Non-Destructive Assay Techniques for Characterization of Radioactive Waste

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MIRION
TECHNOLOGIES

Radioactive Waste Characterization Introduction

- Characterization is the identification of type of waste and quantification
- Why?
  - Determination of the next step in the waste treatment
  - Determination of where the waste must be sent
  - Documentation (for future)
  - Long-term planning
- Summary objective: Volume reduction and cost reduction

Agenda

- Non-Destructive Assay (NDA) Introduction
- Impact of Accuracy and Uncertainty
- NDA techniques
- Measurement Uncertainty and Calibration choices
- Summary

NDA = Non-Destructive Assay

Benefits/Value of NDA:

- Reduces risk of spreading radioactive/contaminated materials – Safety/Environment/cost
- Reduces labor → Lowers cost
- Reduces measurement time → Lowers cost

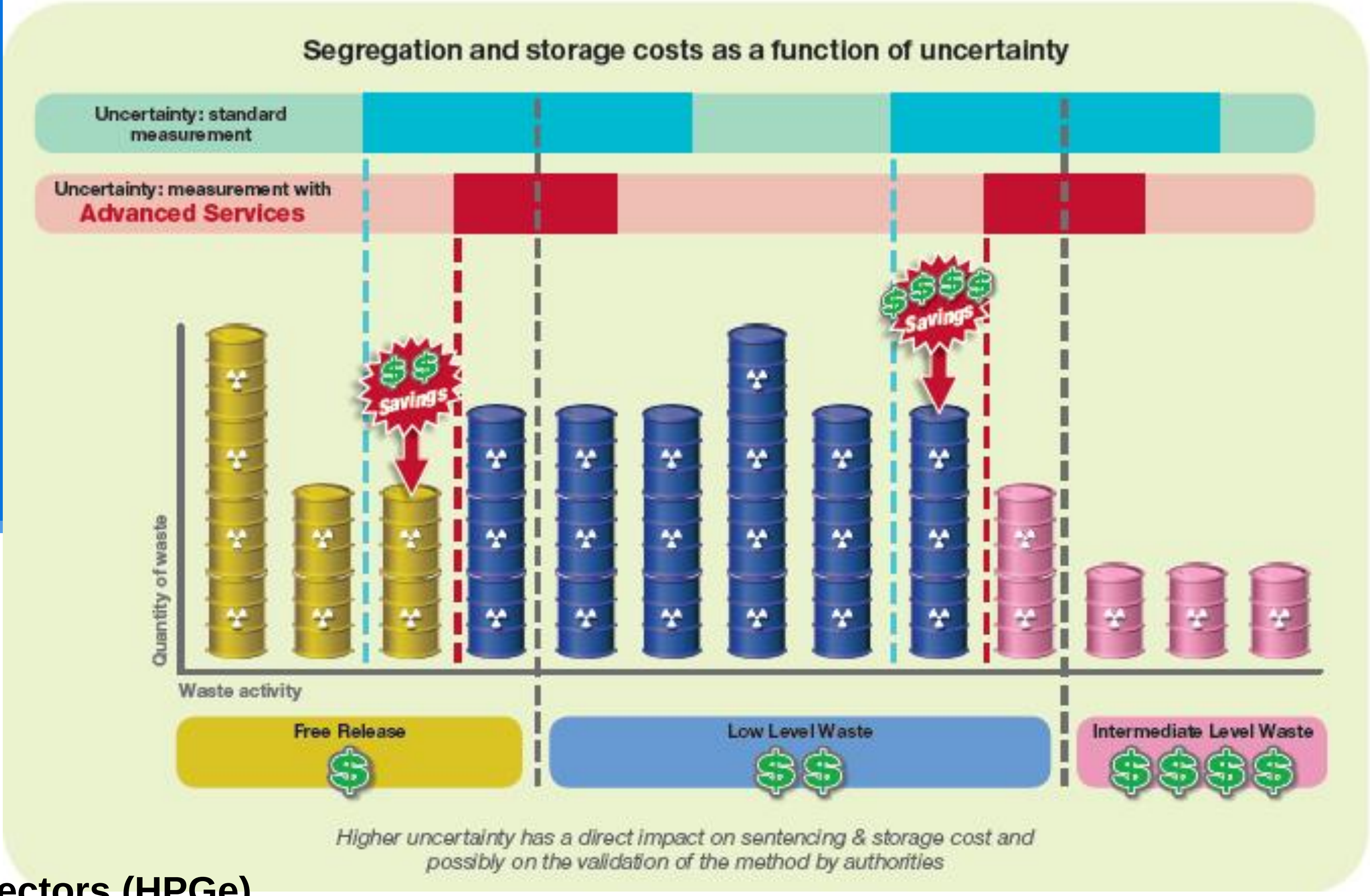
NDA Requirements

Measurement requirements for NDA:

- Validation and proven experience of analysis and algorithms → to obtain an accurate result
- High dependance on calibration
- Good quantification of uncertainty
- Quality requirements for convincing regulators of results

Impact of Accuracy and Uncertainty

- **Impact on costs and planning**



Higher uncertainty has a direct impact on sentencing & storage cost and possibly on the validation of the method by authorities

High-Purity Germanium detectors (HPGe)

NDA Techniques

Depends on:

- Origin of the waste (waste type; what process)
- How it is packaged – Homogeneous, heterogeneous, partially filled
- Container type – 200 L drum, drum overpack, small cans, boxes
- Activity level – Low or High
- "Throughput" – How many containers per day ← Manual or automated loading
- Other logistics considerations (space, environment)

Different Methods:

- *Static measurements*
- *Scanning measurements*

Static Measurements

- Detector(s) do not move
- Drum may or may not rotate
- Example NDA systems: Q2, “Far-field”

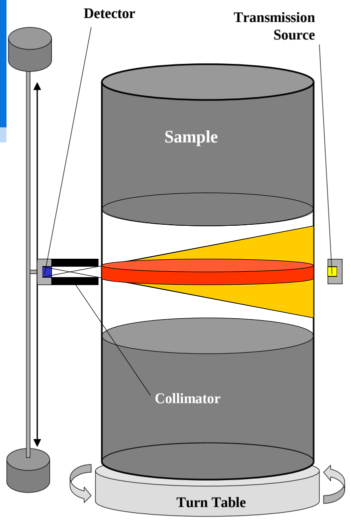
- Low-level waste and confirmation of free release (“clearance”)
- Sensitivity (fast, easy) is more important than accuracy and uncertainty reduction

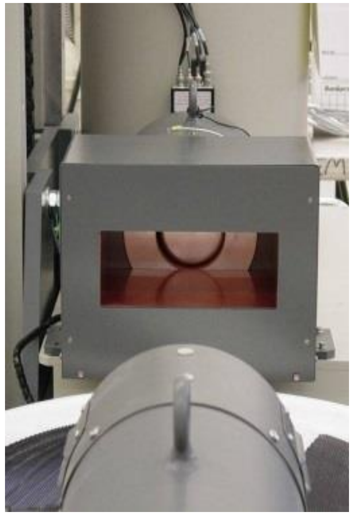
Segmented Scanning

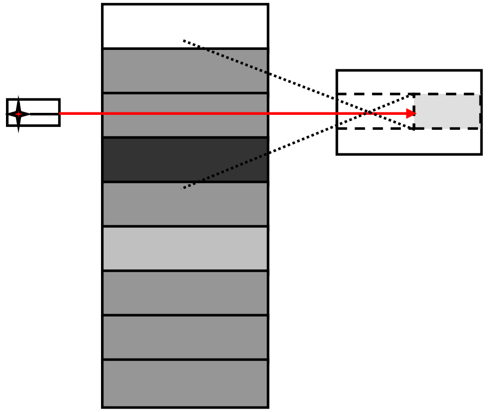
- The detector scans vertically
- The drum rotates
- Example NDA systems: Standard SGS, Modular SGS
  - When radioactive material vertically stratified
  - Wen sample matrix has vertical density variations
  - Accurately quantifies waste activity for disposition
  - Lowers uncertainty

Segmented Scanning Method

- By design & methodology the system improves accuracy
- Segmentation for stratified activity
- Transmission measurement for density variations
- Calibrations can still be based on standards
- Modeled calibration tools offer more flexibility

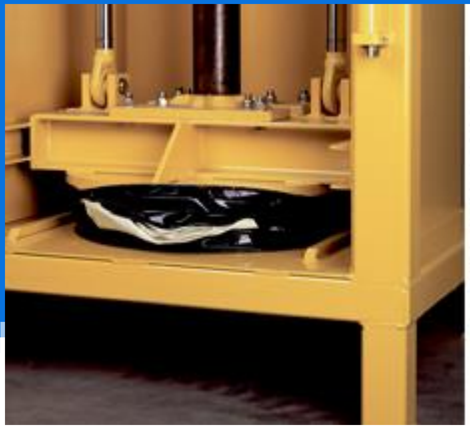


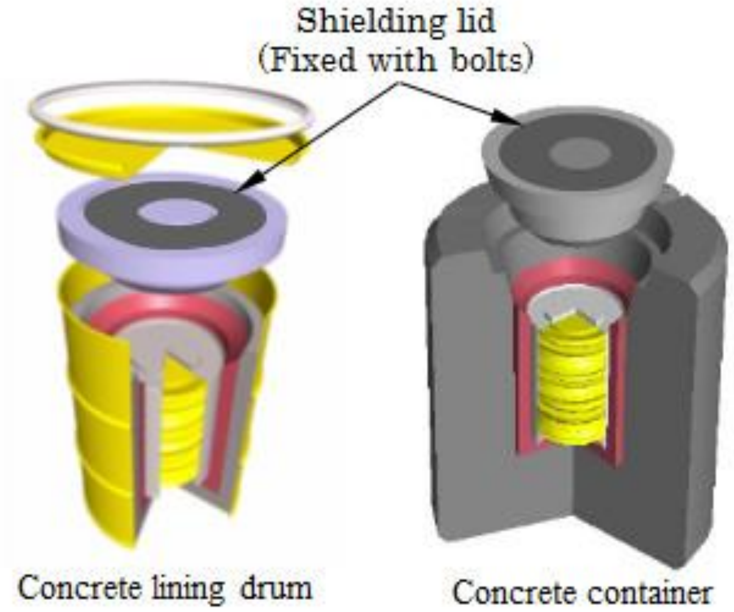




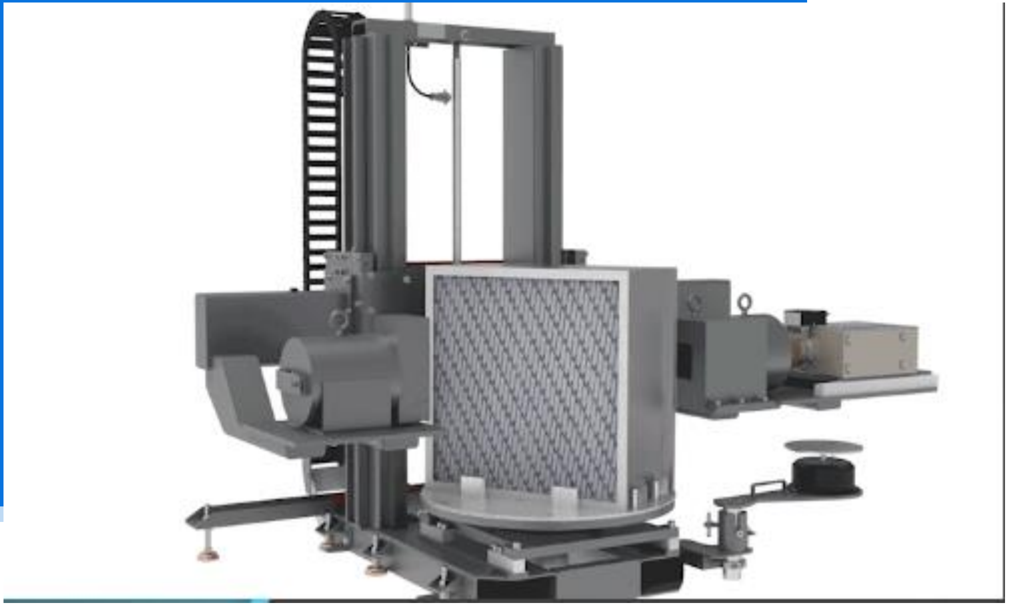
Segmented Scanning for more extreme situations

- Compacted drums
- Overpack drums
- Combination of SGS technique and ISOCS calibrations is the most powerful approach





SGS Flexibility



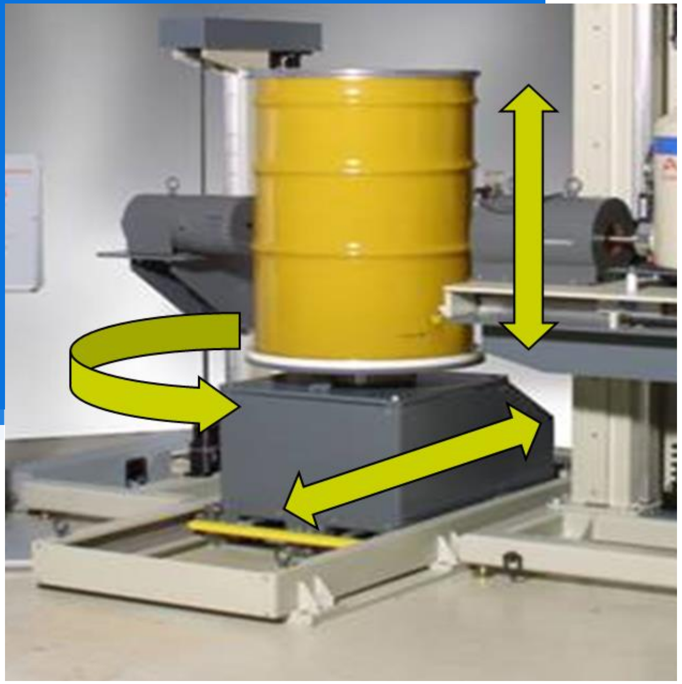
- Can be calibrated for other geometries
  - Examples: HEPA filters, Smaller drums, cans
- Transmission source can be used for fill-height estimation – eliminates bias from assuming uniformly filled drums
- Stronger transmission source can be used for high-density samples
  - Example: Concrete lined drums, HDPE HIC

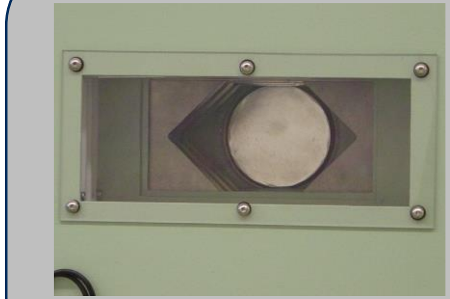
Tomographic Gamma Scanning (TGS)

- The detector scans vertically
- The drum rotates and translates
    - When the radioactive material is non-uniformly distributed in the sample; hot spots
    - When the sample matrix is inhomogeneous (void spaces) and has large density and material variations

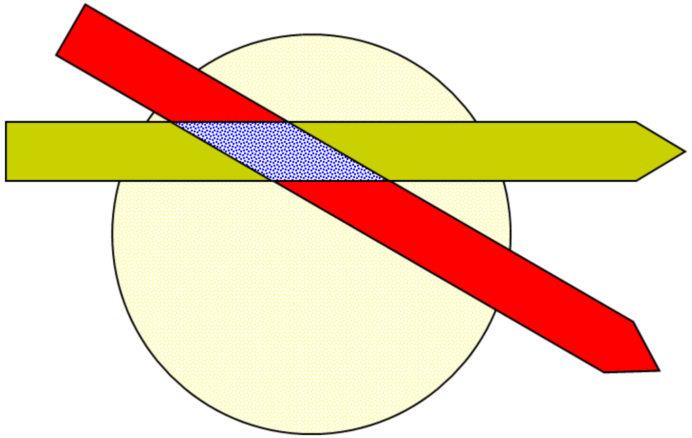
TGS Scanning Protocol

- For each detector height (segment), the drum simultaneously rotates and translates
- For each segment several ray-projections are generated from different overlapping perspectives
- Each segment is then composed of several volume elements ("voxels")



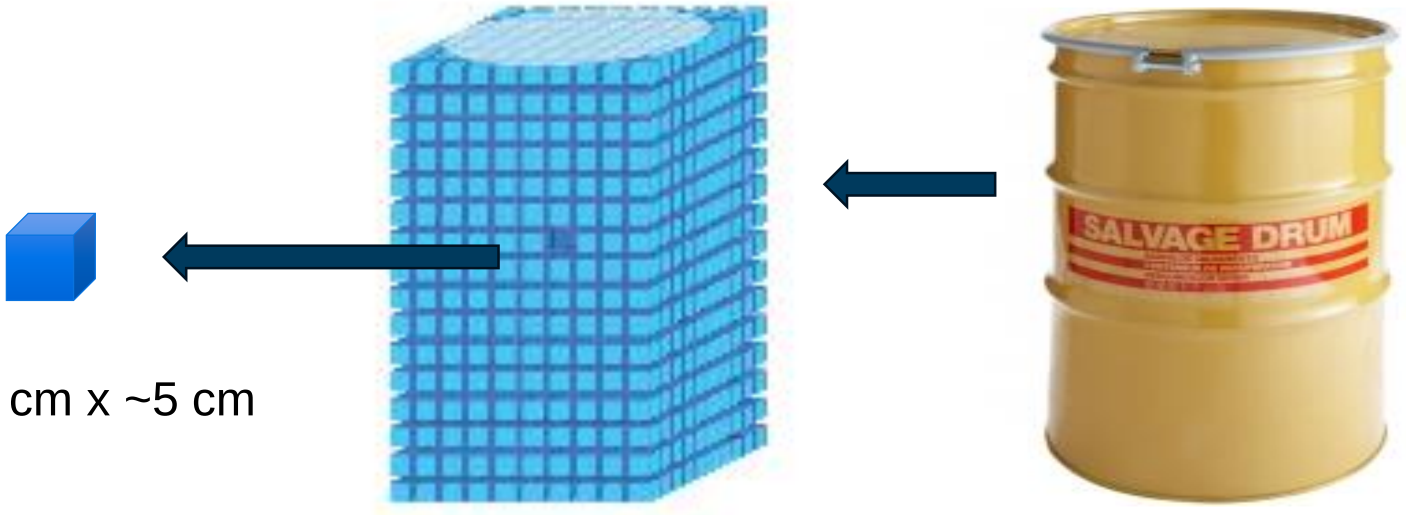


SGS mode



TGS Analysis

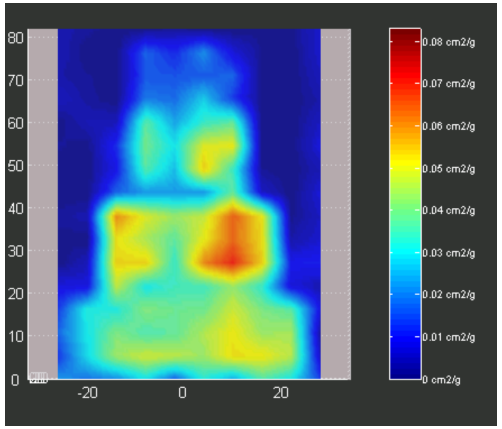
- The matrix is analyzed as a stack of cubes (voxels)
- Each voxel can be different from all others in material, but inside a voxel the matrix & activity is assumed to be constant
- The 200 L (55 gal.) has 10 × 10 × 16 discrete voxels

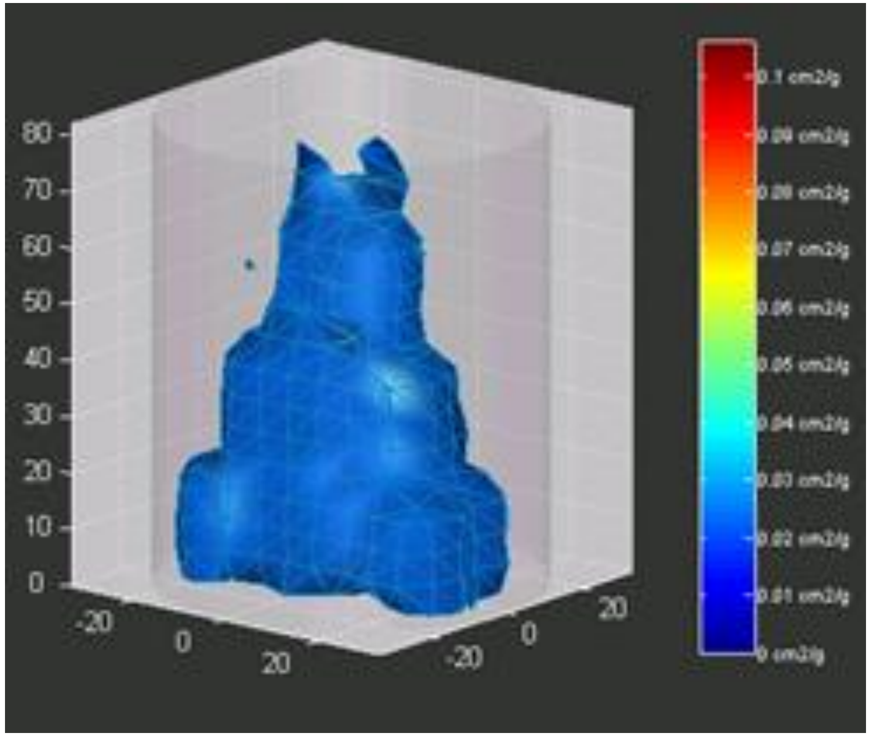


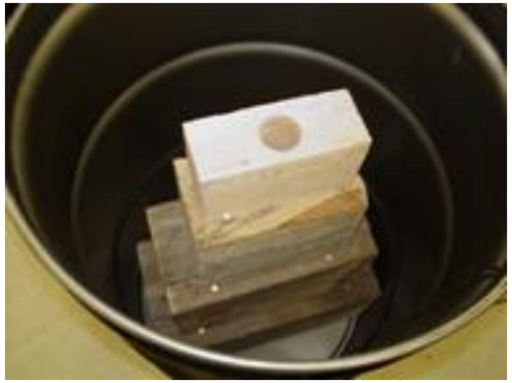
~5 cm x ~5 cm x ~5 cm

TGS Results – Sample Matrix

- **False Color Transmission-measurement rendering**

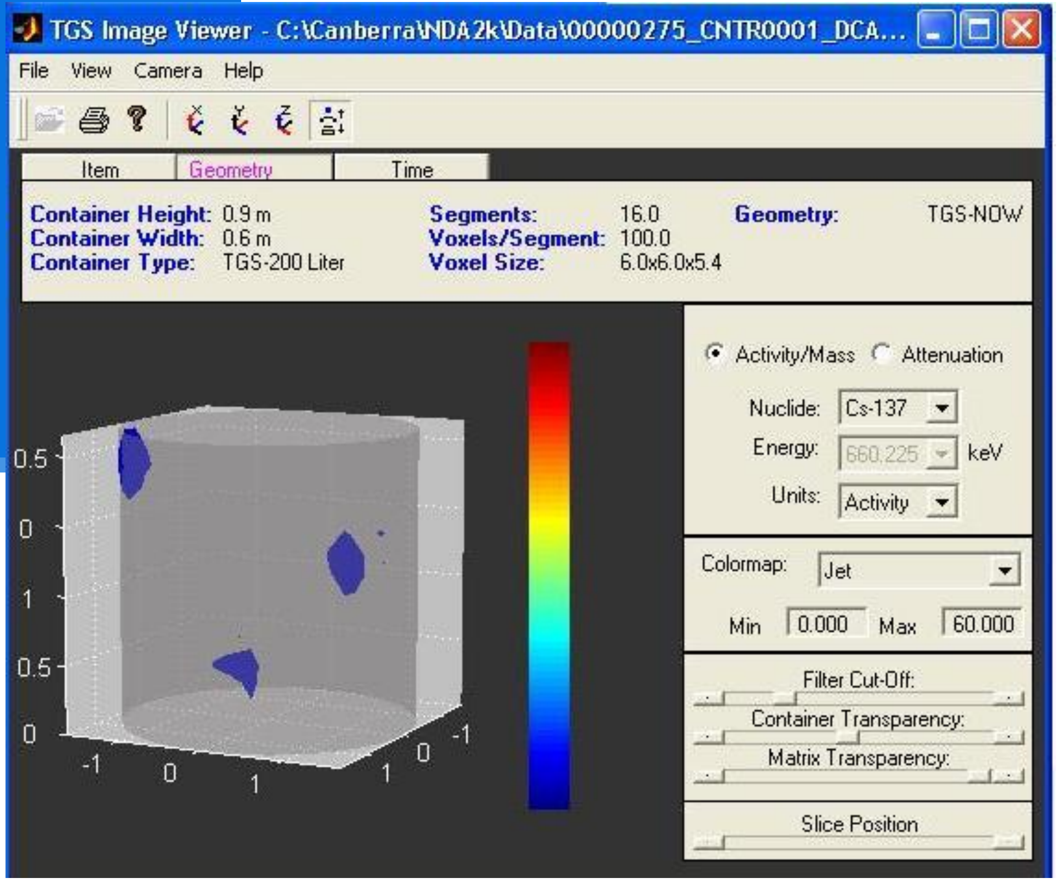






TGS Results – Point Sources

- **Emission measurement image:**
- **Three ^{137}Cs Point Sources (~60 mCi each) in a 200-liter Drum with homosote (0.7 g.cm^{-3}) sample matrix**



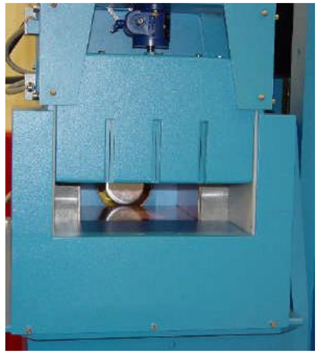
TGS Image Viewer - C:\Canberra\NDA2k\Data\00000275_CNTR0001_DCA...

Container Height: 0.9 m
Container Width: 0.6 m
Container Type: TGS-200 Liter
Segments: 16.0
Voxels/Segment: 100.0
Voxel Size: 6.0x6.0x5.4
Geometry: TGS-NOW

● Activity/Mass ○ Attenuation
Nuclide: Cs-137
Energy: 660.225 keV
Units: Activity
Colormap: Jet
Min 0.000 Max 60.000

High-Activity Measurements

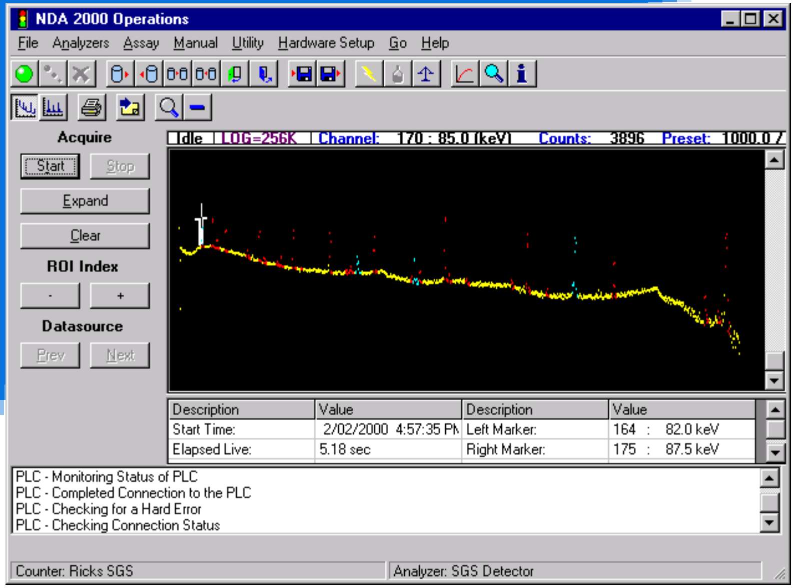
- **Automated collimators and attenuators**
- **Automated detector distance**
- **Positions based on dead-time or dose-rate**



Total Measurement Uncertainty (TMU)

- **TMU includes both random and systematic errors**
- **Systematic - Includes fixed (calibration) and varying (sample specific characteristics) uncertainties**
- **Sample-specific values are calculated in real time in the software analysis**

$$\sigma_{TMU} = \sqrt{\sigma^2_{calibration} + \sigma^2_{random} + \sigma^2_{source\ location} + \sigma^2_{matrix} + \sigma^2_{method}}$$



Idle | LOG=256K | Channel: 170 : 85.0 (keV) Counts: 3896 Preset: 1000.0 /

Description	Value	Description	Value
Start Time:	2/02/2000 4:57:35 PN	Left Marker:	164 : 82.0 keV
Elapsed Live:	5.18 sec	Right Marker:	175 : 87.5 keV

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PLC - Monitoring Status of PLC
PLC - Completed Connection to the PLC
PLC - Checking for a Hard Error
PLC - Checking Connection Status
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Counter: Ricks SGS

Analyzer: SGS Detector

Counting statistics

Source self-absorption

Source distribution

Calibration source errors

Matrix non-homogeneity

Isotopic measurement uncertainty

Calibration Approach

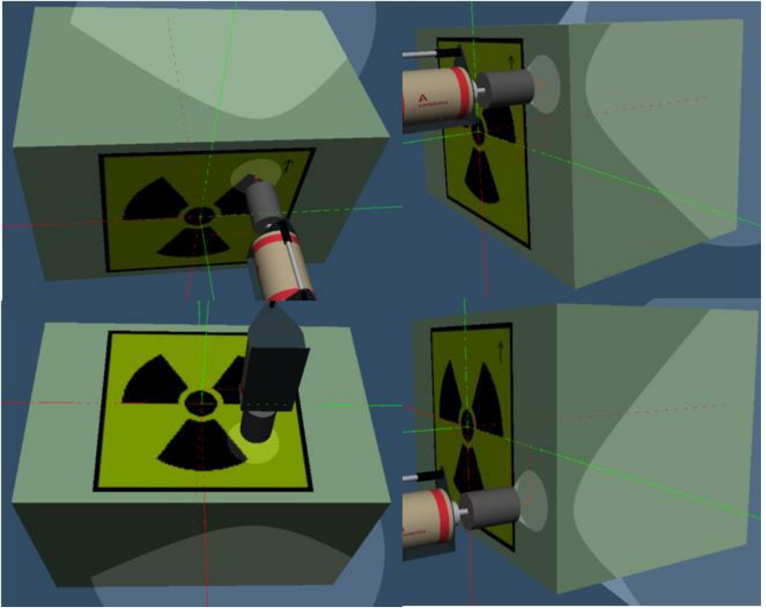
The initial calibration is generated at the factory in two possible ways:

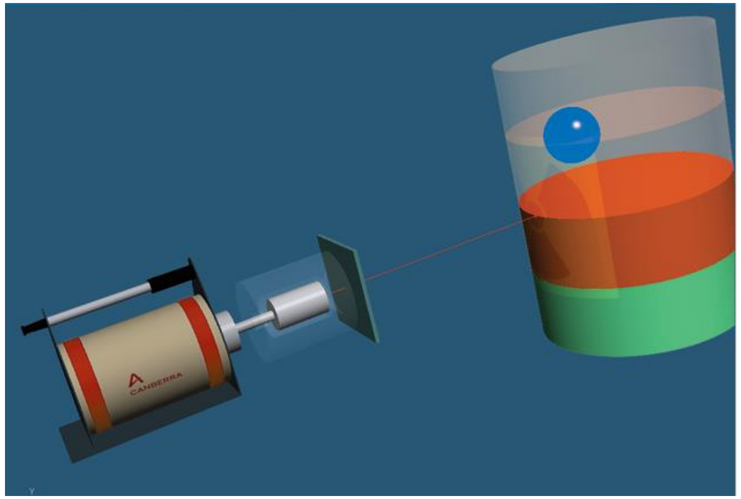
1. Measured - With calibration drum standards & multi-nuclide line sources
2. Mathematical Model –Monte Carlo, ISOCS™ (Mirion) approach

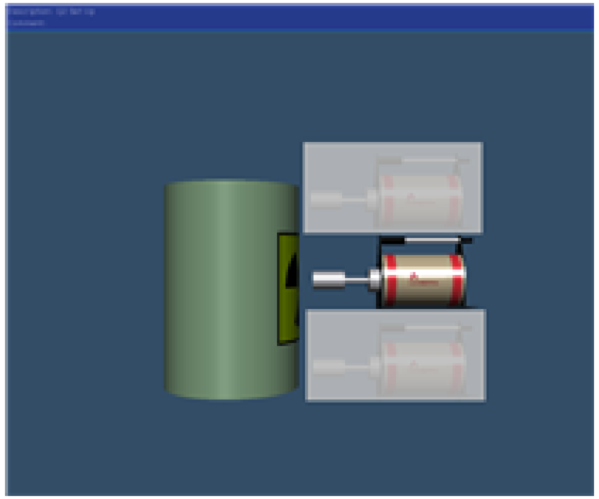
In either case verification measurements are made using factory drums & sources

ISOCS method

- Every detector gets a unique mathematical model
- Validated by MCNP and factory test measurements
- ISOCS software can generate many sample shapes, materials and densities, source locations, and detector positions
- Many decades of validation and excellent results







SUMMARY

- **Radioactive waste fundamental requirements – Volume reduction and cost reduction**
- **If you have accurate characterization you can use reduction techniques:**
  - **Consolidation (to increase activity content)**
  - **Compaction (direct volume reduction)**

- **NDA systems – Characterize a variety of wastes (loose, dry waste, resins and filters)**
- **NDA measurements have a high reliance on analysis algorithms and calibration to obtain accurate results**
- **Most challenging waste measurements have already been solved (or well bounded)**