MIRION Connect 21

Annual Users' Conference

Methods and Tools to Improve Characterization Accuracy for Challenging Legacy Waste from Projects and Measurement Services

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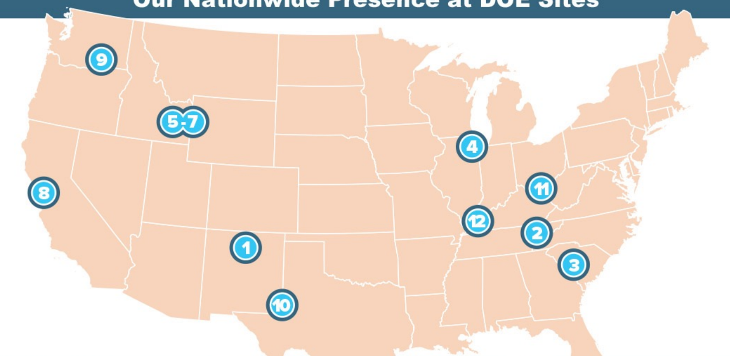
AGENDA

- Discussions For Today
- Introduction and Description of Measurement Services
- Technologies developed in Idaho to improve results and legacy measurements
- Systems and Technologies at SRS that involve specific requirements for accuracy regarding legacy waste
- Currently in development at Los Alamos to determine accuracy of large legacy waste containers.

Measurement Services Introduction

- Onsite measurements for several different sites across the United States
- Gamma spectroscopy performed at most of the Department of Energy Sites and others
- High activity measurements for fuel-based waste and process type waste at various sites
- Neutron measurements performed by the group as well.
- Combined measurements integrating gamma and neutron results .
- Experts all over the place for a number of special needs

Our Nationwide Presence at DOE Sites



1 LANL – New Mexico NDA and Service Personnel: 15	**5** AMWTP – Idaho NDA and Service Personnel: 9	**9** Hanford – Washington NDA and Service Personnel: 2
2 ORNL – Tennessee NDA and Service Personnel: 7	**6** NRF – Idaho NDA and Service Personnel: 1	**10** WCS – New Mexico & Texas NDA and Service Personnel: 2
3 SRS – South Carolina NDA and Service Personnel: 5	**7** INL – Idaho NDA and Service Personnel: 1	**11** Portsmouth – Ohio NDA and Service Personnel: 1
4 ANL – Illinois NDA and Service Personnel: 3	**8** LLNL – California NDA and Service Personnel: 6	**12** Paducah – Kentucky NDA and Service Personnel: 1

Mirion products used at some of these projects

NDA Systems:
ISOCS Systems
WRAP Gamma Systems
HENC System
Slab Counters
ISOCS Software
Gamma Counter
Q2 System
Hex Counter
SGS System
Neutron Multiplicity Counters
HENC System
Falcon 5000 Instrument
MILCC System

NDA WIPP Certified Equipment:
MILCC #1
MILCC #2
MILCC #3
MILCC #4
MILCC #5
HENC#1
HENC#2
HENC#3
SuperHENC#1
IQ3 System
IWAS Systems
SGRS
WAGS
ISOCS Software

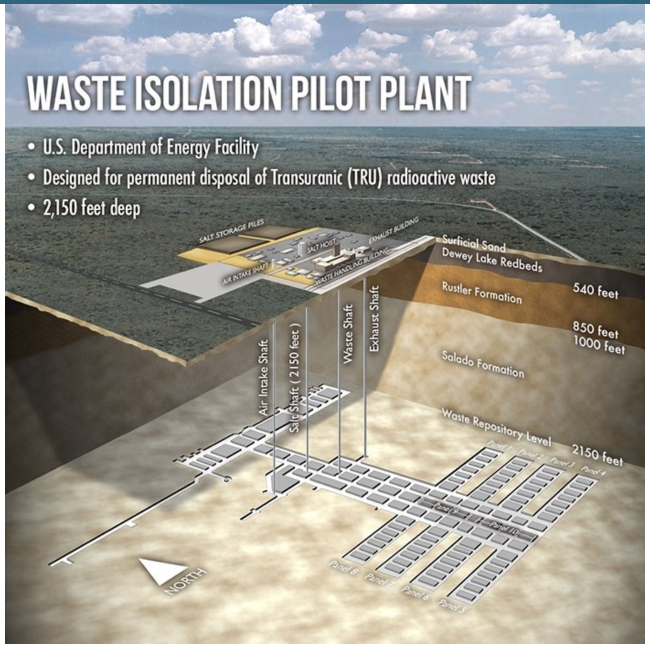
NDA Equipment:
ISOCS Software
Q2 System
SGS System
Box Counter
ISOCS Systems
Shuffler System
Slab Counters

WIPP Certified Equipment:
Osprey DTC

NDA Instrumentation

Current Contracts and Customers

- Largest Customer is the Waste Isolation Pilot Plant in Carlsbad, NM.
- URENCO
- AMWTP Idaho
- Livermore National Laboratory
- Nuclear Fuel Services
- Y-12 National Security Complex



Locations and Number of Employees

- Los Alamos NM 15 individuals supporting the site.
- Savannah River has 6 individuals supporting the site
- Oak Ridge 4 individuals supporting the site
- AMWTP Idaho 6 individuals supporting the site
- Livermore 4 individual supporting the site
- Skills include not only nuclear instrumentation measurements but site processes as well.

Work completed at sites since 1997

- The number of containers measured and emplaced at WIPP is approximately 265,202 total containers.
- We have **assayed more than 200,000 containers of TRU waste** destined for WIPP, representing approximately 75% of all waste placed in the underground
- Assay issues solved at a number of different sites.
- Total emplaced containers shown to right
- Mirion has measured most of these as stated above and has worked at each site
- All containers at LANL and SRS were measured on Mirion systems.
- Majority of waste at INL was measured on Mirion systems.

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Certifier Site	Payload Cntrs	Waste Cntrs
ANL-E	553	977
BAPL	5	15
HANFORD	14,132	16,789
INL	88,690	134,260
LANL	22,345	28,163
LLNL	1,308	1,319
NTS	1,819	1,860
ORNL	5,757	5,908
RFETS	40,548	40,588
SNL/NM	19	33
SRS	12,120	35,183
VNC	32	94
WIPP	21	13
Total:	187,349	265,202

Specific Tasks Performed by Measurement Services

- Gamma spectroscopy
- Neutron measurements
- ISOCS modeling for several different applications
- SISOCS modeling if modeling is required beyond the basic ISOCs templates
- NDA 2000 experts and ability to setup most NDA systems.
- Individuals with significant amount of Genie knowledge
- Ability to interact with government agencies such as the EPA and DOE
- Procedure development and assistance with certain parts of readiness assessments for NDA equipment.

Largest Customer WIPP and Appendix A

- What are some of the basic requirements we must follow for our work. One of the requirements is confirmation of calibrations.
- In order to confirm that the calibration of a modality (e.g., a gamma efficiency curve) of an NDA system was correctly established, the accuracy and precision of the system are determined after each calibration or re-calibration. Accuracy and precision for fixed geometry systems are determined by performing replicate measurements of an appropriate surrogate matrix selected from within the expected operating range of the calibration being confirmed.
- Interpretation was each calibration performed needed a confirmation performed each time with a similar matrix as to what was being measured.

Largest Customer WIPP and Appendix A

- What are some of the basic requirements we must follow for our work. One of the requirements is confirmation of calibrations.
- In order to confirm that the calibration of a modality (e.g., a gamma efficiency curve) of an NDA system was correctly established, the accuracy and precision of the system are determined after each calibration or re-calibration. Accuracy and precision for fixed geometry systems are determined by performing replicate measurements of an appropriate surrogate matrix selected from within the expected operating range of the calibration being confirmed.

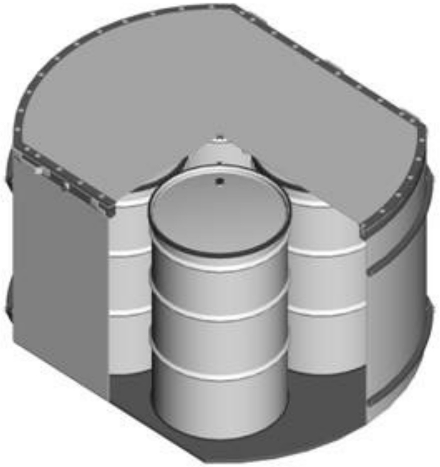
Largest Customer WIPP and Appendix A Cont.

- What are some of the basic requirements we must follow for our work? One of the requirements is the basic accuracy requirements for the calibration as well.
- Accuracy is reported as percent recovery (%R). Accuracy shall be 100% ± 10%. The justification for accuracy outside of the 90% - 110% range will be documented. For gamma systems, the accuracy shall be calculated for each useable gamma energy line over the calibration range. The accuracy for each line shall be 100% ± 10%. The justification for not using certain gamma lines due to matrix density, filter density, or attenuation will be documented. Precision is reported as percent relative standard deviation (%RSD)
- Can be difficult to meet for most matrices over a significant range of energy lines.

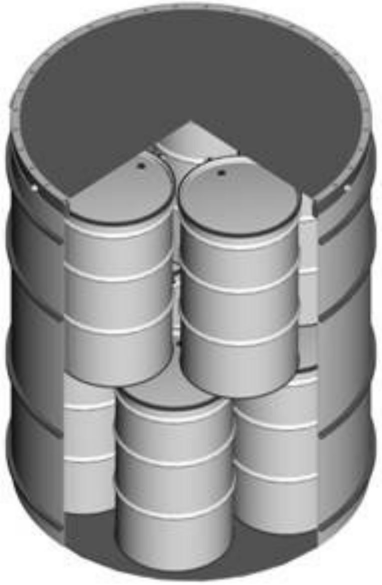
Solution for Containers and meeting requirements (Gamma)

- Predefined efficiency calibrations were difficult to meet requirements for several containers.
- Applying a different analysis method was needed to provide the needed accuracy for the data quality objectives.
- NDA2000 already used onsite at Idaho so the question was how to perform efficiency calibrations.
- Integration of ISOCS into NDA2000 to improve Accuracy.
- How to meet the calibration confirmation portion of the WAC
- Figure of Merits (FOM)

55-Gallon Drum



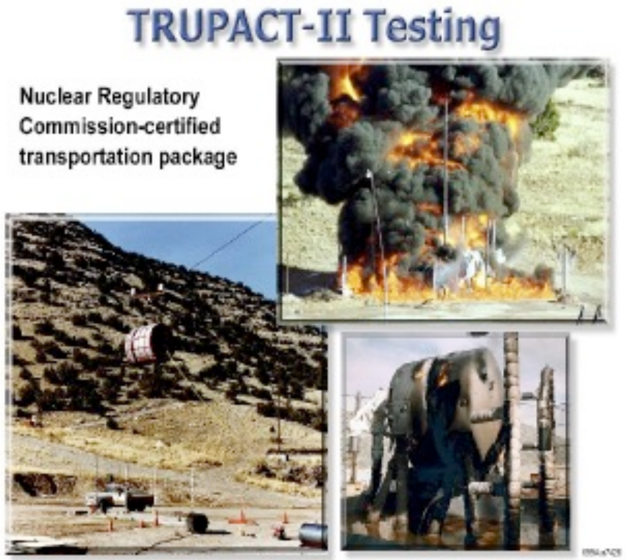
Standard
Waste Box



10 Drum
Overpack

SLB-2

WIPP TRU PACT Shipping Containers



WIPP Transportation Routes

Why we perform the measurements

Game of Acronyms

- DOE
  - Department of Energy
- AMWTP
  - Advanced Mixed Waste Treatment Plant
- NDA
  - Non-Destructive Assay
- ISOCS
  - In-Situ Object Counting System
- EPA
  - Environmental Protection Agency
- EM
  - Environmental Management
- NNSA
  - National Nuclear Safety Administration
- WIPP
  - Waste Isolation Pilot Plant
- SISOCS
  - SUPER In-Situ Object Counting System

Efficiency Types

- Predefined Efficiencies
  - Modeled
  - Empirical
- Require sources for validation many times multiple sources
- Matrix Containers for each efficiency also required
- Maintenance, tracking and upkeep of containers and sources
- Calibration confirmations required

- Extended ISOCS Models
- Modeled calibrations no sources
  - On The Fly for each Container
- Equivalent confirmations required with no sources.
- Figure of Merits to confirm calibration once assay completed
- Multiple types of FOM's to assist with validation
- Non-container specific

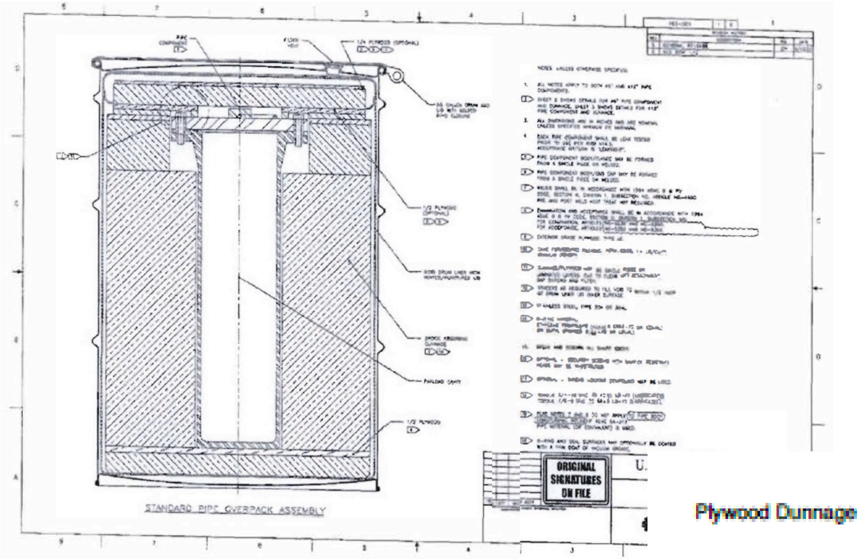
Historical Measurements at Los Alamos

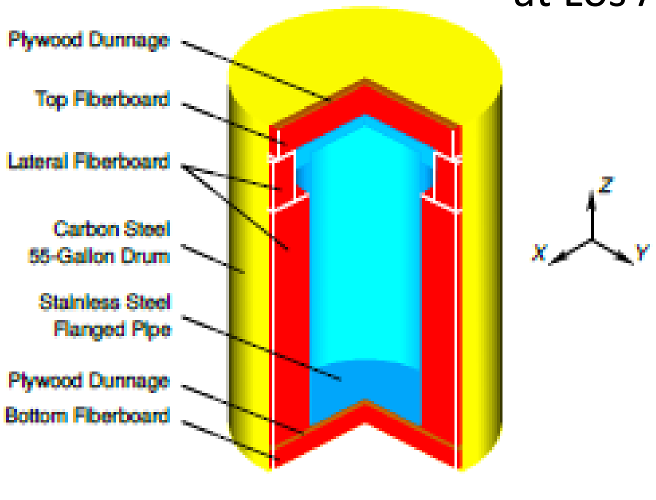
High Efficiency Neutron Counter with Integrated Gamma Detector

- Lead lined containers at Los Alamos
- Empirical calibrations with lead lined Containers ($50K)
- Line Sources required for calibration
- Data below is results compared against Acceptable Knowledge data
- Example of complete empirical process with no modeling

Drum ID	MT	Density (g/cc)	Baseline Total Pu (g)	Measured Total Pu (g)	Pu %R	Baseline Total ^{241}Am (g)	Measured ^{241}Am Mass (g)	^{241}Am %R
1	WG	2.05	86	83.9	97.6%	7.2	6.48	89.95%
2	WG	1.98	34.1	34.5	101.1%	8.7	6.85	79.0%
3	WG	1.98	17.6	20.7	117.4%	6.4	6.57	102.5%
4	WG	1.34	61.4	58.5	95.3%	N/A	6.28	N/A
5	WG	1.15	8.23	12.4	150.7%	N/A	9.94	N/A
6	WG	1.24	92.32	61.7	66.8%	N/A	6.34	N/A
7	WG	1.18	29.00	29.4	101.4%	N/A	3.34	N/A
8	WG	1.94	71.3	77.9	109.3%	7.5	6.99	93.2%
9	WG	2.03	40.0	44.9	112.3%	8.3	7.50	90.36%

Historical Pipe Overpack Container Measurements





(b) 12-inch Standard

- Pipe Overpack Containers
- Used for Higher activity containers
- Contain pipe component with waste material inside a 55-gallon drum with fiberboard
- Container used for a significant amount of waste at Los Alamos and Savannah River

Results from POC measurements

- Compared HENC data vs validated calorimetry data
- Measured by Los Alamos NDA group to verify HENC measurements
- Significant cost and time to load and measure POC's with calorimetry data.
- Well defined empirical calibration verification however time consuming and expensive

Neutron Data Results

Calorimetry Results	Average Value Pu239/Pu238 Mass (g)	%R	STDEV	%RSD
92.2 grams MT-52	111.1	121	6.3	5.6
117.5 grams MT-52	129	110	9.5	7.4
5.5 grams MT-83	5.1	93	0.3	5.1
12.4 grams MT-83	11.3	91.2	0.2	1.9
19.6 grams MT-83	16.7	85	0.4	2.4

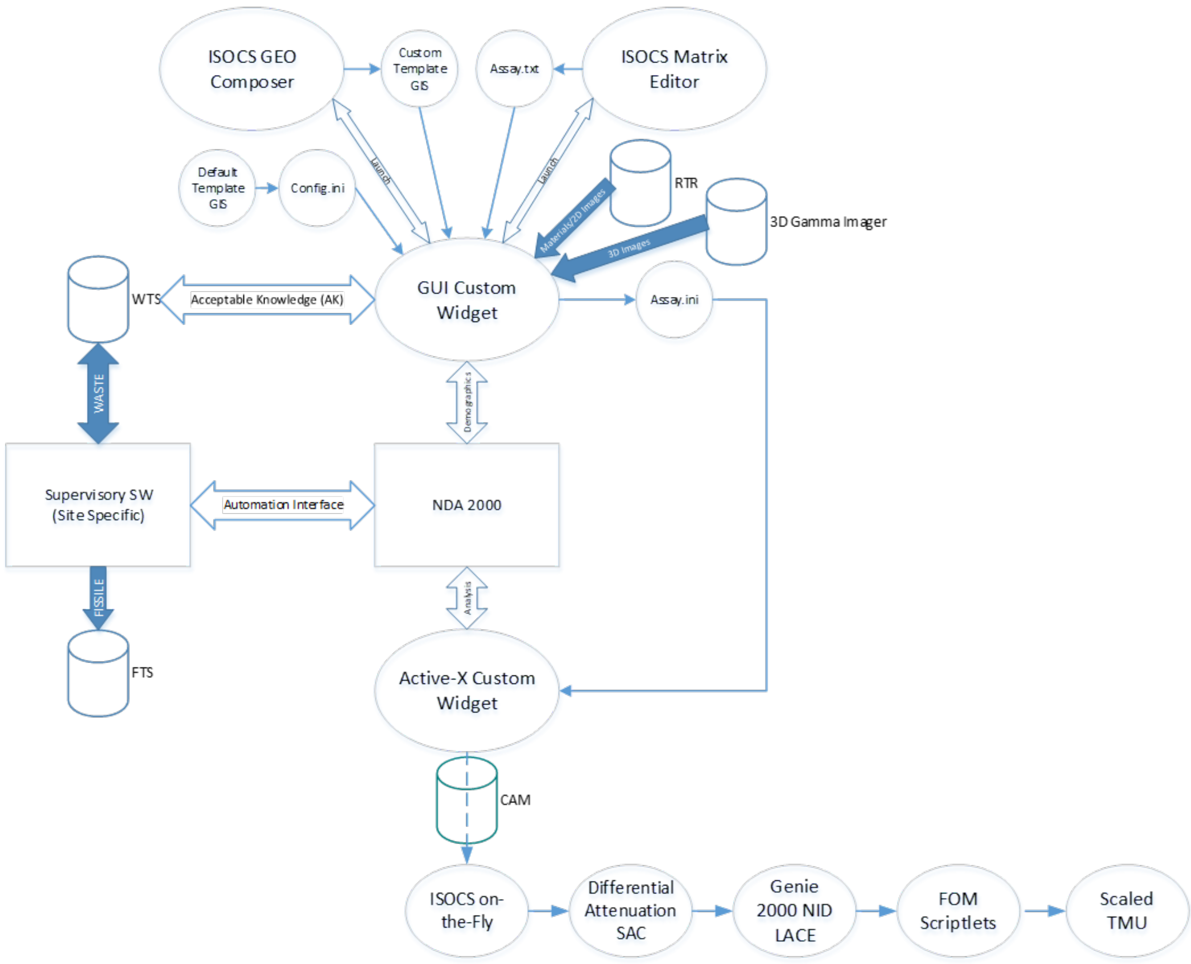
Gamma Data Results

Calorimetry Results	Average Value Pu239/Pu238 Mass (g)	%R	StDev	%RSD
92.2 grams MT-52	112	121	2.3	2.0
117.5 grams MT-52	126	107	3.4	2.7
5.5 grams MT-83	4.89	89	0.2	3.3
12.4 grams MT-83	9.58	77.3	0.1	1.5
19.6 grams MT-83	15.0	77	0.3	1.7

IDAHO Solutions to TRU and LLW Waste

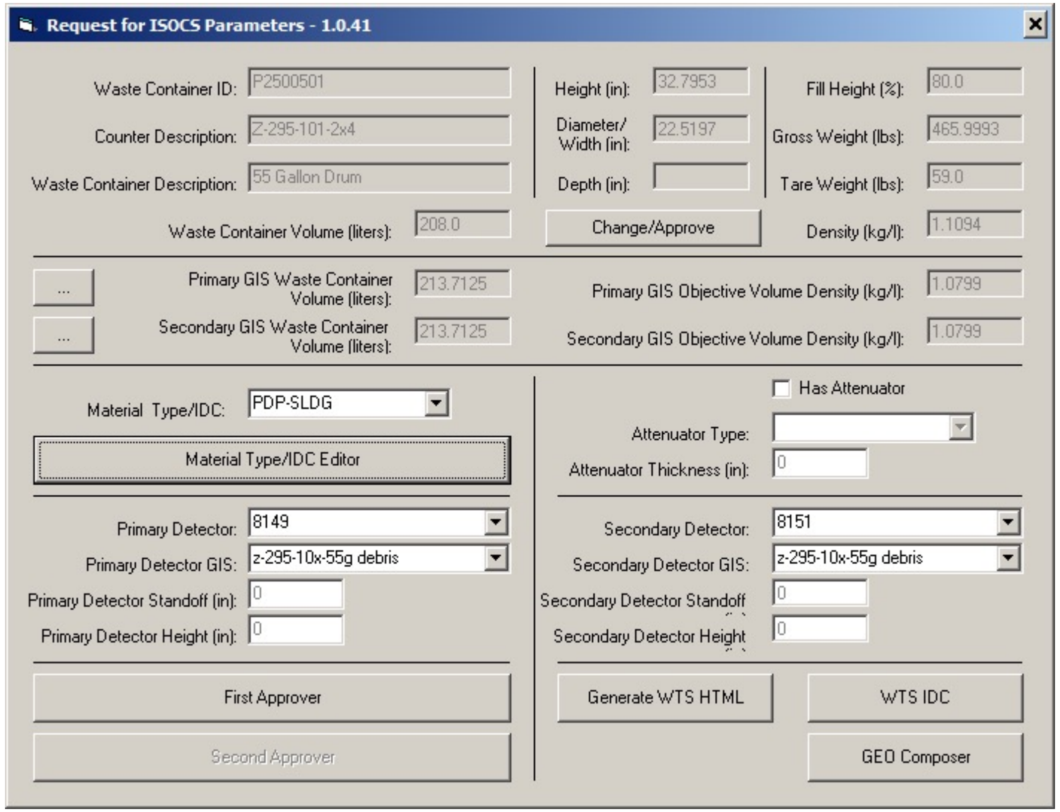
- Addresses the issues related to the conventional means of extracting predefined efficiencies
  - What container shapes? What material types? When will we know?
  - Predefined efficiencies usual require “commissioning” or “validation” for the range of container shapes and material types.
  - Predefined efficiencies usual cover a broad range of physical parameters, *e.g.*, fill height, material type, material distribution, *etc.*, and inherently have rather large Total Measurement Uncertainties (TMU’s).
  - Maintenance for a plethora of predefined efficiencies can be extremely cumbersome.
  - Predefined efficiencies are extremely costly ($$$) and time consuming (weeks/days/months)
- With the expansion of ISOCS to the NDA 2000 environment
  - Any container shape that can be supported by ISOCS
  - Methodology for efficiencies “on-the-fly” that can be internally validated for each assay.
  - The methodology is NQA-1 and approved by the DOE including boxed and drummed waste materials at LLW designated for disposition to WIPP.
  - Need only a fiducial TMU for cylinders and/or boxes.
  - Works with any gamma NDA instrument, ISOCS cart, Q2, SGS, IQ3, MILCC, etc.
  - Saves time, $$$ and training is usually less than a week.

IDAHO Solutions to TRU and LLW Waste



- Developed for TRU materials for disposition to WIPP.
- Involve site customization which may take several months.
- Many pieces are now newly released standard products.
- Main goal is to establish an efficiency, which can be validated, for an object which can be modeled with standard ISOCS (currently) and even Super ISOCS and MCNP (near future).
- Validation involves utilizing Figure-Of-Merits (FOM) which can be customized.
- Interoperates, using custom binaries and scripts, with the customers databases such as WTS (Waste Tracking System), FTS (Fissile Tracking System), RTR (Real-Time Radiography) and 3-D Gamma Imager and whatever other database or data source the customer might have.
- Custom GUI widget launched during assay (demographics); yields Assay.ini.
- Custom Active-X control interprets waste container data to CAM (analysis) via Assay.ini.

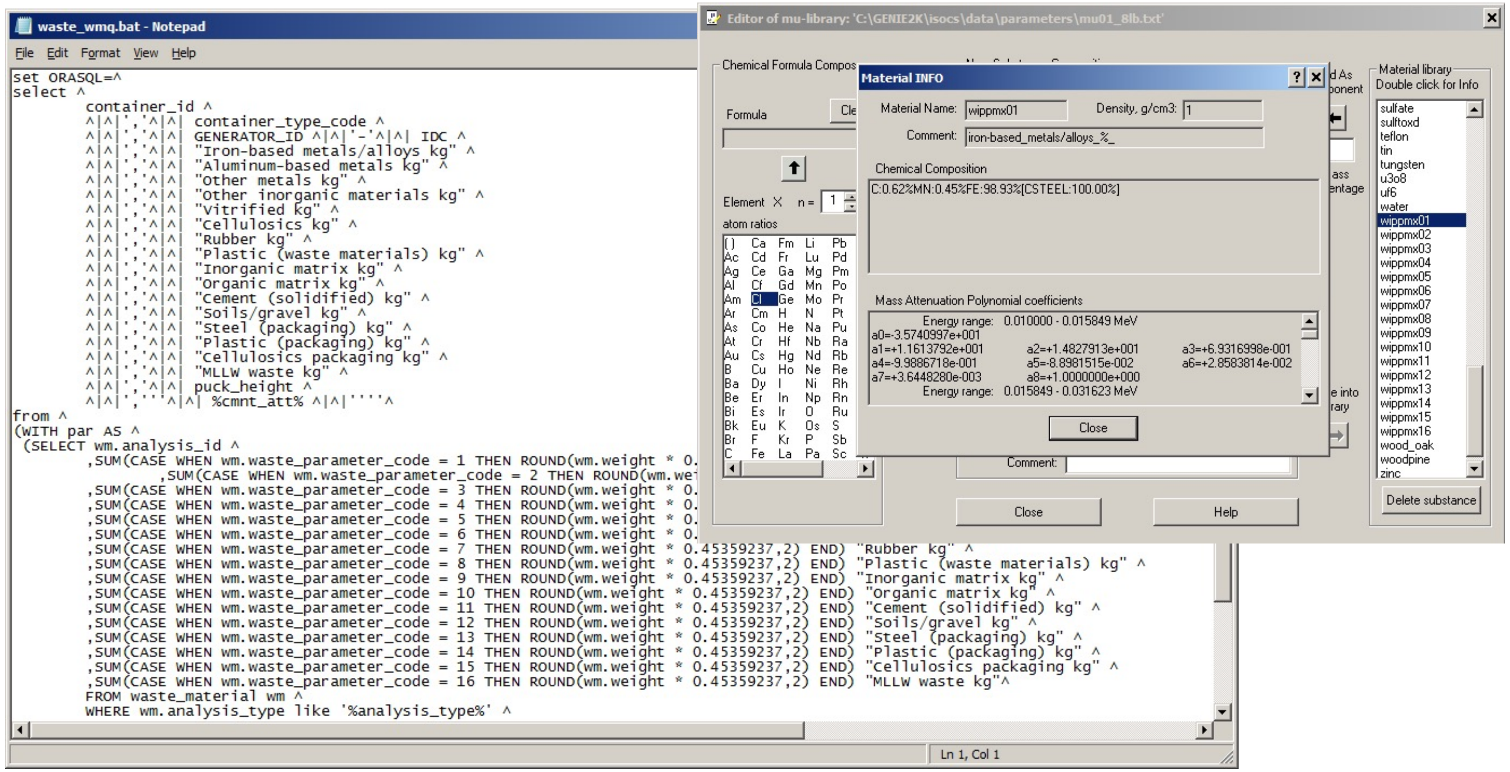
Main Data Input Form



- Executable that gets called (shelled) from within NDA 2000 Operations.
- Generic version incorporated into standard product (48-8711).
- Can be completely customized by Canberra or by the customer themselves with some supervision.
- Must follow a few simple rules as defined by the NDA 2000 Expanded ISOCS architecture.
- Otherwise, very flexible since the output to the INI is also read, and interpreted, by the Active-X control which is also customizable.
- Works with and without supervisory SW via the NDA 2000 Automation interface.

- Several controls to access a plethora of demographic information about the waste container.
- The operator can create a material type or GIS that is specific to the waste container.
- If there is an additional attenuator of Pb, Cd, SS, CSTEEL, etc., it is easily added – no need to be previously defined in the default GIS file.
- Material type editor creates custom mu library for the assay only; performs temporary swap on SPACE.INI when analyzing.
- Approval scheme for detector parameters only possible at assay time.

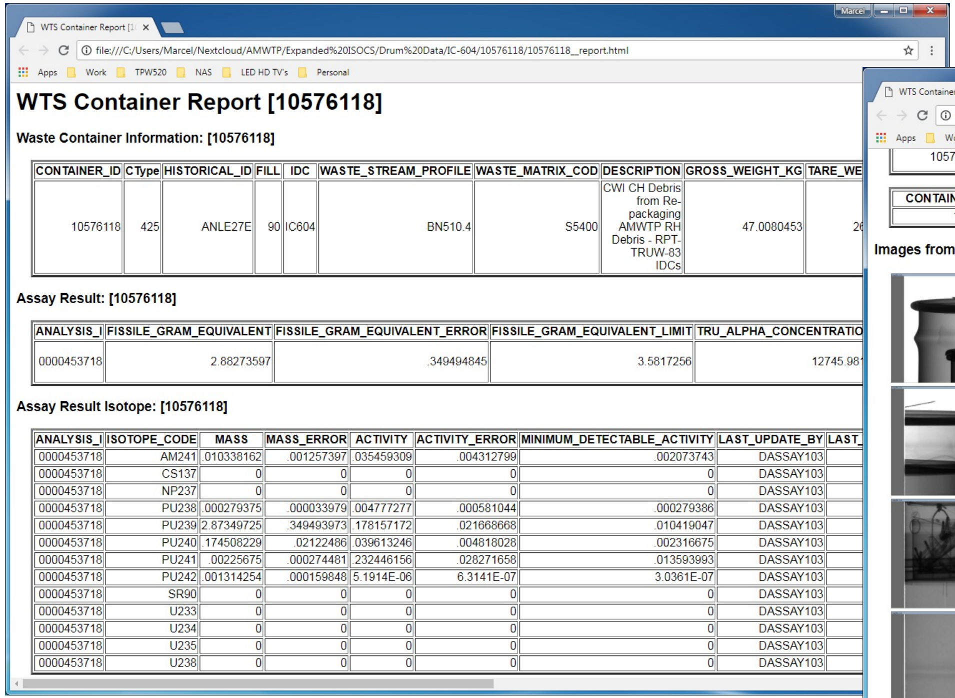
WTS Query

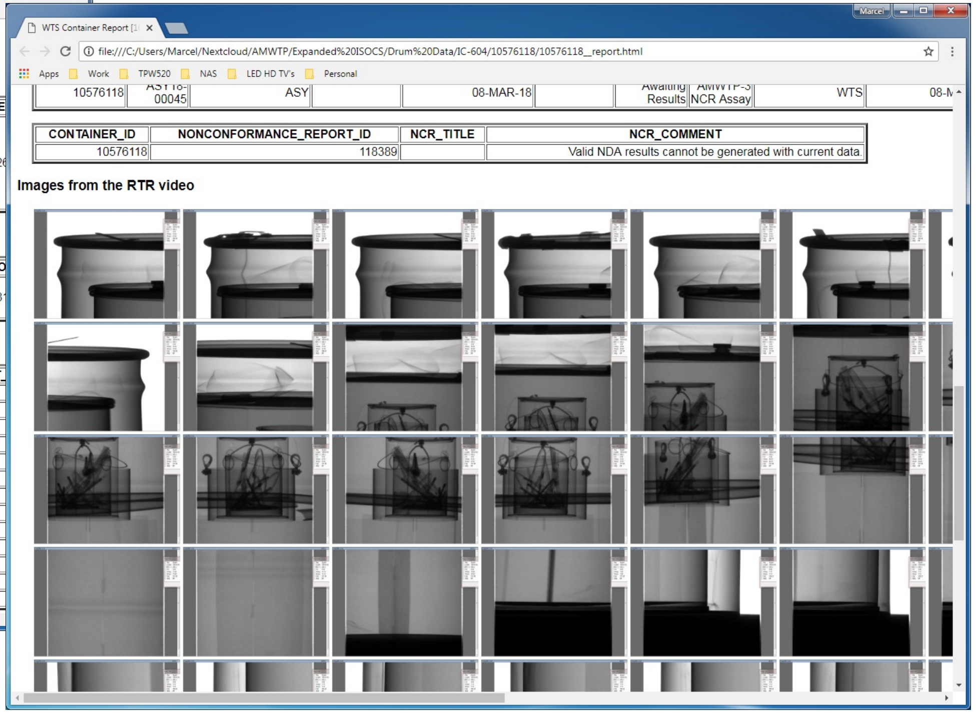


- These 16 parameters are entered by the RTR analyst and the Oracle query reduces to weight percent per material type.
- The Operator or ETR accesses the information and seamlessly enters the material weight percents in the ISOSC materials editor.
- Future plans to completely automate this process so no human intervention required.

- GUI widget, upon loading, calls customizable script file that calls a site specific BAT file that queries the customers WTS database.
- We wok with the customer in developing the customizable interfaces; start with a generic set of QA'd interfaces.
- In general, the information returned is core AK and RTR.
- The core AK information contains info such as the waste container type, gross weight, tare weight, IDC, etc.
- The core RTR information consists of the distribution of materials, over-pack information, IDC verification, puck heights for compacted drums, etc.
- To the left is an example were the 16 WIPP identified material types are accessed from the customer's ORACLE database.

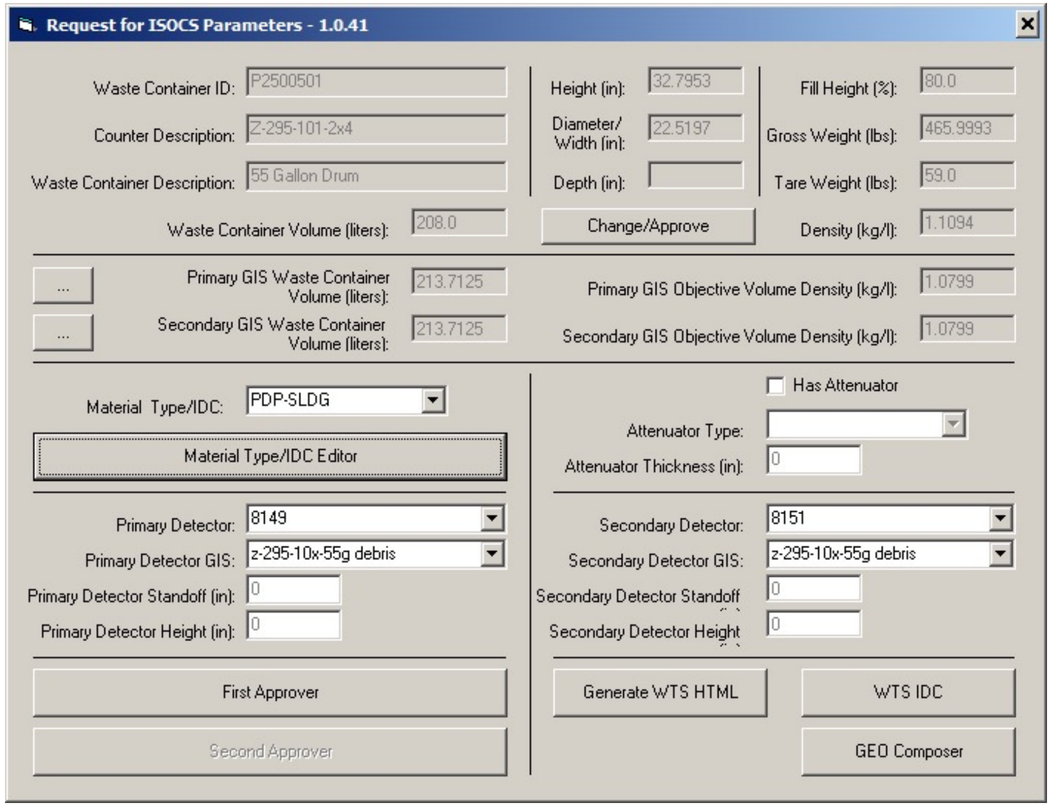
RTR Query/Generate HTML

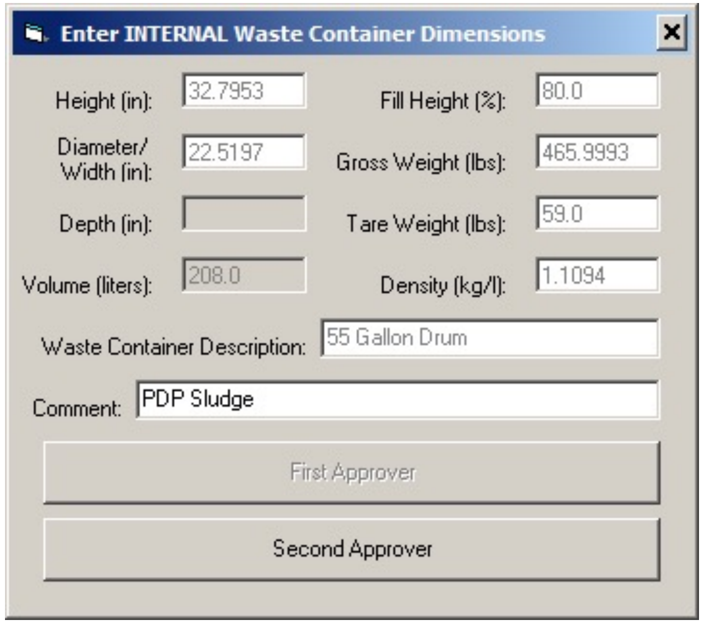




- Custom query
- Displays complete RTR report in HTML format.
- Takes x second intervals of frames (stills) from MP4 video.
- Aids Operator/ETR in changing GEO/GIS on-the-fly.

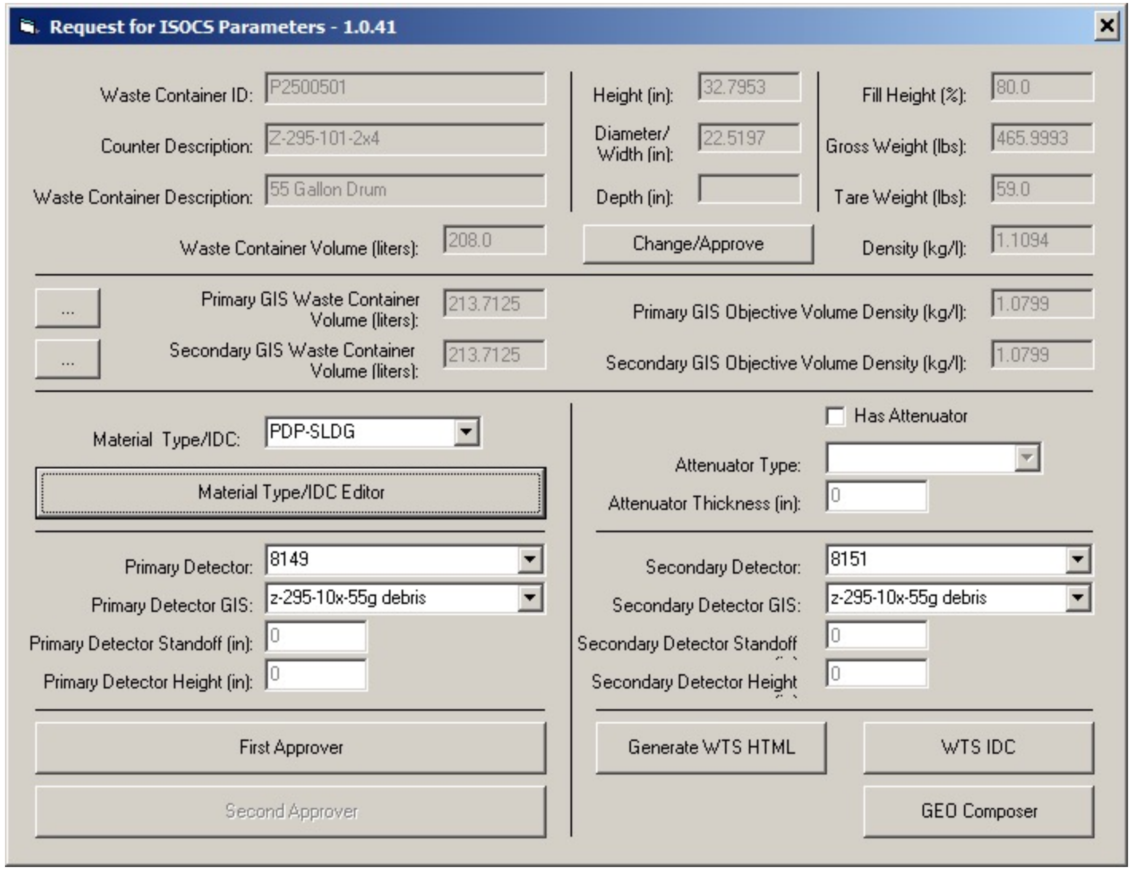
Detector-Standoff/Centerline

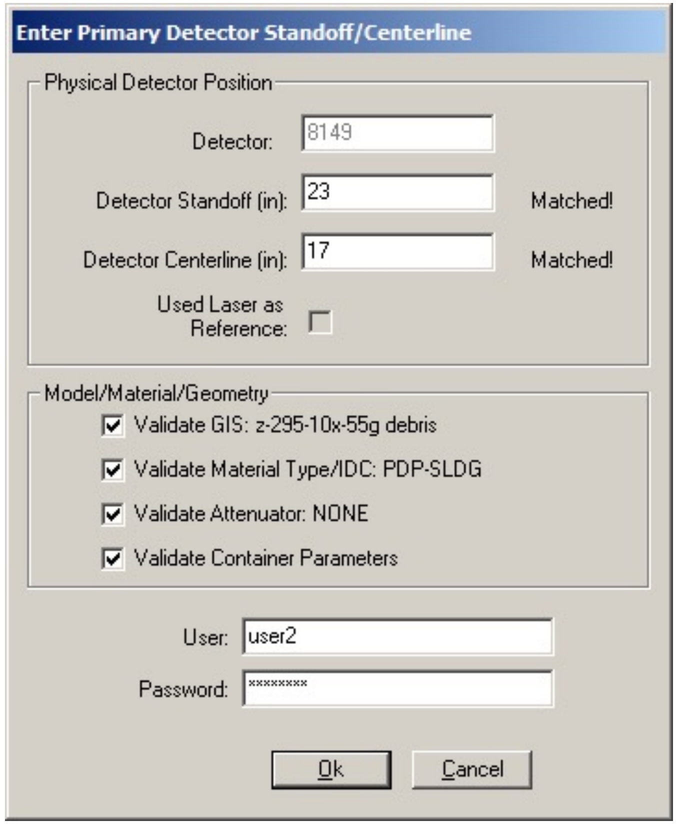




- Waste container parameters are passed from NDA 2000 Operations.
- Actual values used for debris drums but not for overpacks.
- Net weight is computed from GW and TW; GW >= TW.
- Dual approver scheme.
- REQUIRED comment field (V1.1).

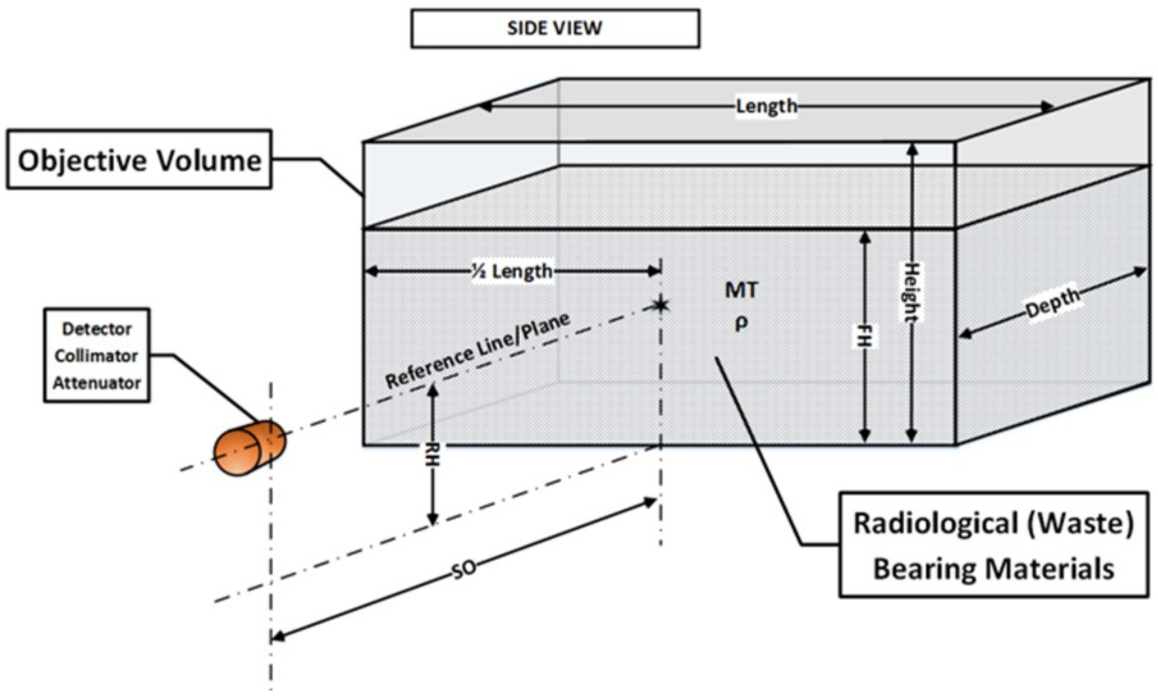
Secondary Approver





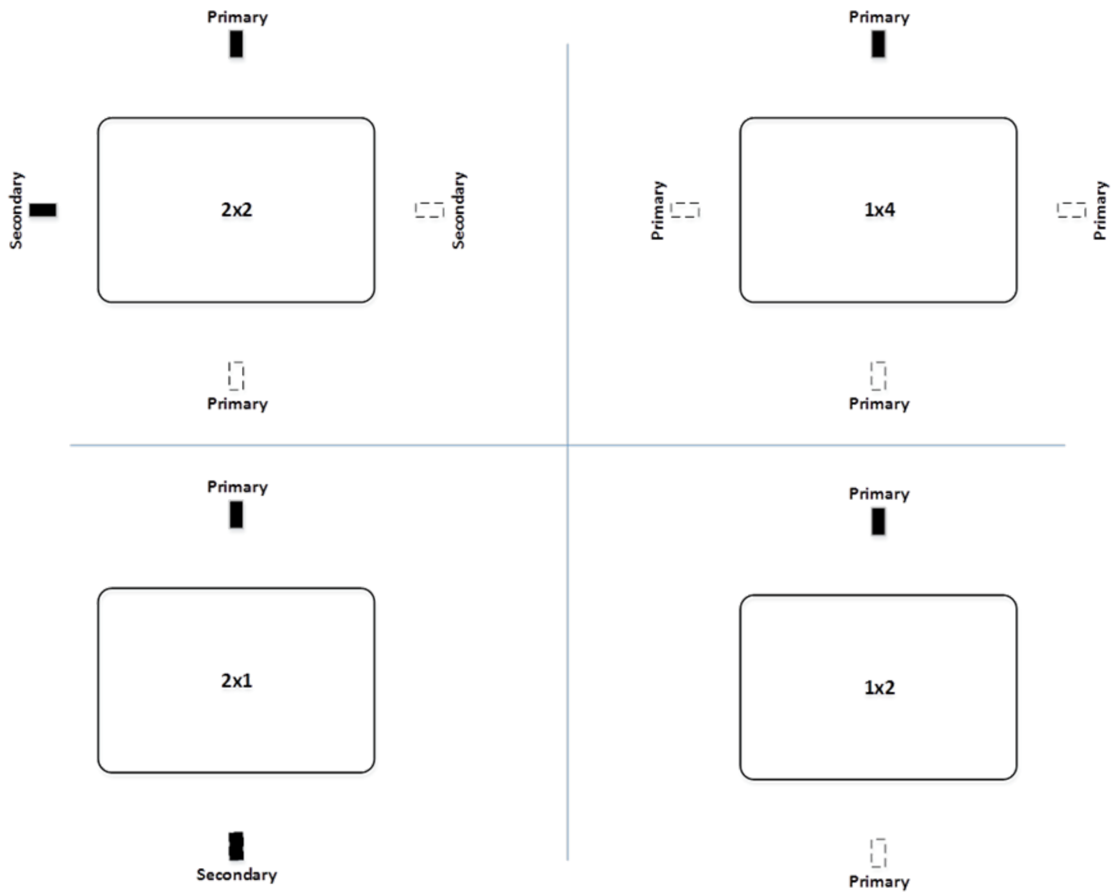
- First/second approver scheme where the detector distance and centerline are entered into the GUI widget and ultimately to the assay specific INI file.
- These two dimensions, detector distance and centerline, are the most important pieces of information that are gone once the cart/detectors have been moved so this step is crucial.
- ISOCS LASER can be used as a reference point (LASER offset located in Config.ini).
- Optional LASER range finder for accurate detector distance.
- Passwords set in Config.ini.
- Once Second approver completes successfully then the GUI widget is dismissed.

IDAHO Solutions to TRU and LLW Waste



- Boxed waste containers are defined by the inner height (H), inner length/width (L) and inner depth (D) which define the box objective volume (HxLxD).
- By convention, a rectangular box has L > D. The radiological-bearing waste, of material type MT and density ρ, occupies the objective volume scaled by the fill height (FH) which occupies the lower portion of the objective volume. The box also has a gauge thickness (12 GA, 14 GA, etc.) made of construction materials such as carbon steel, plywood and fiberglass.
- As with cylinders, the detectors are collimated and may optionally contain an attenuator with a defined thickness.
- The detector faces the box in the horizontal midpoint (L/2 on the length side and D/2 on the depth side) and approximately the height midpoint (H/2) which defines the reference height (RH).
- The detector/collimator must be at a standoff (SO) distance such that the box corners are in the detector view as defined by the collimation but not too far away so as not to introduce unwanted background.
- To get the best sensitivity the box is scanned on the midpoint of all four sides. This can be accomplished with a single, primary, detector or, optionally, with a secondary detector. The scan with a single, primary, detector involves starting on the length (L) side and moving to the right (CCW) by 90o shifts until all 4 sides have been assayed.

IDAHO Solutions to TRU and LLW Waste



- Architecture has a concept of primary and secondary detector for both cylindrical and rectangular geometries.
- Primary and secondary should be like-for-like as their physical spectra can be summed to further improve sensitivity.
- Only the primary detector need be defined; the secondary detector is a bonus for throughput and sensitivity.
- General concept is M x N where M is the number of detectors (1-2) and N is the number of positions.
- The box/drum is moved N-1 times after the initial position. SW keeps track of the segments/detectors and summing (physical spectra and NID results).
- **2x2** –the long side determines the primary detector for a reference point; the secondary detector is to the right facing the box as viewed through the primary detector (to facilitate GIS selection). Assay for 600 s and then rotate the box (fork lift truck) by 180 degrees.
- **1x4** – same as 2x2 but only the primary detector and the box is rotated three times.
- **2x1/1x2** – MILCC arrangement for a two detector MILCC (**2x1**) and a one detector MILCC (**1x2**)

TMU Scaling/FOM Reduction (Correction)

- Two main aspects of TMU scaling: ISOCS object volume and FOM correction.
- ISOCS Object Volume Scaling
  - IUE is utilized to establish TMU budget for VWA, 100% FH, fiducial volumes/containers – very costly!
  - Need to adjust, on the fly, for either a slightly different container and/or FH.
- FOM Correction
  - VWA TMU budget includes point source and lumpy matrix randomization which together can be 35% - 75% depending in the matrix materials, density and volume.
  - FOM evaluation limits, computed per assay, tell us that the efficiency field is actually known, validated, to a degree much better than the hypothesis from the IUE VWA randomization.
  - Analytical formula for drastically reducing the point source and lumpy matrix TMU budget scaled to the FOM evaluation limits.

Okay Let's Discuss

- Does everyone see the process steps and the overall intent with the Idaho assay process?
- Comments so far?

PDP Results for this Process

- Performance Demonstration Program (PDP)
- Defined in Appendix A and has a specific process
- Entails yearly blind measurements of matrices usually a 55-gallon drum or Standard Waste Box (SWB)
- Material usually is placed randomly in the containers with varying activities.
- Types of material is usually weapons grade type material but could also be enhanced Am-241 or heat source.
- Specific accuracy and precision requirements depending upon activity and matrix.
- Within a specific timeframe the results must be reported to DOE.
- Failure of a PDP can be a painful process to recover from depending upon the issue.

System	Site	Recovery(%)	%RSD
ISOCS-200	Idaho	73.79	1.64
ISOCS-201	Idaho	79.82	0.57
MILCC (Predefined) ISOCS)	LANL	107.18	1.84
MILCC3 (Predefined ISOCS)	LANL	82.04	0.87

Box PDP results for measurements taken in September 2020.

Figure of Merit Description and Functionality

- Highly intense, customizable, calculations sent directly to the report fil (Genie 2000 feature).
- Three main FOMs: LACE, Multi-View (MV) and ISOTOPIC.
- LACE FOM checks the integrity of the LACE curve with respect to slope and curvature.
- MV FOM evaluates the consistency of the ISOCS efficiency versus response for static (non-rotating) measurements for 2 or more independent views of a cylindrical or box shaped object.
- ISOTOPIC FOM determines if the nuclide NID ratios are consistent with those either from measured and/or declared isotopics.
- All FOM's involve evaluation limits which are associated with site customizable tension parameters.

Lessons from historical measurements

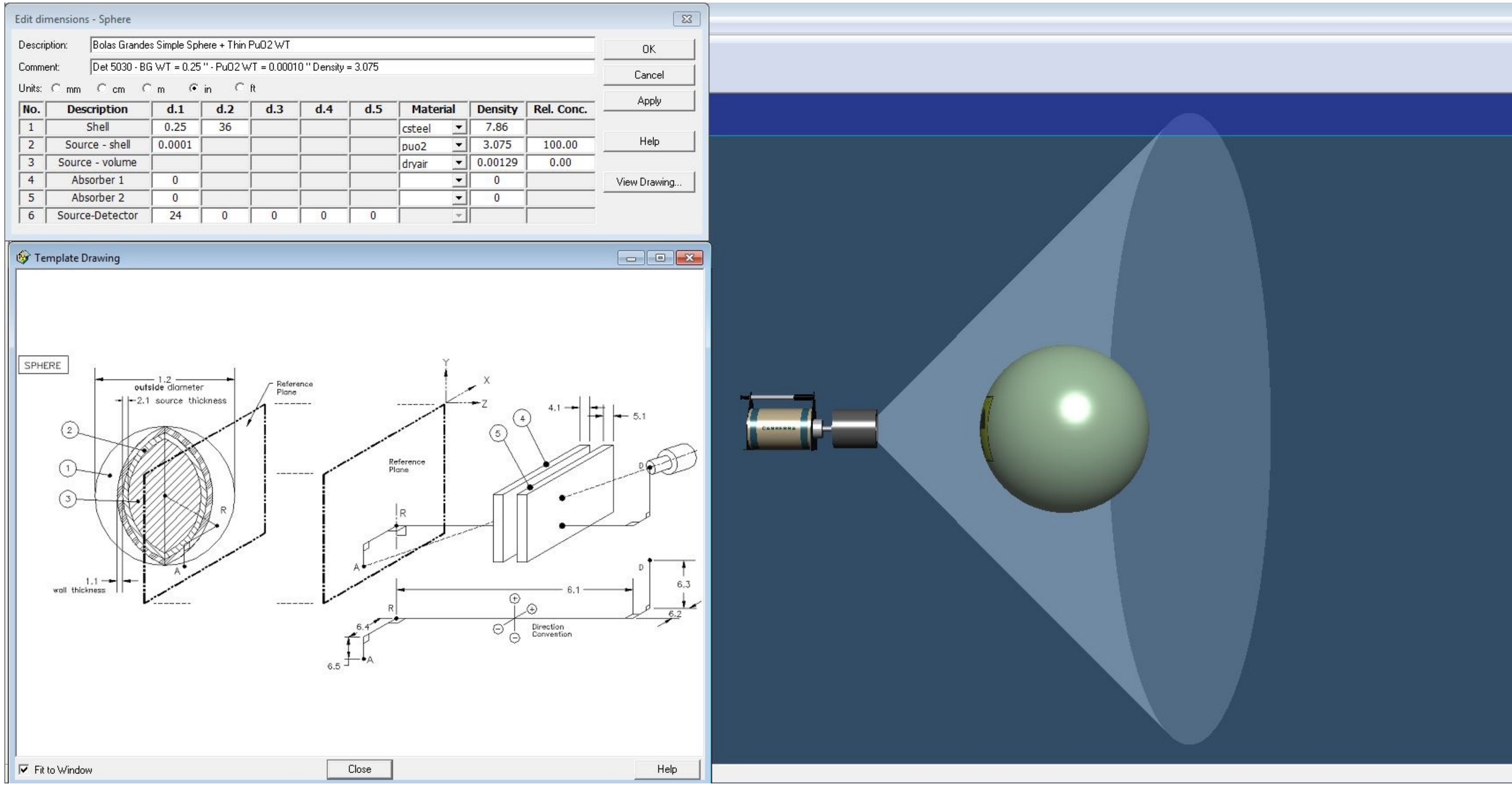
- Quality empirical measurements can be made using specific sources and containers
- Almost every WIPP system as we move towards the more difficult waste would need similar sources and containers.
- Source movements are becoming more difficult at DOE D&D facilities.
- It has taken months for N3B at Los Alamos to recover from a number of DSA issues that are still not solved.
- Modeling is already a significant part of the overall measurement scheme.
- The next step is to continue to develop the efficiency verification tools for each measurement reducing the need for source movements and additional matrix containers.

Bolas Grande Los Alamos

- Large containers used for specific experiments at Los Alamos
- Designated as dynamic experiments to measure the effects by detonation of high explosives.
- Difficult to size reduce and place in some WIPP shipping containers.
- Can they be measured in their current form.

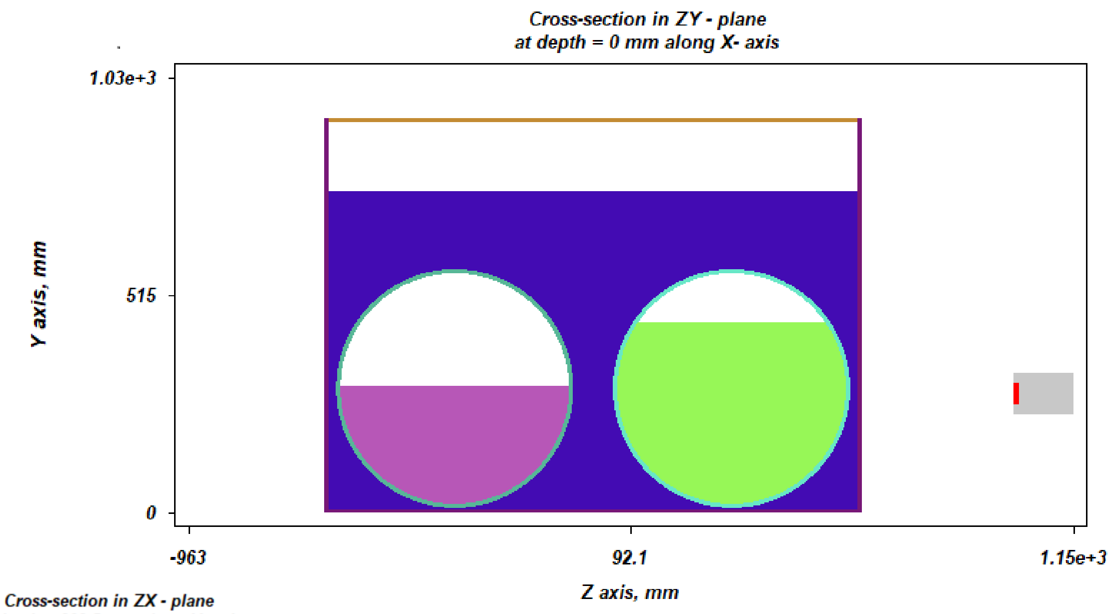
Bolas with Standard ISOCS

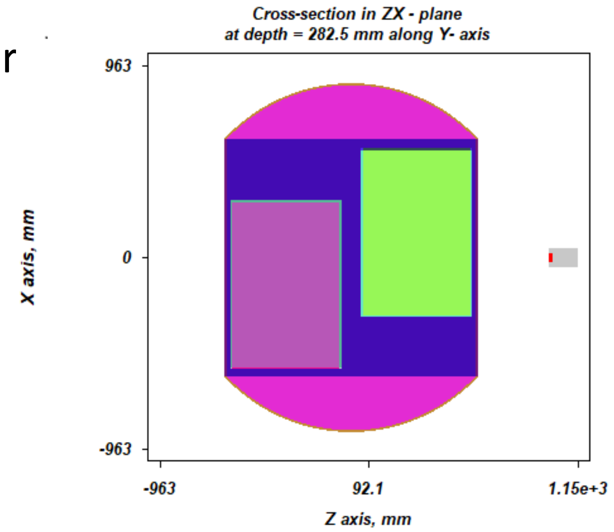
- Apply use of standard ISOCS sphere
- SISOCS not required currently from how we foresee the analysis path.
- Initial Bolas data looks promising during initial analysis.
- Plan is to integrate extended ISOCS pathways similar to Idaho.
- Not possible to provide confirmation objects to meet that specific part of the WAC.
- Figure of Merit processes will have to be applied.



SWB's with cemented containers SISOCS

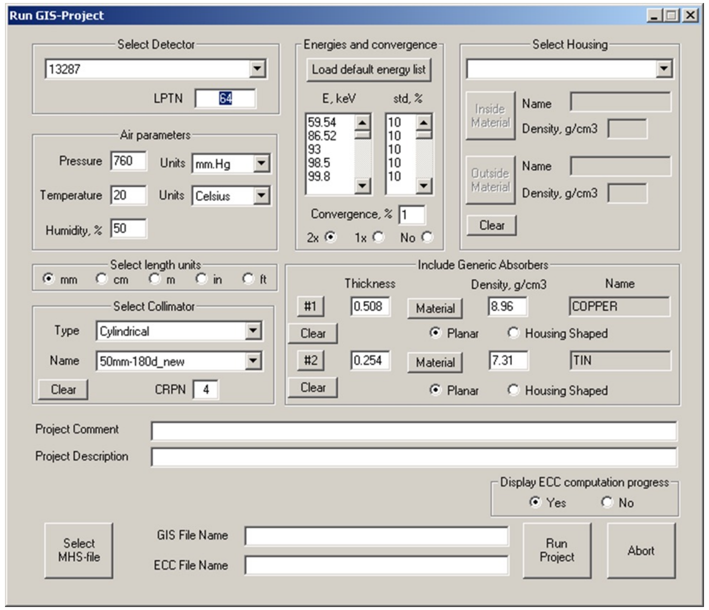
- Another different waste form at Los Alamos will be a SWB with two cemented drums place into the larger container.
- The larger analysis issue will be SWB's with one cemented container and one empty container.
- Current calibrations cannot be used to analyze the SWB with an empty drum.
- Another example of how we will need to apply SISOCs and the portions of integration with NDA2000 that will be required.
- SISOCS renderings are shown on this page for the two full containers.

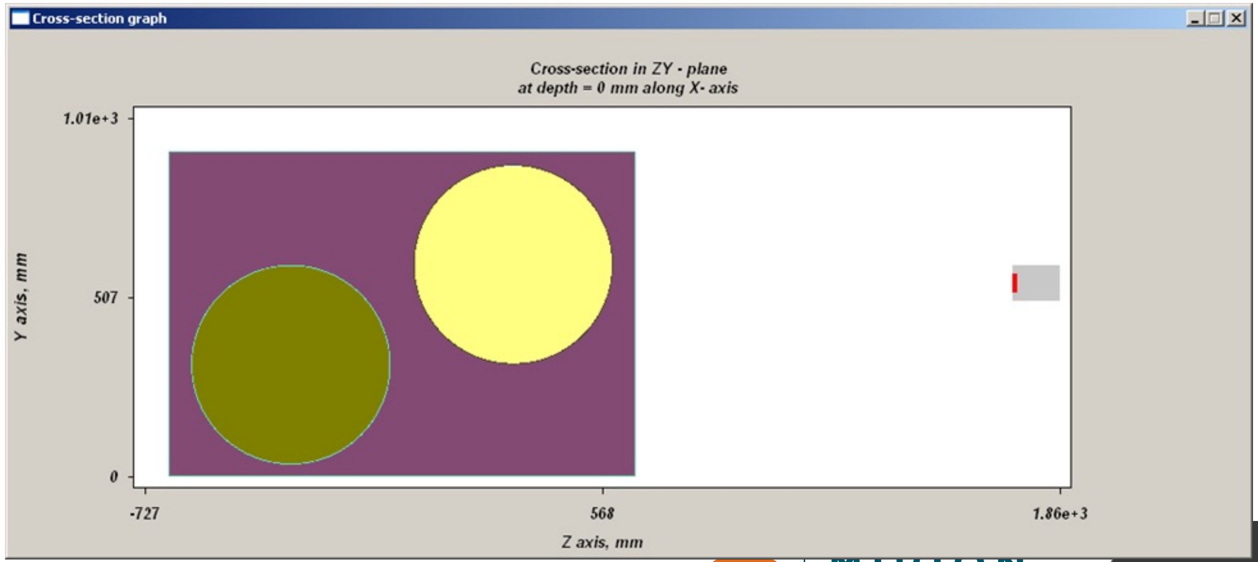




SWB's with one dunnage drum

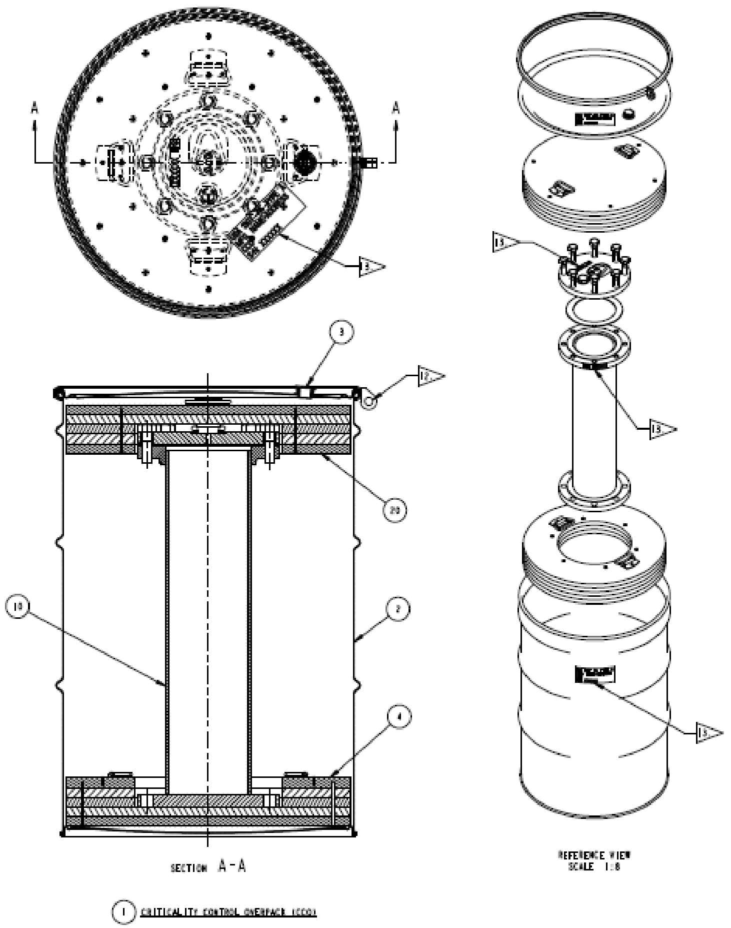
- SWB with dunnage and waste container.
- The N3B EM contractor not willing to repackage.
- ISOCS needed for the inclusion of spherical objects within a box
- Additional attenuators tha cannot be modeled in traditional ISOCS templates.





Criticality Control Overpack (CCO) Savannah River

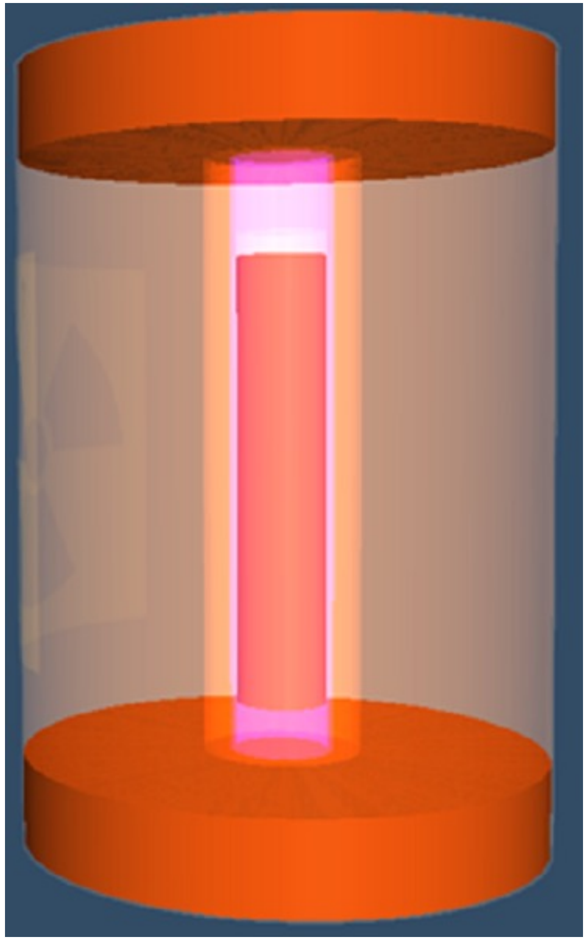
- CCO is a specific container built for WIPP shipments that can transport large amount of Plutonium
- Large amounts of Plutonium can be place in the CCO.
- The certified limit is 325 grams of Pu.
- There will be a significant number of these measured at Savannah river.
- Most will be measured on a High Efficiency Neutron Counter (HENC).
- Predefined efficiency calibration using ISOC’s modeling techniques.
- Combined neutron and gamma analysis



Criticality Control Overpack (CCO) Savannah River

- Example ISOCS model rendering showing the basic mode for the CCO.
- Inner pipe container with cans of material loaded evenly into the pipe.
- Usually, will contain at least two cans of material placed into the CCO.
- Gamma results shown below.

Sequence #	239 Pu Gamma Ray Energies (keV)						
	375.05	392.53	413.71	422.6	451.48	645.94	769.26
725	1.06E+07	1.06E+07	1.10E+07	1.04E+07	1.12E+07	9.98E+06	1.04E+07
726	1.07E+07	1.06E+07	1.10E+07	1.11E+07	1.11E+07	9.87E+06	9.73E+06
727	1.06E+07	1.04E+07	1.11E+07	1.07E+07	1.11E+07	1.07E+07	1.01E+07
Average:	1.06E+07	1.05E+07	1.10E+07	1.07E+07	1.11E+07	1.02E+07	1.01E+07
Std Dev:	8.30E+04	8.69E+04	8.24E+04	3.49E+05	6.60E+04	4.40E+05	3.47E+05
%R:	95.55%	94.58%	99.20%	96.47%	100.06%	91.41%	90.52%
%RSD:	0.78%	0.83%	0.75%	3.25%	0.59%	4.33%	3.45%



Neutron Results for CCO

- Neutron measurements were even better for this material.
- Usually more accurate measurement when you have enough material.
- Did I mention neutron measurements are usually the way to go if possible.

Sequence #	Measured Pu Mass Total (g)	Measured ^{240}Pu Mass Fraction	Measured $^{240}Pu_{eff}$ Mass (g)
725	1.897E+02	6.193E-02	1.175E+01
726	1.874E+02	6.193E-02	1.160E+01
727	1.897E+02	6.192E-02	1.175E+01
Average:	1.889E+02	6.193E-02	1.170E+01
Std Dev:	1.35E+00	3.32E-06	8.34E-02
%R:	98.69%	102.92%	101.57%
%RSD:	0.71%	0.01%	0.71%

Just something for the commercial Side
TMI Measurements

- **Exelon required measurements of chemical cleaning tanks at the Three-Mile Island Nuclear Generating Station**
- **These Chemical Cleaning Tanks (CCT) are located in the Chemical Cleaning Building (CCB)**
  - The CCB was originally intended to be used in the chemical cleaning of the steam generators for TMI Units I and 2.
  - EPICOR-II System contains the following components which are located in the chemical cleaning building: five processing pumps, a transfer pump, pre-filter/demineralizer (containing pre-coat material and cation bed resin), two demineralizers (one cation bed followed by a mixed bed), clean wastes (holding) receiver tank (CHRT; formerly the rinse hold tank; RHT or CCT-2), off-specification water (holding) receiving/batch tank (OHRT; formerly the chemical cleaning solution tank; CCT-1), chemical cleaning building sump pump, monorail hoist system, and ventilation filtration system.

- **These chemical cleaning tanks were modified in the early1980's to accommodate waste water processing from the March, 1979 TMI-2 accident**

Figure 1: Bottom view of CCT-1

Radionuclides required for Identification and specific tank to be measured

- **CCT-1 Description and expected radionuclides with initial survey**
- The CCT-1 is a 95,000 gallon tank and is the smaller diameter tank.. The RHT/CCT-2 is a larger 135,000 gallon tank. The CCT-1 is a capsule-shaped tank 38' 6" in height with 10' 11" radius hemispheres at the top and bottom.
- The CCT-1 is currently in service and the water fill height may change daily. Typical fill heights might be 30' and sediment depths might be as high as 3' but more than likely the sediments are suspended due to pumps agitating the water within CCT-1.
- Volatile fission products such as Cs-137 and I-131 might be expected as well as Co-60 from activation of steel in the form of rust sediments that work their way to the tank. In an initial investigation, a two position survey, using a Canberra Inspector 1000 with NaI probe, was conducted by Canberra when visiting the TMI site on August 29th, 2016. The first survey, acquired just outside the CCB, there was a significant Compton scattering continuum but no discernable peaks albeit the count time was relatively short. The second survey was conducted within 10' of the CCT-1, presumably near the bottom and Cs-137 and Co-60 is evident, and abundant. Note that I-131 was not detected and this is expected as the decay half-life is extremely short. Also note that the NaI probe is not collimated so it is not certain if the Cs-137 and/or Co-60 was actually emanating from the contents of the CCT-1 but might be originating from a nearby pipe of valve or even the larger tank (RHT/CCT-2).

Equipment Description

- Equipment used for characterization activity
  - Falcon-5000
    - Mechanically cooled detector with smaller BEGE2830 High Purity Germanium Detector
    - Detector is ISOCS characterized for source less efficiency calibration
    - Special tungsten collimator with small aperture that attaches to standard collimator
    - 100 foot Ethernet cable
  - Inspector-1000 with NaI probe
  - IPIX-Gamma camera for hotspot identification
  - QA/QC's were performed daily.
- Data reporting requirements
  - Quantify Co-60 and Cs-137 in activity concentration with associated uncertainties.

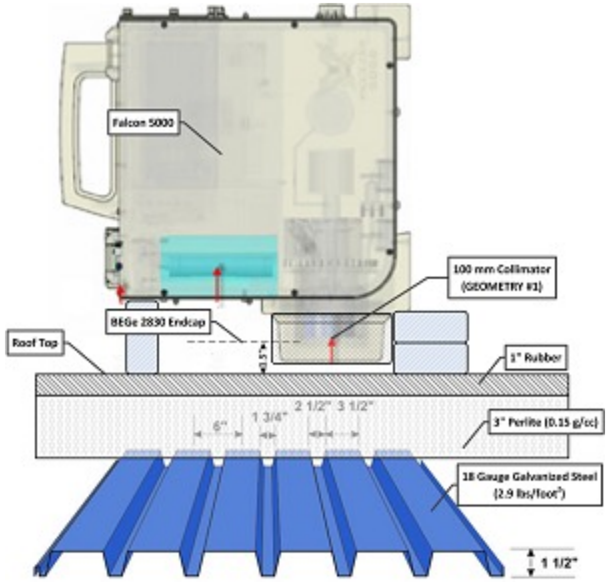


Figure 2: Shows location of Falcon down looking into CCB.

Measurement Description Up looking

- Measurements were made of the CCT-1 using the Falcon 5000 and the IPIX.
- Measurements using the Falcon were taken looking-up from just below the CCT-1.
- Collimation was used to reduce interference from other source.
- Tungsten and Pb used for attenuation.
- Several Super ISOCS models were create for this geometry.
- Measurements were taken with and without the tank full (90% capacity) of water.
- IPIX views were also acquired at this location.

Figure 3: Shows bottom view of CCT-1.

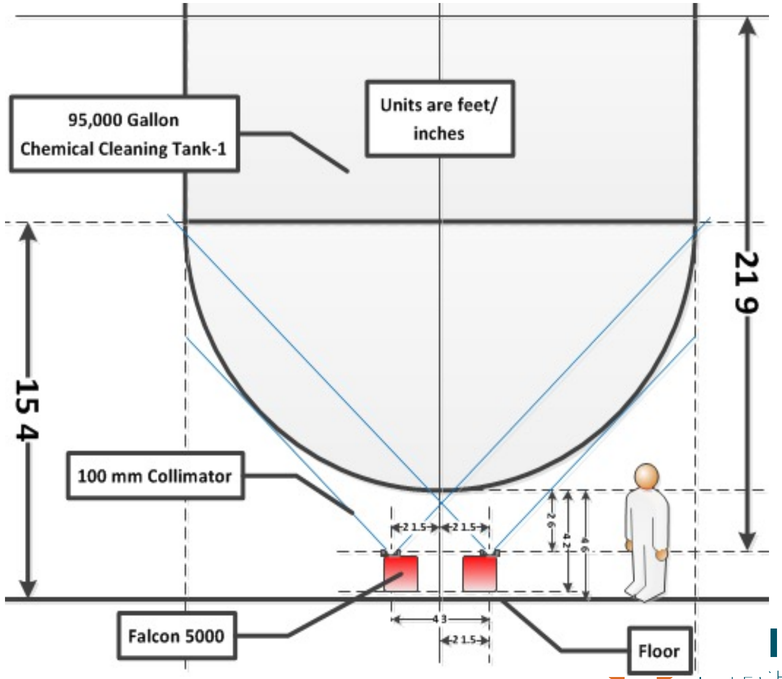


Figure 4: Upward view of CCT-1.

Measurement Description Down looking

- **Measurements were made of the CCT-1 using the Falcon 5000 and the IPIX.**
- **Measurements using the Falcon were taken looking straight down on the the CCT-1 from through the roof.**
- **Collimation was used to reduce interference from other source**
- **A single Super ISOCS model was created for this view.**
- **These measurements were accomplished with the tank 90% full of water.**
- **IPIX views were also acquired at 50-75% the tank height.**

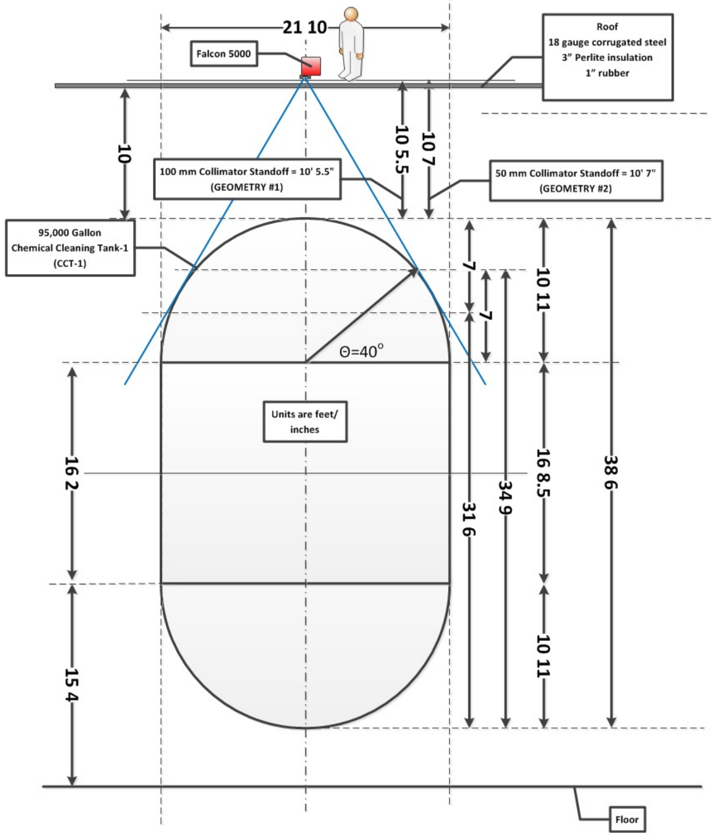


Figure 5: Down looking view of CCT-1.

Super ISOCS Model description

- **Models were created down looking and up looking**
- **Example model is shown in figure 6 (to the right).**
- **Layers of sediment and water were separated in the model.**
- **Another model included potential volumetric hotspots assuming several superhot resin beads may have worked their into the system.**
- **Hotspots were also observed from the IPIX gamma camera views.**

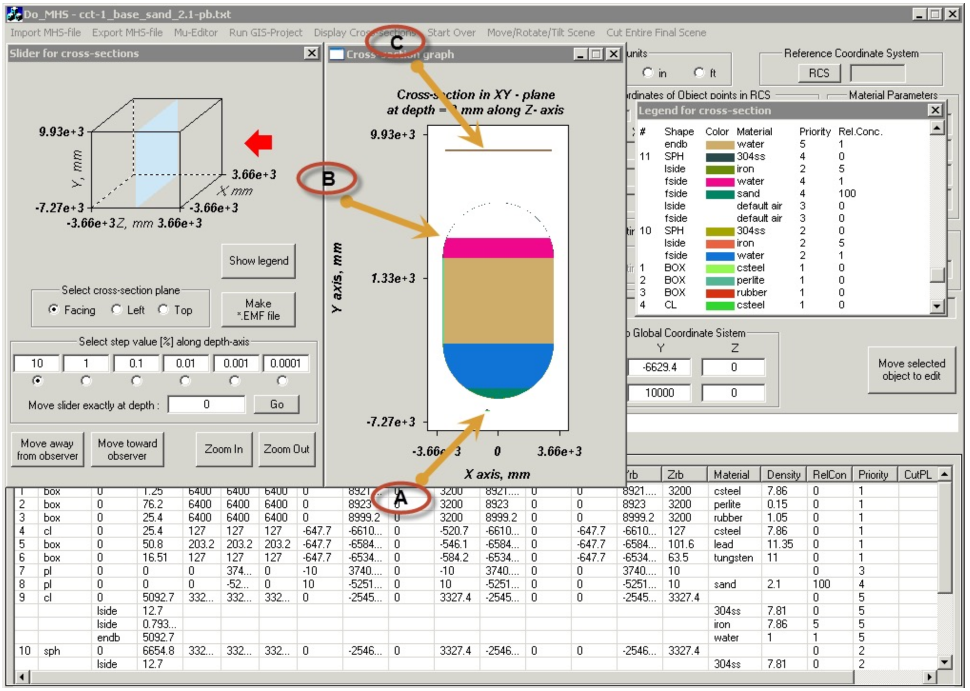


Figure 6: Example basement SuperISOCS model description.

Results and Analysis

- The results are separated into CCB roof and CCB basement measurements.
- The CCB roof measurements are sensitive to the radioactive material plated within the inner CCT-1 walls.
- The CCB basement measurements were sensitive to the volume within the bottom hemisphere of the CCT-1.
- The maximum **Cs-137** activity concentration measured from the CCB roof is **5.84x10-4 uCi/ml** and that for the CCB basement is **2.19x10-2 uCi/ml**. The total **Cs-137** activity concentration is the sum of these two values **2.25x10-2 uCi/ml** with a 2-σ Total Measurement Uncertainty (TMU) of 73%. This implies that the total **Cs-137** activity concentration is well less than the class A limit of 1 uCi/ml limit including a 2-σ TMU.
- The maximum **Co-60** activity concentration measured from the CCB roof is **5.01x10-1 uCi/ml** and that for the CCB basement is **2.16x10-2 uCi/ml**. The total **Co-60** activity concentration is the sum of these two values **5.23x10-1 uCi/ml** with a 2-σ Total Measurement Uncertainty (TMU) of 48%. This implies that the total **Cs-60** activity concentration is well less than the class A limit of 700 uCi/ml limit including a 2-σ TMU.
- Reported Values based on the CCB Roof Model and Basement Model:

Nuclide	Activity Concentration (uCi/ml)	2-σ TMU
Cs-137	2.25X10-2	73%
Co-60	5.23X10-1	48%

Stories of Issues Encountered in the Field

- Mysterious reduction in Neutron Background
- Mysterious increase in Gamma Background
- Neutron Add-A-Source QA/QC failure
- Unexplained noise on system
- Saturation of neutron counting software
- Another neutron background issue

Background

- Cannot say how many measurements have not had full background evaluations before starting.
- Understanding your measurement environment before you start actively acquiring data cannot be overstated for accuracy and quality of measurements.
- Understanding your background can be even more important for neutron type assays.
- Once again I like neutron measurements.

What we were aiming for today?

- Introduction and some understanding of measurement services.
- History of measurements from predefined empirical efficiency to predefined modeled efficiencies ending with objective specific efficiencies.
- Initial data shows work still needed to improve accuracy for the FOM type analysis.
- Very positive results for the FOM type analysis for new projects at other sites within the WIPP program.
- Move this type of data review into other projects were technical viable.