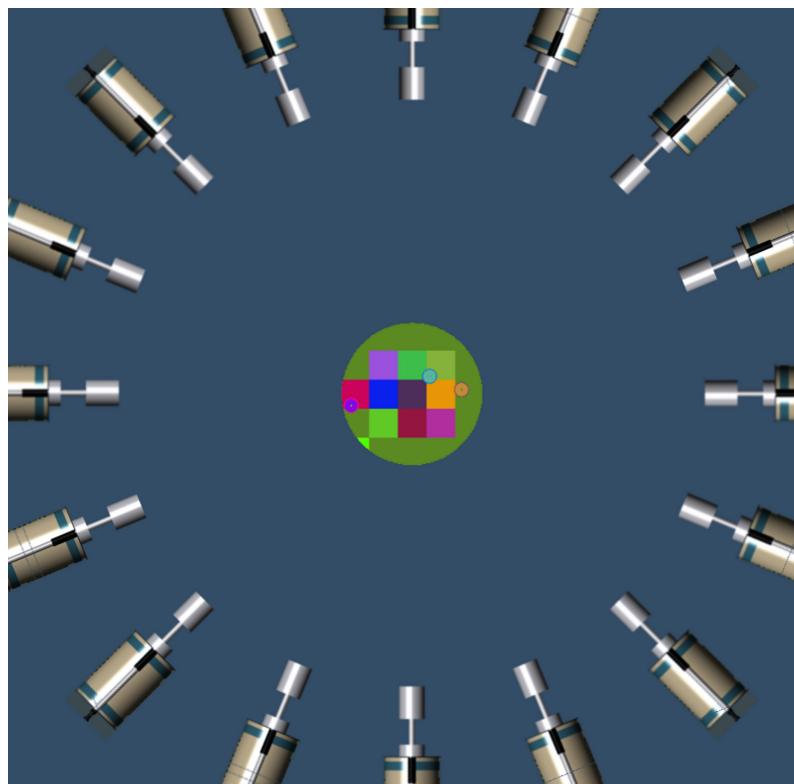
Radioactive point sources and line sources were positioned at set of various positions in the drum to reproduce multiple configurations during the gamma spectroscopy measurements. One measurement results is presented in this poster:

- Three line sources of similar activities positioned at 3 radii (A-B-C holes in picture below) to simulate source homogeneity.

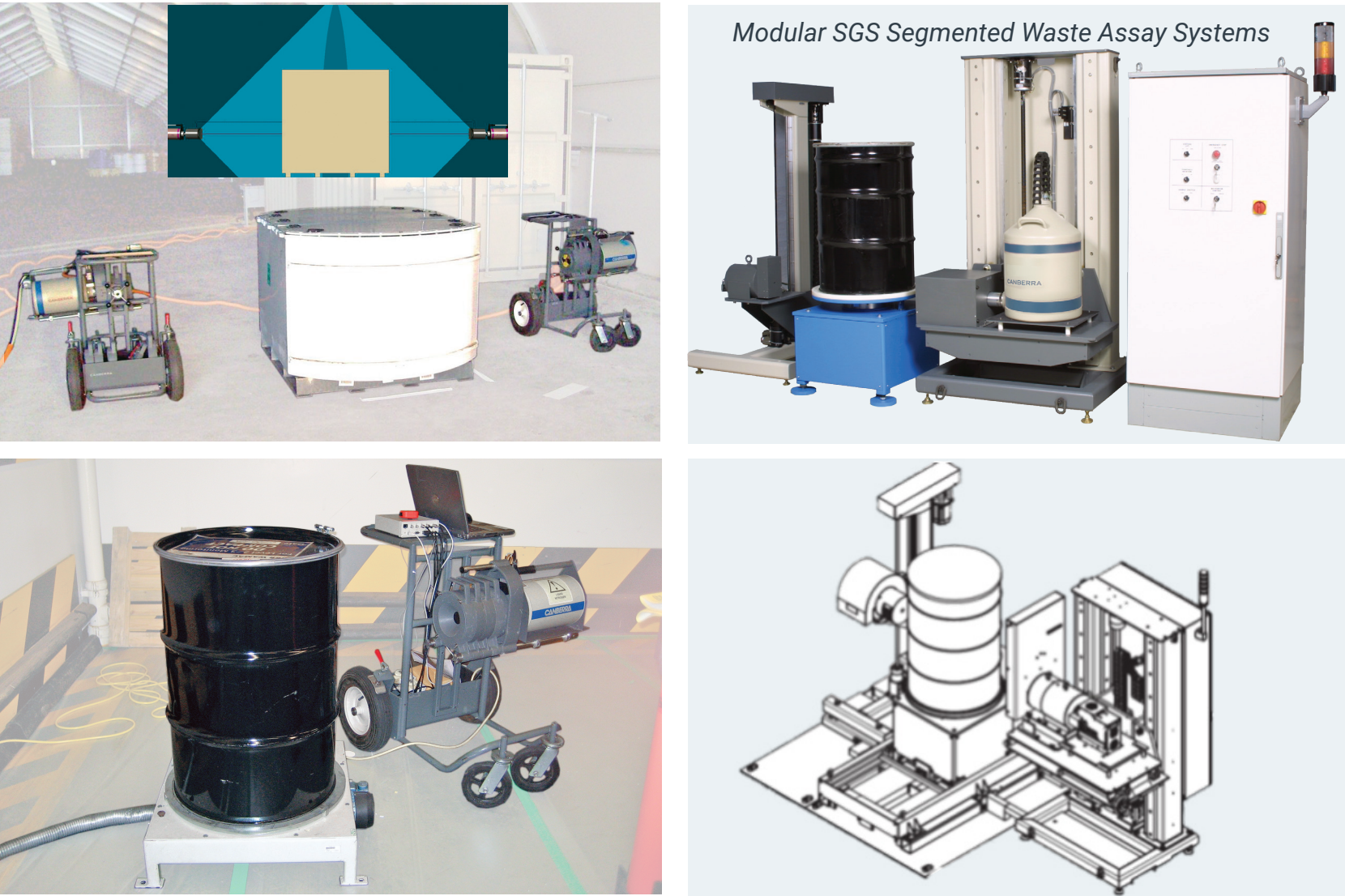


A 3D density map was then generated from the CT scan, integrated in a SuperISOCS template and used to simulate the detection efficiencies of the spectroscopy measurement.

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

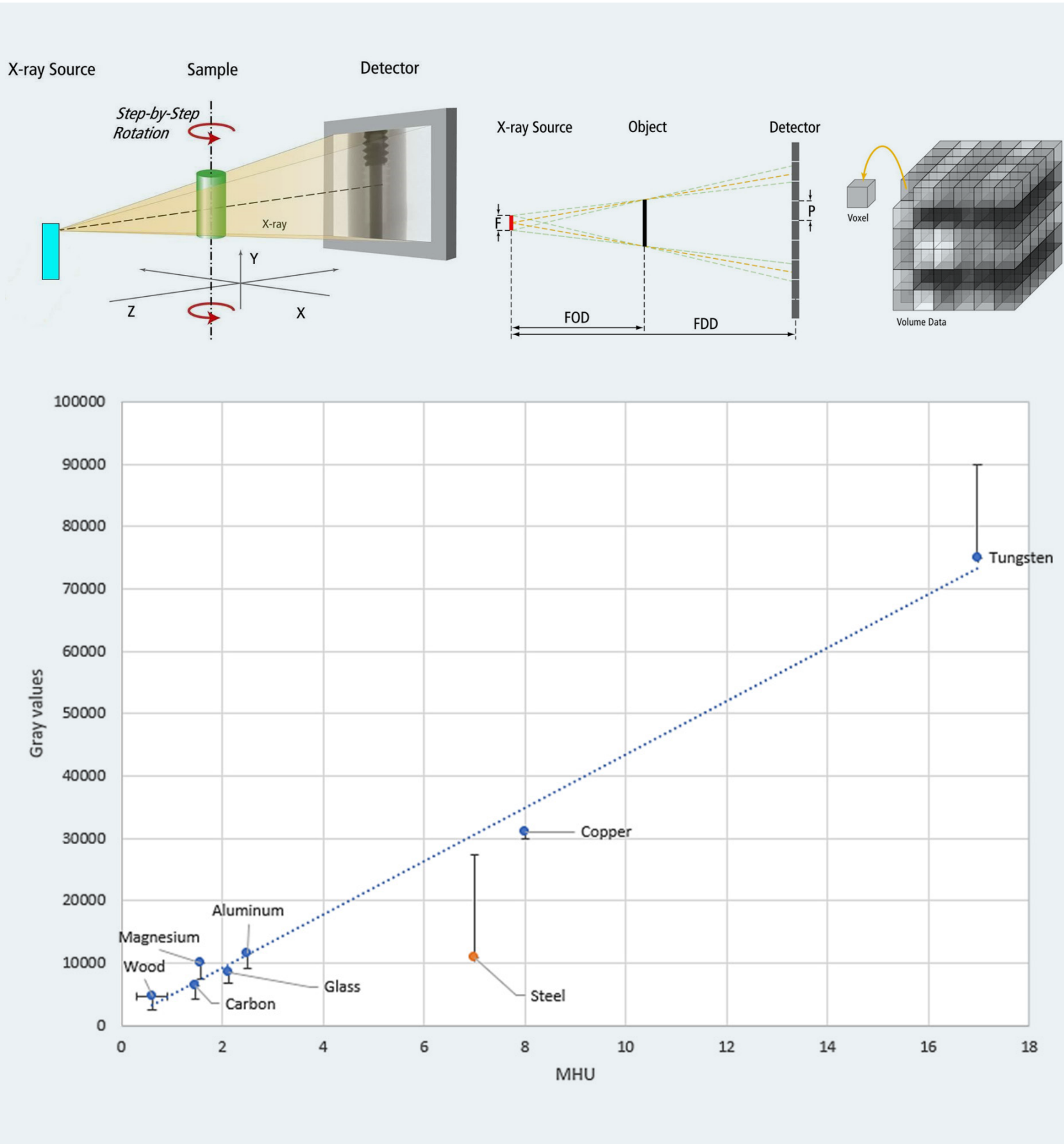


NDA Systems

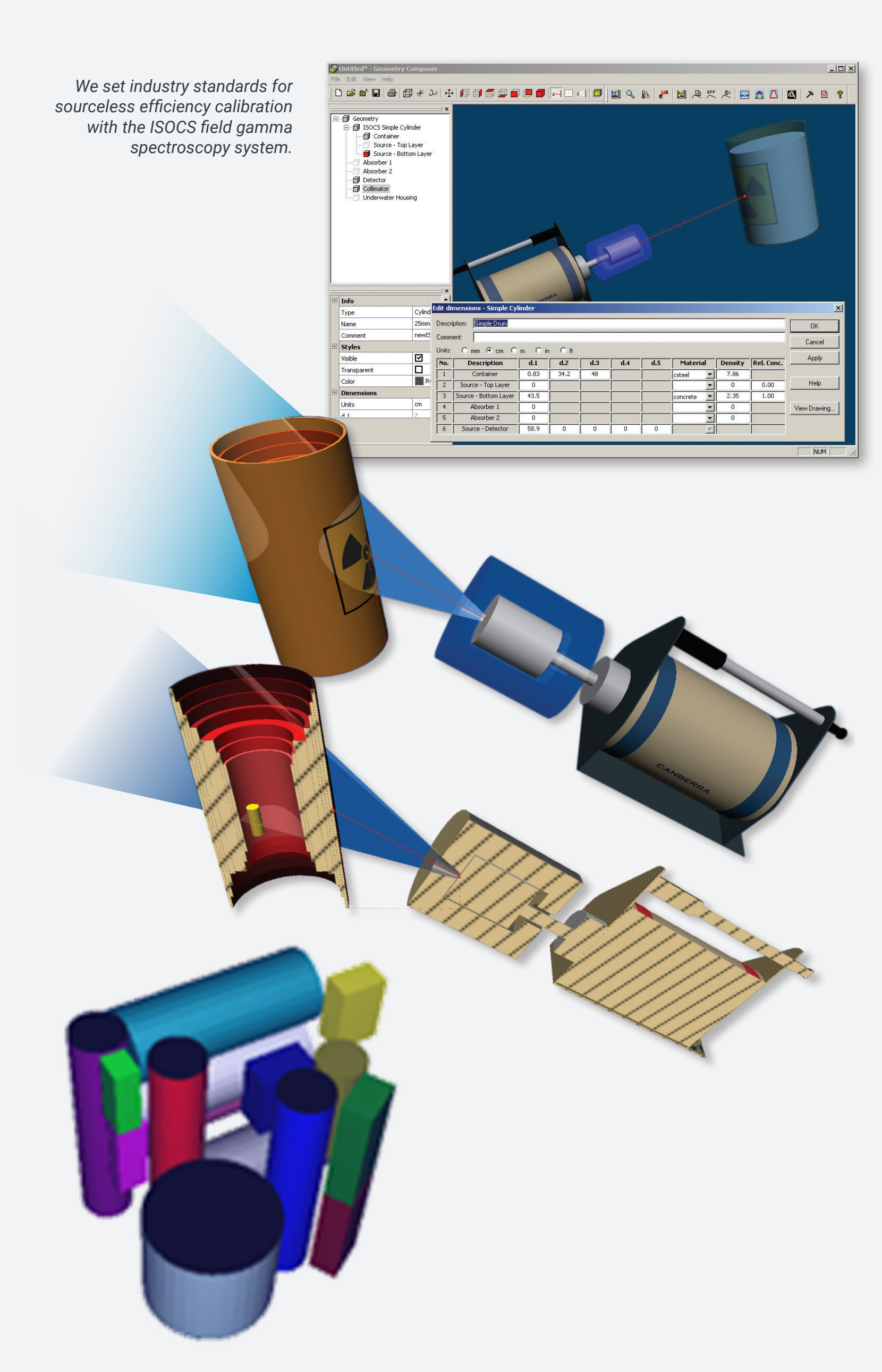


TMU (Total Measurement Uncertainty)

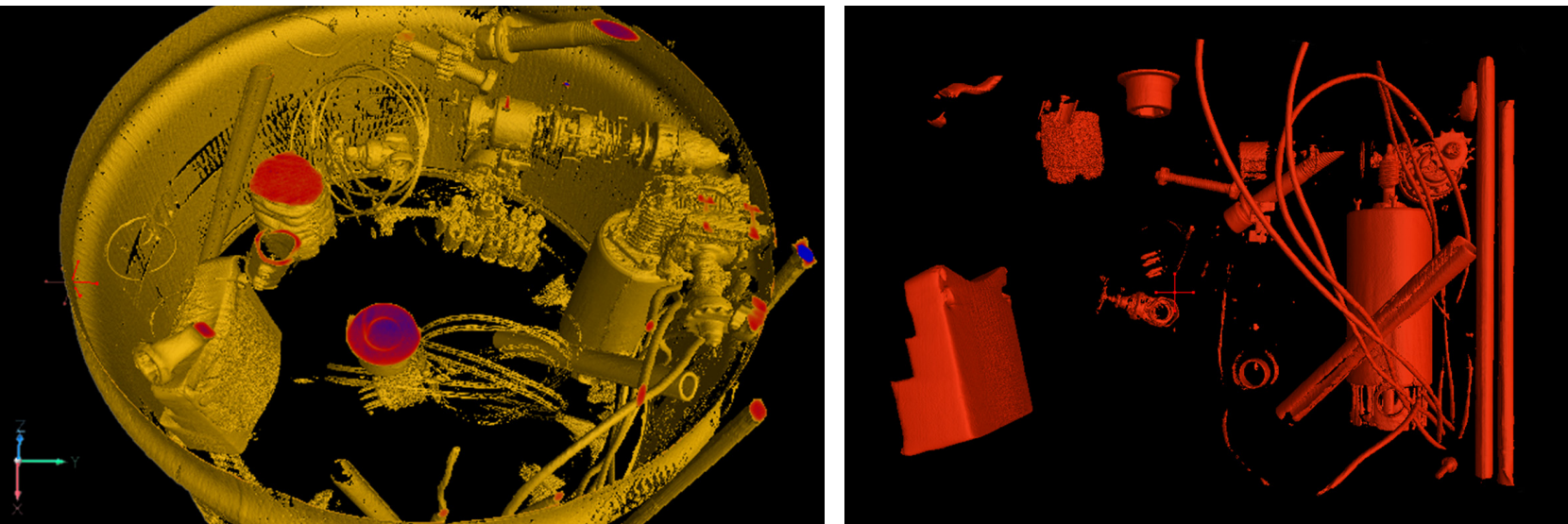
X-Ray CT – density evaluation



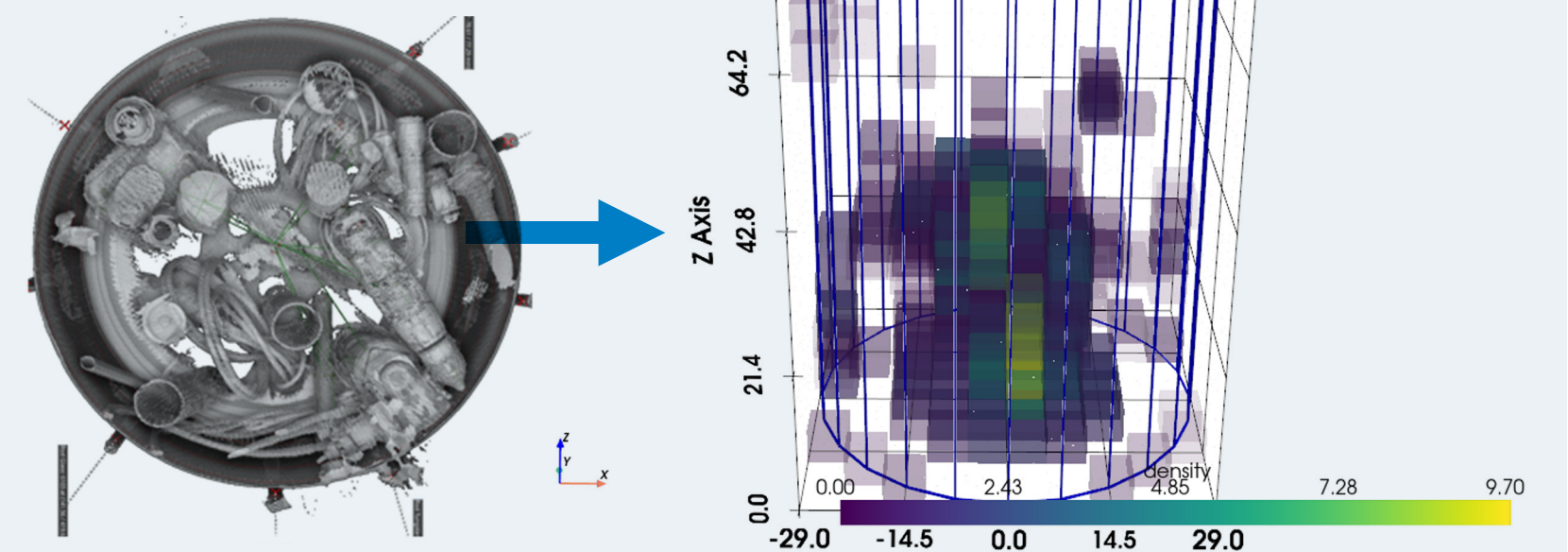
ISOCS/SuperISOCS



200L Results



Voxel	Material	Av. density	Material number	Wgt composition
25	mat007	0.1998	mat006 =	matrix:100%
26	mat009	4.6694	mat009 =	lead:97.56%
27	mat010	1.5189	mat010 =	matrix:2.44%
28	mat011	0.2007	mat010 =	lead:88.53%
29	mat012	0.2121	mat010 =	matrix:11.47%
30	mat013	0.2008	mat012 =	dryair:0.28%
31	mat014	3.4089	mat012 =	copper:5.75%
32	mat015	1.6478	mat012 =	matrix:93.97%
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		



Voxel grid		5x5x10 with EG-Line sources modelled	
Source distribution		EG-Line sources	
RN	Certificate Activity [Bq]	Activity [Bq]	Rel. deviation to certif. value
241Am	1.15E+06	1.46E+06	27%
133Ba	3.47E+06	3.69E+06	7%
137Cs	5.72E+05	5.95E+05	4%
60Co	5.75E+05	5.89E+05	2%

Matrix distribution		Homogeneous density (1x1x1)		XCT data (5x5x10)	
Source distribution		Volumetric average		Volumetric average	
RN	Certificate Activity [Bq]	Activity [Bq]	Rel. deviation to certif. value	Activity [Bq]	Rel. deviation to certif. value
241Am	1.15E+06	8.46E+06	636%	1.30E+06	13%
133Ba	3.47E+06	5.26E+06	52%	3.70E+06	7%
137Cs	5.72E+05	7.15E+05	25%	6.05E+05	6%
60Co	5.75E+05	6.65E+05	16%	6.04E+05	5%

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 ¹³³Ba, ¹³⁷Cs, ⁶⁰Co) 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 has been manually demonstrated recently. But performance and automation remain to be explored.

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

- 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.
- Integration of X-Ray Computer Tomography with Gamma Spectroscopy: Applications and savings for complex waste management challenges, P. Chard, L. Leong, A. Baldwin, S. Halliwell, R. Mazziuk and S. Philips, Poster presented at the Waste Management Symposium, Phoenix, Arizona, 26 February - 2 March, 2023.