Australian Government
Australian Radiation Protection and Nuclear Safety Agency

ARPANSA Licence S0340

Koongarra, Northern Territory site survey

Field Trip report

14 to15th June 2023

Monitoring and Emergency Response Section
-
Health Physics Measurements

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Acknowledgements

Acknowledgement of Country

ARPANSA respectfully acknowledges Australia's Aboriginal and Torres Strait Islander communities and their rich culture and pays respect to their Elders past and present. We acknowledge Aboriginal and Torres Strait Islander peoples as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely.

We recognise and value the ongoing contribution of Aboriginal and Torres Strait Islander peoples and communities to Australian life and how this enriches us. We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

The members of the ARPANSA Health Physics Measurement filed team would also like to acknowledge Brayden Miller, Gisi Lamche, Che Doering, John Miller and Sally-Anne Atkins from the Office Supervising Scientist, Department of Climate Change, Energy, the Environment for their patience, help and assistance in planning this field trip.

Executive Summary

The health physics monitoring (HPM) group within the monitoring and emergency response section at ARPANSA on behalf of the regulatory services branch (RSB) are to undertake a series of health physics measurements at the Koongarra source in the Northern Territory from Tuesday 13th June to Friday 16th June 2023.

In-situ gamma spectrometry performed at the site indicates that the shipping containers contain between 1.25 Bq/g and up to 3.16 Bq/g activity for radionuclides in the uranium decay series, and 0.156 to 0.209 Bq/g activity in the thorium decay series. The activity for actinium decay series was calculated using the ratio of the natural abundance of uranium-235 (^{235}U) to that of uranium-238 (^{238}U) giving an estimate of activity for radionuclides in the actinium decay series between 0.113 to 0.148 Bq/g.

Objectives of the field trip

There are three main objectives of the field trip which are detailed below in figure 1. A fourth objective which is supplementary to the those conducted on behalf of RSB is to make use of unique site and source characteristics to test out current, legacy, and on-loan equipment in a field environment with measurable natural radiation.

- Perform site measurements to inform occupational and visitor safety decisions.
    - Dose rate measurements around shipping containers and perimeter fence
    - Ground surface measurements around the shipping containers with the aim of identifying possible breaches of shipping container integrity.
    - Water sampling from any nearby readily accessed surface or near surface drinking water.
    - Photographs of the site and photographs of the condition of the shipping containers
- Determine activity concentration each of the shipping containers (five in total)
    - Gamma spectrometry of the radiological contents of the shipping containers (five in total) if feasible and estimate of mass in each container.
- Issue a report to RSB detailing results from the field trip.

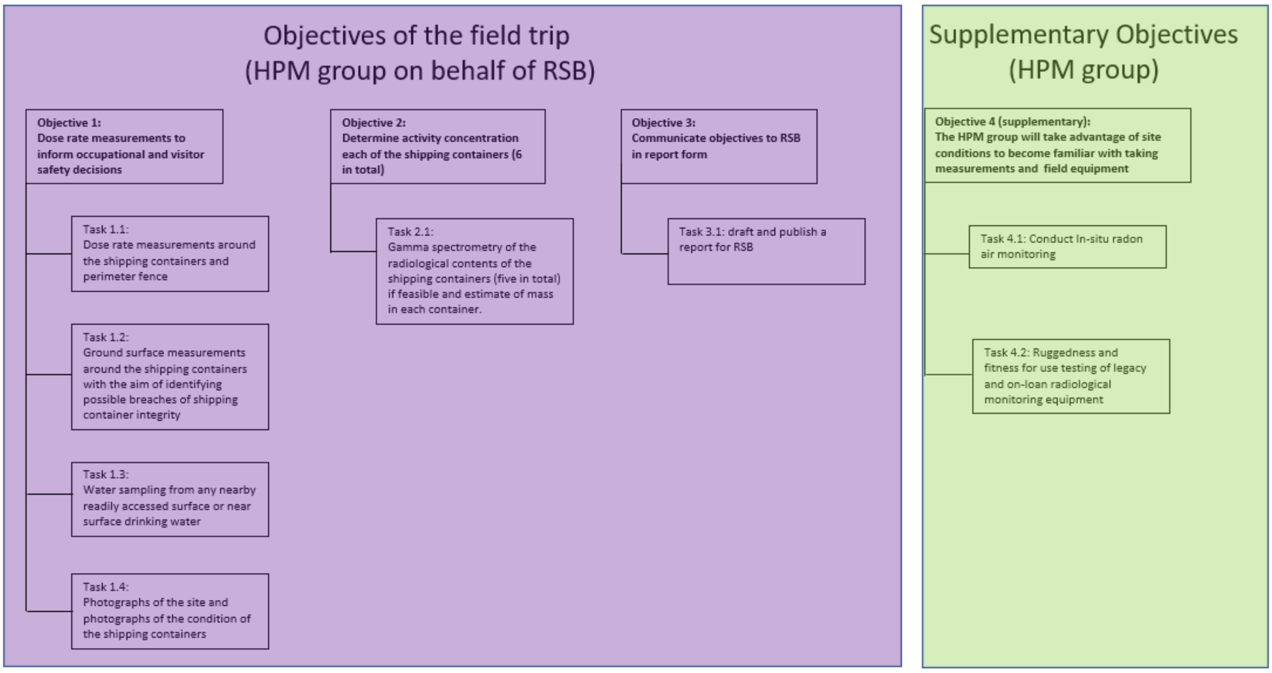

Figure 1. Objective and task flow chart for the field trip

1. Methodology

1.1 Dose rate measurements around the site

The in-house developed ARPANSA gamma mapping system (AGMS) using a 2 x 2-inch sodium iodide (NaI) crystal and AccuRad personal radiation detectors (PRDs) were used to create dose rate maps around the site and shipping containers with a pictorial overlay. Additional spot measurements were also taken at features of interest.

The AGMS and AccuRad gamma dose rate measurements were taken at a distance of 1 metre (m) from the ground, to approximately 5 m out from the fenced perimeter. Spectral data acquired by the AGMS detector crystal is known to be related to absorbed dose in the crystal and the air kerma rate in gray per hour (Gy/h). The detector crystals in the AGMS system have been calibrated for air kerma rate which is then converted into ambient dose equivalent H*(10) (Castle, L. 2009).

The AccuRad PRDs are externally calibrated by a NATA accredited laboratory, copies of certificate of calibration can be found in Appendixes 1 to 5. The energy and efficiency response of the AGMS NaI backpack detector were confirmed before use using an Eckert and Ziegler standard reference source (SRS) (radioactive source inventory number (RSIN) 1001, SRS number 107216A) traceable to the national institute of standards and technology (NIST). Certificate of calibration for RSIN 1001, SRS number 107216A can be found in Appendix 6.

1.2 Ground surface measurements

Where degradation of the shipping containers was apparent, judgemental non-probabilistic sampling of soil material samples were taken to identify and determine contamination to the environment IAEA (2019). Replicate or triplicate samples were taken using scoop/shovel sampling as per EPA (1992). Volume and area of the samples taken was not critical and the soil appeared to be mixed material likely to be a composite sample of the samples that have leaked from the shipping containers. Samples taken are likely to be not representative of the site and no statistically interpretation will be made on them.

Any samples taken were of a size that could at least fill a small sample container (small petri or large Petri geometry) typically used for sample analysis on a laboratory based high purity germanium (HPGe) detector.

A summary of the sample collection procedure can be found in Appendix 7. Samples were analysed in accordance with ARPANSA-SOP-1184 Sample preparation for measurement by gamma-ray spectrometry. Reported activities for the uranium, actinium and thorium decay series are presented in table 3, with reported activities for the thorium decay series based on gamma line emission activity for actinium-228 (^{228}Ac), the uranium decay series activity based on the 63 and 92 Kiloelectron (keV) gamma emission lines of thorium-234 (^{234}Th), and the actinium decay series activity reported based on the 186 and 84 keV gamma emission lines and 89 keV X-ray line.

1.3 Water sample measurements

No readily accessible surface or ground water was available for sampling.

1.4 In situ gamma measurements

A Canberra Falcon 5000 portable HPGe detector was used by the HPM team to perform this task. Due to Health and Safety concerns from Supervising Scientist, the shipping containers were not opened, and as such estimates of the fill heights inside the container which are required for the activity mass calculations were obtained through measurements from visual observation and estimates based off two photos taken through cracks in the door of two of the shipping containers where the doors were not closed properly. Dose rate mapping with AccuRad PRDs was also performed along two lengths of walls of shipping containers number 4 and 5.

1.4.1 Configuration and set up of the Portable HPGe detector for different site geometry views

Multiple gamma measurements of the shipping containers on the Koongarra site were acquired. Figure 2 shows positioning of the Falcon 5000 around the source site enclosure so as to obtain orthogonal and oblique measurements of the source site. As the activity in the shipping containers was going to be magnitude of orders greater than the surrounding environment, background spectrums were not considered appropriate for measurement. The highly variable background of the site also made background spectrums inappropriate. Each geometric configuration of the shipping container will be modelled within the constraints of the labSOCS and the total activity for each container calculated through subtraction and differentiation of the varying measurement points.

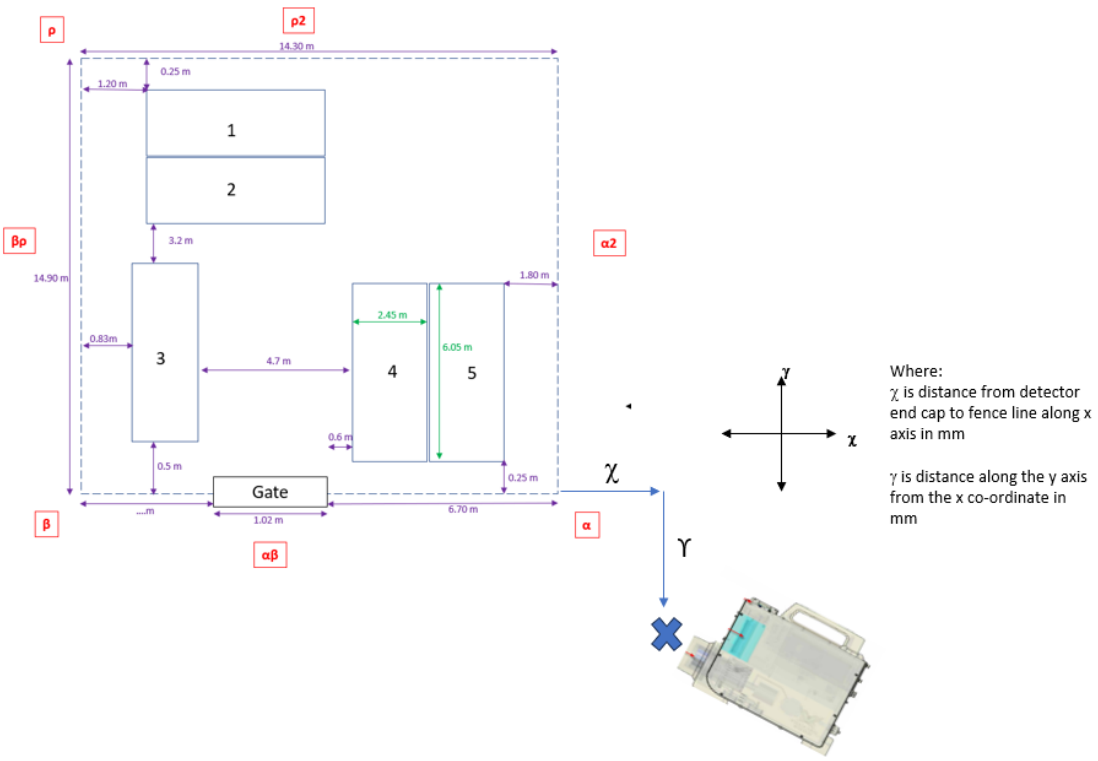

Figure 2. Source site schematic showing positioning of portable HPGe for gamma spectrum acquisition for corner measurements α, β, ρ. Axis co-ordinates for the 3 corner measurements taken can be found in Table 1

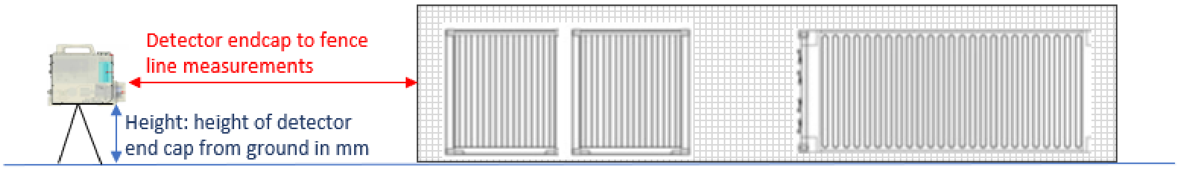

Figure 3. Schematic showing side view of the positioning of the portable HPGe for gamma spectrum acquisition for side measurements α2, αβ, βρ and ρ2. Axis co-ordinates for the 4 side measurements taken can be found in Table 1

Table 1 Axis coordinates for distance between portable HPGe detector and source fence line

HPGe measurement	Original file name	χ and γ axis coordinate (mm)
α	k-alpha-20230614	Height: 1170 Detector endcap to fence line distance: 1476 χ: 1048 γ: 1149
α2	k-alpha2-20230614	Height: 1150 Detector endcap to fence line distance: 7870 χ: NA γ: NA
αβ	k-alphabeta-20230614	Height: 1140 Detector endcap to fence line distance: 9250 χ: NA γ: NA
β	k-beta-20230614	Height: 1250 Detector endcap to fence line distance: 1112 χ: 1168 γ: 1146
βρ	k-betarho-20230615	Height: 1152 Detector endcap to fence line distance: 9080 χ: NA γ: NA
ρ	k-rho-20230614	Height: 1150 Detector endcap to fence line distance: 895 χ: 860 γ: 800
ρ2	k-rho2-20230614	Height: 1160 Detector endcap to fence line distance: 10700 χ: NA γ: NA

1.4.2 *Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) Calibration*

An europium-152 check source (ARPANSA RSIN 0549) was used for energy calibration on the Falcon HPGe detectors prior to shipment to the site. The energy lines of isotopes present in the natural environment, radium-226 (^{226}Ra), bismuth-214 (^{214}Bi) and potassium-40 (^{40}K) were used to correct any slight (1 to 2 keV) energy shifts due to variations in on-site temperature throughout the day and perform peak full width half maximum (FWHM) calibration. For details for energy and FWHM calibration for each spectrum refer to Appendix 8-14.

2. Results

2.1 Results for dose rate measurement around the site

Results for site dose rate measurements are presented in figure 4. Measured dose rates of up to 2.4 µSv/h were measured using the backpack system. Ad hoc measurements made using a AccuRad are presented in figure 5 and show good agreement with the AGMS dose rate mapping system.

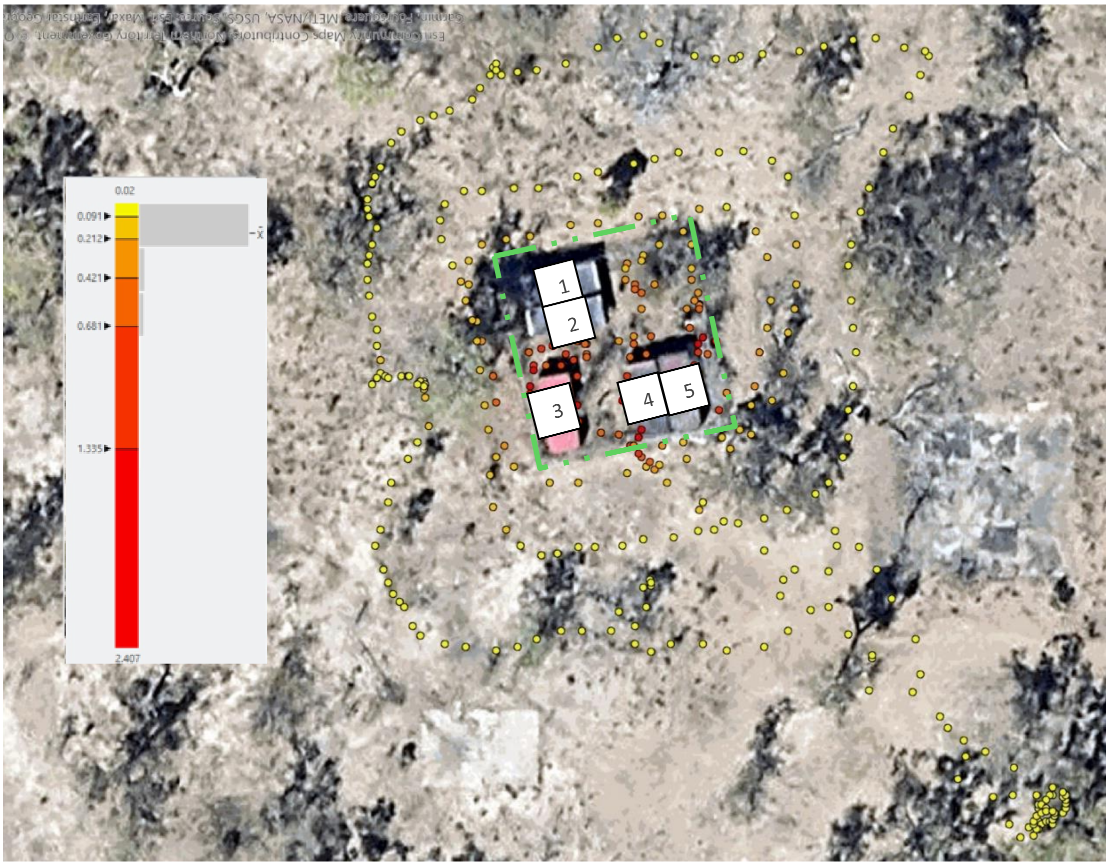

Figure 4. AGMS dose rate map of the Koongarra source site. The secure fence boundary is indicated by the green dashed line and shipping containers are labelled

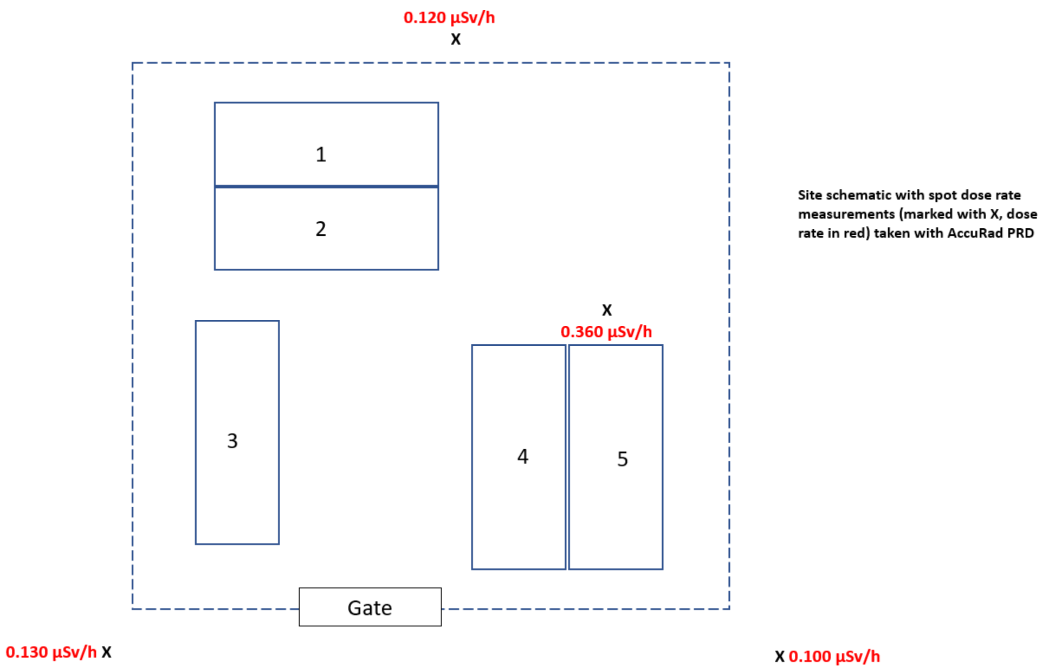

Figure 5. Ad hoc dose rate readings made using a AccuRad PRD in µSv/h

2.2 Dose rate mapping of shipping containers

Dose rate mapping using the AccuRad PRDs was performed on the sides of shipping containers 4 and 5 by holding the AccuRad PRD against the side of the container at set interval points of either 1m or 0.5m (as indicated in the descriptions of figure 6 and 7). As can be seen in figures 6 and 7, measured hot spots of activity up to 23 µSv/h were found along the length of container 5 and 5.62 µSv/h along the length of container 4.

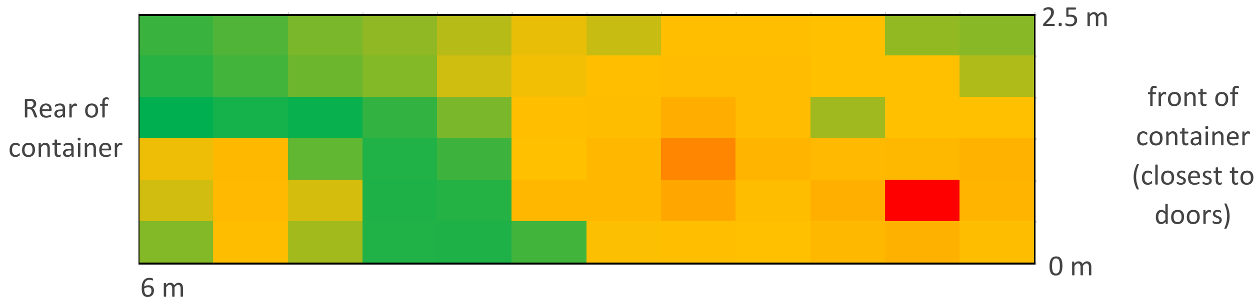

Figure 6. dose rate heat map of the long length of container 5, side closest to fence. Measurement intervals were every 0.5 m along the length and height of the container. Highest dose rate measured indicated by the red colour was 23 µSv/h.

Figure 7. dose rate heat map of the long length of container 4. Measurement intervals were every 1 m along the length and 0.5m or 0.25 m along the height of the container Highest dose rate measured indicated by the red colour was 5.62 µSv/h.

2.3 Ground surface measurements results

Some of the shipping containers showed physical degradation at stress points around the bottom edges and on the top of the containers due to harsh environmental conditions and age, leading to contents from the containers leaking out and subject to potential dispersion. With permission from the source licence holder, Parks Australia, ground samples were taken from areas around shipping containers 3 and 5 for further laboratory analysis. Sample results, details and locations are detailed in Table 2, 3 and figure 8.

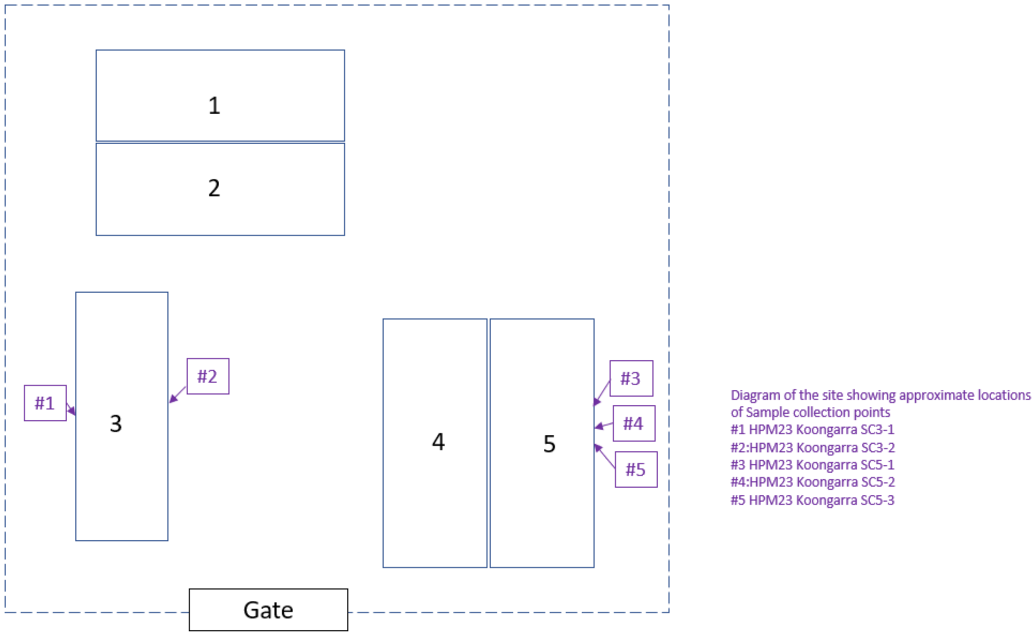

Figure 8. Site schematic showing 'soil' sample collection points.

Table 2. Sample log and field notes for soil samples

Sample RAS Lab #	Sample name	Observations/comments	Photos
EA23-023-0227	HPM23 NTK SC3-1	Shipping container #3, on fence side along bottom of shipping container where integrity has been breached.	
EA23-023-0228	HPM23 NTK SC3-2	Shipping container #3, on inside side along bottom of shipping container where integrity has been breached.	
EA23-023-0229	HPM23 NTK SC5-1	Shipping container #5, on fence side along bottom of shipping container where integrity has been breached. Sample is visually a chunk of red dirt. There is a geological sample tag which was also collected with the sample	
EA23-023-0230	HPM23 NTK SC5-2	Shipping container #5, on fence side along bottom of shipping container where integrity has been breached. Visually sample is powdered or fine dirt	
EA23-023-0231	HPM23 NTK SC5-3	Shipping container #5, on fence side along bottom of shipping container where integrity has been breached. Small bits of old plastic bag are in in the sample which visually looks like fine dirt.	
	Collected by:	CW and MT	
	Collection date:	15th June 2023	

Table 3. Sample results for ground surface soil measurements

Sample RAS Lab #	Actinium decay series Bq/g	Uranium decay series Bq/g	Actinium decay series Bq/g
EA23-023-0227	0.0289 ± 0.0044	0.060 ± 0.018	0.0029 ± 0.0014
EA23-023-0228	0.0134 ± 0.0022	0.189 ± 0.037	0.0084 ± 0.0025
EA23-023-0229	0.0379 ± 0.0060	3.71 ± 0.56	0.205 ± 0.029
EA23-023-0230	0.0307 ±0.0037	0.664 ±0.090	0.0432 ±0.0060
EA23-023-0231	0.0572 ± 0.0069	2.42 ± 0.31	0.112 ± 0.020

2.4 Water sample measurements results

Not applicable. No readily accessible surface or ground water was available for sampling.

2.5 Photographs of the site and conditions of sources

Photos for the site and shipping containers are presented in Appendices 15 to 24. Table 4 summarises the conditions of the site and the shipping containers. Figure 9 shows site schematic with some point of note. Refer to Table 4 for description of the site features and appendixes 15 to 21 for photographic details.

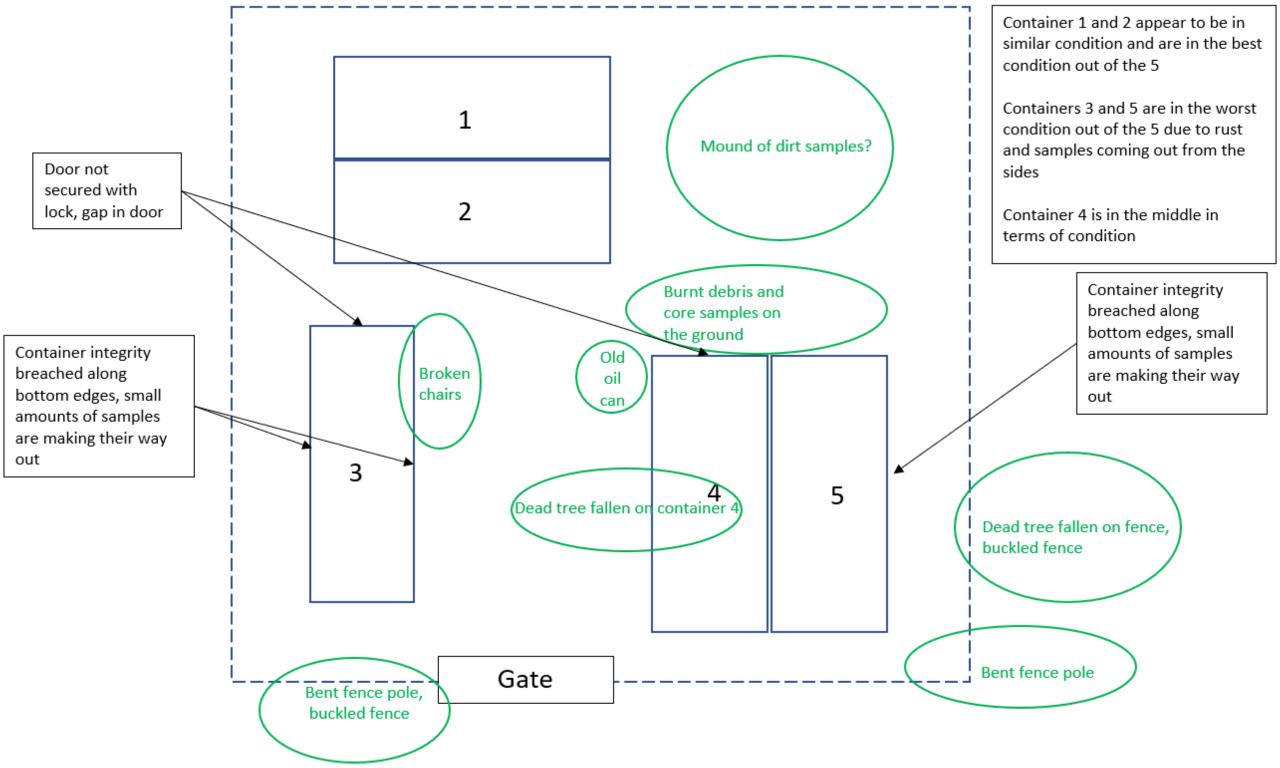

Figure 9. Site schematic showing some points of note highlighted in green

Table 4. Summary of shipping container conditions and integrity at site

Aspect	Observations/comments
Site photos Refer to Appendix 15	• Right corner fence bent, and wire fence buckling inward due to a fallen tree close to the fence line on the outside • Tree in middle of enclosure has died and fallen on shipping container 4 and 5. • Pole to left of gate bent and wire fence buckling inwards as a result. • Debris inside the enclosure includes old broken chairs, wooden poles, rusted oil can • Gate is secure with padlock and chain and enclosure displays restricted area and radiation warning signage
Shipping container #1 Refer to Appendix 16	• Rust was observed around edges of container. • This is one of the containers in better condition out of the 5 • Container #1 abuts container #2 so photos are only available of the long edge that does not abut container #2. • Container #1 is on a bit of a lean towards the fence line, this is likely due to uneven ground • Container #1 is secured with padlock and chain and radiation warning signage

Shipping container #2 Refer to Appendix 17	• Rust was observed around edges of container, there could be a small amount of sample spill out near the lower hinge of the door (refer to figure 28). • This is one of the containers in better condition out of the 5 • Container #2 abuts container #1 so photos are only available of the long edge that does not abut container #1 • Container #2 is secured with padlock and chain at the bottom of the container door and displays radiation warning signage
Shipping container #3 Refer to Appendix 18	• Rust was observed around edges of container, especially the bottom of the door and both long sides where small amounts of sample appear to have worked its way out of the container and onto the ground, refer to Table 3. • Two of the containers were judged to be in poorer condition than the others due to the rust, the door not shutting properly, and samples coming out along the bottom sides. This is one of those two. • The Door of the container cannot be secured with a chain and lock due to door seizing up or misalignment. A radioactive materials label is affixed to the door
Shipping container #4 Refer to Appendix 19	• Rust was observed around edges of container, especially the bottom and top of the door. Burnt material is present in front of the door along with what looks like mining core samples and an old, rusted oil can nearby. • In terms of degraded condition, this container is in the middle out of the 5 in terms of degraded condition. • The Door of the container cannot be secured with a chain and lock due to door seizing up or misalignment. • A radioactive materials label is affixed to the door. • A dead tree in the middle of the enclosure has split with dead branches resting on the top of the shipping container
Shipping container #5 Refer to appendix 20	• Rust was observed on the container, especially around edges and door and on the walls. Along the long fence side there appears to be small amounts of sample that have worked their way out of the container and onto the ground, refer to Table 3. • Burnt material is present in front of the door along with what looks like mining core samples. Two planks of wood rest on the doors as if to help hold them close. • Two of the containers were judged to be in poorer condition than the others due to the rust, the door not shutting properly, and samples coming out along the bottom sides. This is one of those two. • The door of the container has been secured with a chain and lock at the top but due to the door seizing up or misalignment there is a gap in the door of about 5 to 10cm. A radioactive materials label is affixed to the door
Shed photos Refer to appendix 21	• Sheds are degrading, with metal sheeting coming off the structures leaving large gaps that can be walked through. • Shed contain both empty sample core trays and trays containing degraded samples (i.e., in plastic bags that are falling apart or mixing with other samples due to weathering. • Dose rates measured with an AccuRad inside the sheds ranged from 1.55 µSv/h to background levels (0.040 µSv/h) to refer to figure 51c and 52b
Photos taken by:	HPM field members

Collection date:	14th and 15 June 2023

2.6 Analysis of the shipping containers

2.6.1 Data and information used for in-situ object counting system (ISOCS) geometry models

A summary of the standard dimensions used for the ISOCS models is presented in Appendix 22.

Door gaps in two of the containers were wide enough to allow for insertion of an iphone for photos of the interior of container #3 and #5 allowing for visual assessment of fill heights. As the containers were not opened, the visual fill height estimates from containers #3 and #5 were used in the standard ISOCs model used for estimating activity for all containers. Based on visual estimate from these photos, a fill height of 2m inside the containers is used for the models.

Shipping containers are built to ISO standards, specifically ISO 6346:1995, ISO 1161, and ISO 830 which detail definitions, terminology, size and type code, and additional optional markings (Discover containers, n.d.). key shipping container dimensions are reported in Appendix 22.

Steel core trays, filled geological sample bags and cardboard boxes are visible in the photos taken through the door cracks of shipping container #3 and #5. The ISOCS models for the material in the shipping containers is based on the composition of mining core trays (Made-in-China.com, n.d.) and racking systems (West Australian Steel Sales, 2023) with estimates made of the number or amount of:

- Sample cores that could be present and contained in each tray
- how many trays and racking systems could fit in a shipping container
- Expected cubic capacity of the shipping container at 2 m fill height.

If shipping containers were opened a better estimate of the contents and weight could be made using this data. Figure 10 shows some pictorial examples of what is likely to be present in the shipping containers based off the available photographs.

Estimates for core content and density are based on that reported in Duerden et al., 1992. An average dry density of 2.7 g cm^3 is used for the ISOCS Koongarra core material. For composition of the core material in the containers, an average was taken of the percent elemental mineral abundance for Core M1 in Table 9.1 in Duerden et al., 1992 to account for majority of the material makeup, with estimates of the average percentages of other minor elements likely to be present in the core samples read from crude graphs in the same report. The remaining 3.83 % of the material was assigned to uranium. This is a realistic percentage likely to be present as up to 10% uranium has been reported for some of the early Koongarra sample and site exploration studies (Duerden et al., 1992).

a) B) c)

Figure 10. Pictorial examples of internet searchable products that are representative of what is likely to be present in the shipping containers. a) picture of steel core tray racking system and core trays (West Australian Steel Sales, 2023), b) example of a calico sample bag, popular with geologist (Dynamics G-Ex, 2023) c) inside contents of container #5 showing boxes and core tray present, estimated fill height is 2 m and cardboard content in the material and bag material has not been included in any calculations.

2.6.2 Equilibrium assumptions and key gamma emission lines for Activity determination

When analysing nuclides in natural decay chains, a key point of interest is understanding whether equilibrium exists between the parent nuclides and radioactive decay products. Equilibrium in terms of radioactive decay is where there is a fixed ratio between formation and decay of a radioactive product (Hendee et al., 2004). Once equilibrium is achieved there is no increase in radioactivity and the activity is constant. There are two equilibrium conditions of interest when analysing the decay series – transient equilibrium (where after reaching equilibrium, the product activity starts to decay and net activity decreases due to decreasing amounts of parent radionuclide) and secular equilibrium which occurs in situations where the parent half life is very long compared to the daughter allowing for constant production and subsequent decay of the daughter product resulting in no change in net activity. Due to the long half lives of the uranium and thorium parent, we can assume they are at maximum activity and neither increasing or decreasing, and that they will be equal to that of their daughter products and secular equilibrium exists. (Long et al., 2012)

Isotopes in the uranium, actinium and thorium decay series of interest for activity determination are presented in figure 11 to 13. These three decay series start with the parent nuclides of ^{238}U (the Uranium decay series), ^{235}U (the actinium decay series) and Thorium-232 (^{232}Th)(the thorium decay series), which are all long lived alpha emitters, and undergo radioactive decay which is further continued through their daughter products before ending in stable lead. Many of the nuclides within the decay chains include alpha, beta, and gamma emitters.

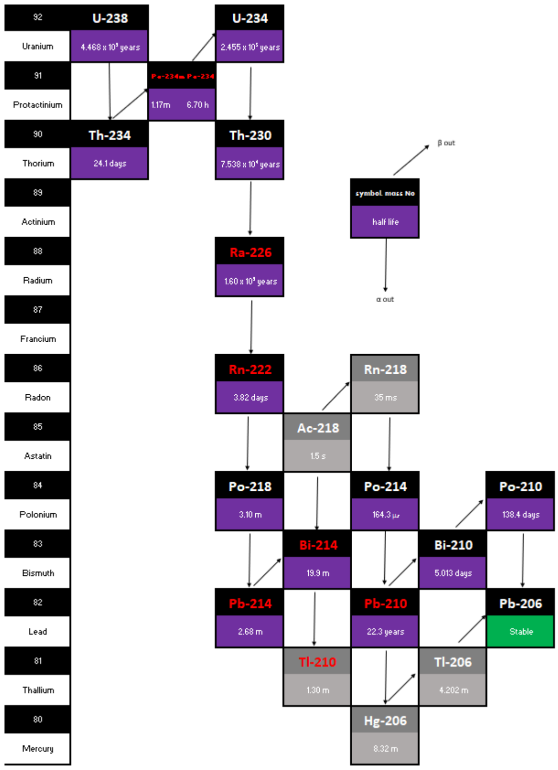

Figure 11. Important radionuclides in the Uranium decay series

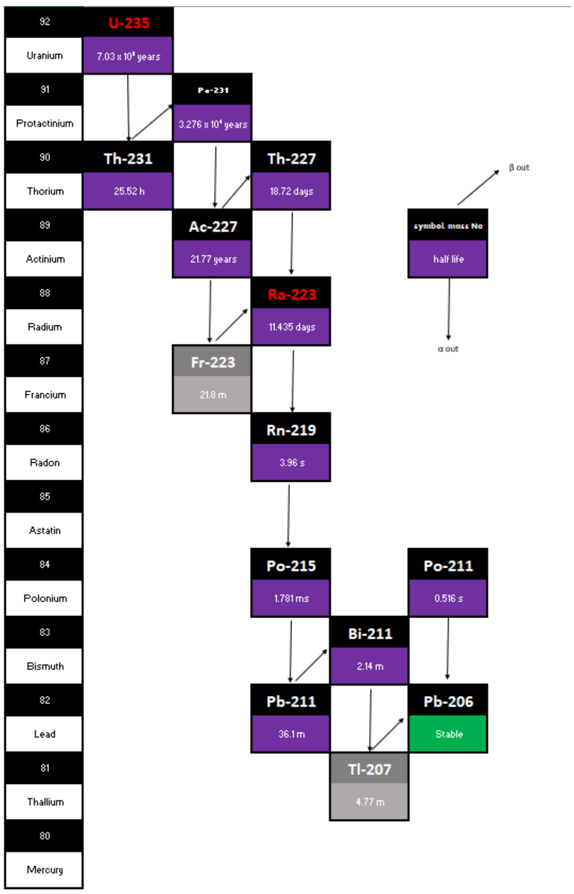

Figure 12. Important radionuclides in the Actinium decay series

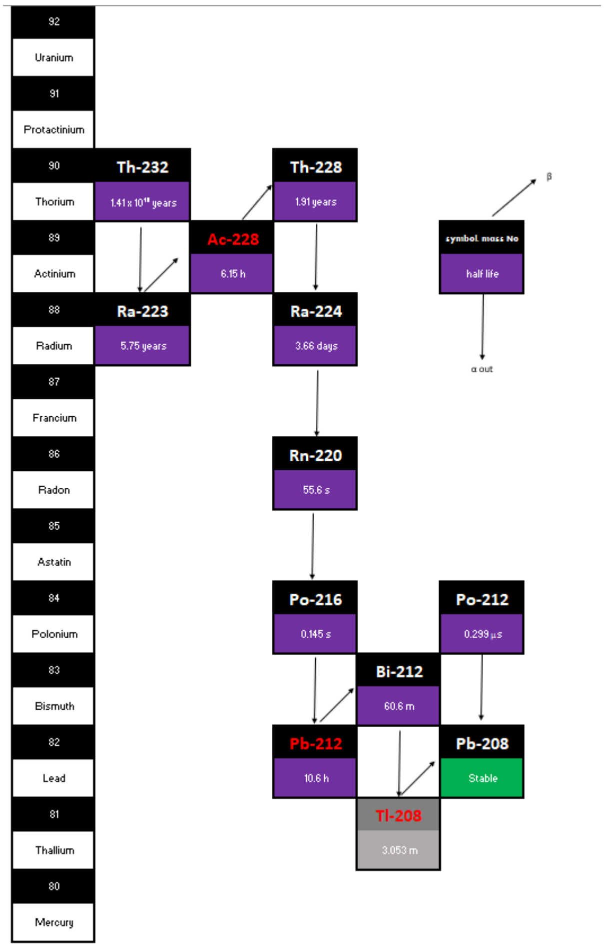

Figure 13. Important radionuclides in the Thorium decay series

Key gamma emitting nuclides have had their symbol and mass number highlighted in red in figures 9 to 11, many of these nuclides are not suitable for activity determination either due to poor gamma emission probability or interference at the gamma emission energy from other radionuclides within the same decay series or from different decay series. An example of this is the 186 keV gamma emission from ^{226}Ra in the Uranium decay series. ^{235}U in the Actinium series also has a high probability emission at this energy, and poor counting statistics for the measured sample spectrums (50 to 500 counts for the 1001 keV protactinium-234m (^{234m}Pa) gamma emission, depending on the spectrum) mean it is not feasible to accurately extrapolate ^{235}U to ^{238}U contribution based on daughter activities. Specialised and time-consuming radiochemical separation for alpha spectrometry analysis or ICP-MS is required if more accurate determination was warranted.

Some of the daughter radionuclides in the Uranium and Thorium decay series do have gamma emission lines with good emission probability and no interference. These are tabulated in Table 5 and 6. As we are assuming secular equilibrium, the activities from the key line (highest abundance) for the nuclide with the highest emission probability will be used are used to report activity for a series, in this case the 609.3 keV of ^{214}Bi and the 911 keV gamma emissions from ^{228}Ac. The Actinium decay series does not have any good gamma emission lines that can be used for activity determination. Activity determination for this series will be based on the well-known assumption that ^{235}U makes up 0.7% of the natural abundance of uranium present in the environment, with ^{238}U making up the 99.28% and ^{234}U 0.05% respectively.

Table 5. Radionuclides with good gamma emission probability and little interference in the Uranium decay chain

Radionuclide	Uranium decay series	
	Gamma energy	Emission probability
^{214}Bi	609.3	46.1 %
	1764.5	15.4 %

Table 6. Radionuclides with good gamma emission probability and little interference in the Thorium decay chain

Radionuclide	Thorium decay series	
	Gamma energy	Emission probability
^{228}Ac	911.2	25.8 %
	969.0	15.8 %

2.6.3 Discussion of the analysis of ISOCS modelled shipping containers

ISOCS geometries were constructed for the spectrum site views using a combination of box, complex box and rectangular plane geometry templates (refer to figures 14 to 16). Due to constraints of the ISOCS geometry templates, the α2 side views and ρ2 side views with all three shipping containers were unable to be constructed with the predefined templates. However, geometry models with two of the three shipping containers which were closest to the detector were able to be modelled for the α2 side views and ρ2 side views (refer to figure 15). Decay series activity results are presented in table 7 for each of the side geometries modelled.

Table 7. Uranium and Thorium decay series results for each spectrum view

Detector position	Uranium decay series activity	Thorium decay series activity
	609 keV	911 keV
Corner Spectrums (α, β, ρ)	Activity concentration (Bq/g) k=2	
α view: spectrum k-alpha-20230614	2.92 ± 0.36	0.151 ± 0.049
β view: k-beta-20230614	3.29 ± 0.41	0.209 ± 0.087
ρ view: spectrum k-rho-20230614	**1.25 ± 0.16**	**0.158 ± 0.049**
Side view Spectrums (α2, αβ, βρ, ρ2)		
α2 view: *spectrum k-alpha2-20230614*	*6.75 ± 0.87*	*1.64 ± 0.37*
αβ view: spectrum k-alphabeta-20230614	3.30 ± 0.42	0.80 ± 0.14
βρ view: spectrum k-betarho-20230614	3.46 ± 0.44	0.56 ± 0.13
ρ2 view: spectrum k-rho2-20230614	2.82 ± 0.19	1.25 ± 0.21

For the side view spectrums αβ and βρ in with well-constructed ISOCS geometries with a 3-shipping container view (figure 14), the activity for the Uranium decay series is in good agreement and within uncertainty (3.30 ± 0.42 and 3.46 ± 0.44 Bq/g).

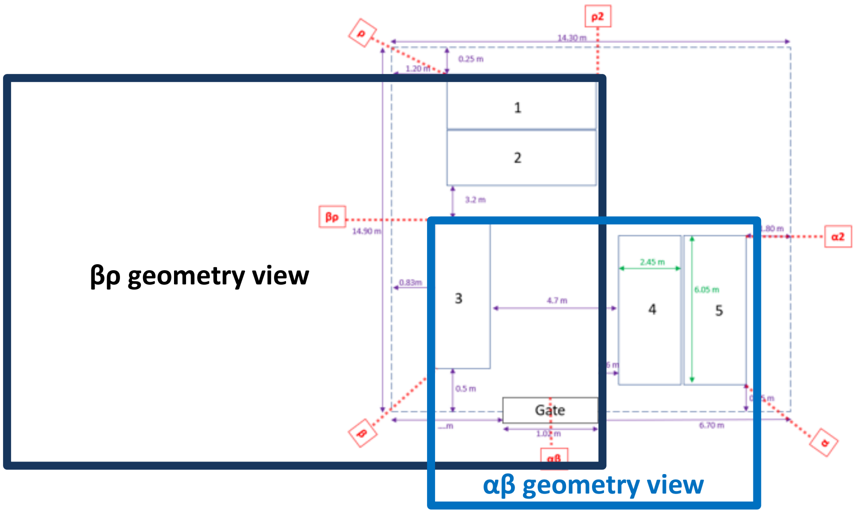

Figure 14. diagram showing the shipping containers were captured in the αβ and βρ detector side geometry views

For the side view spectrum of α2, which has shipping containers 4 and 5 modelled, the activity for the uranium series is higher (6.75 ± 0.87 Bq/g) compared to the other results for the other modelled geometries (which with the exception of the ρ view with a result of 1.25 ± 0.16, range from 2.82 ± 0.19 to 3.46 ± 0.44 Bq/g). This could be due to a hot spot which was found when performing a dose map on the side of the container 5 (refer to figure 5) which just happened to be very close to the detector line of site for the α2 geometry. This is consistent with the ambient dose rate map (refer to figure 4) which was performed around the site and showed higher dose rate readings around containers 4 and 5.

The side view spectrum for ρ2, which contains containers 1 and 2 modelled (refer to figure 15, and third line of results in Table 7) has the lowest activity for the uranium decay series for the whole side views.

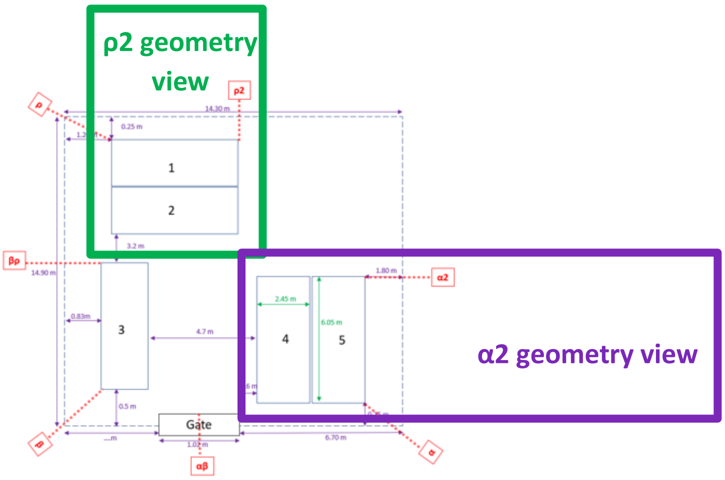

Figure 15. diagram showing the shipping containers were captured in the α2 and ρ2 detector side geometry views

This is consistent with the result for the ρ corner view spectrum taken of containers 1 and 2 (figure 16) which has around 70% less activity (1.25 ± 0.16 Bq/g) compared to the two other corner shots α and β (which are 2.92 ± 0.36 Bq/g and 3.29 ± 0.41 Bq/g respectively). The lower activity for the ρ2 spectrum view could also be due to the detector field of view also having less material.

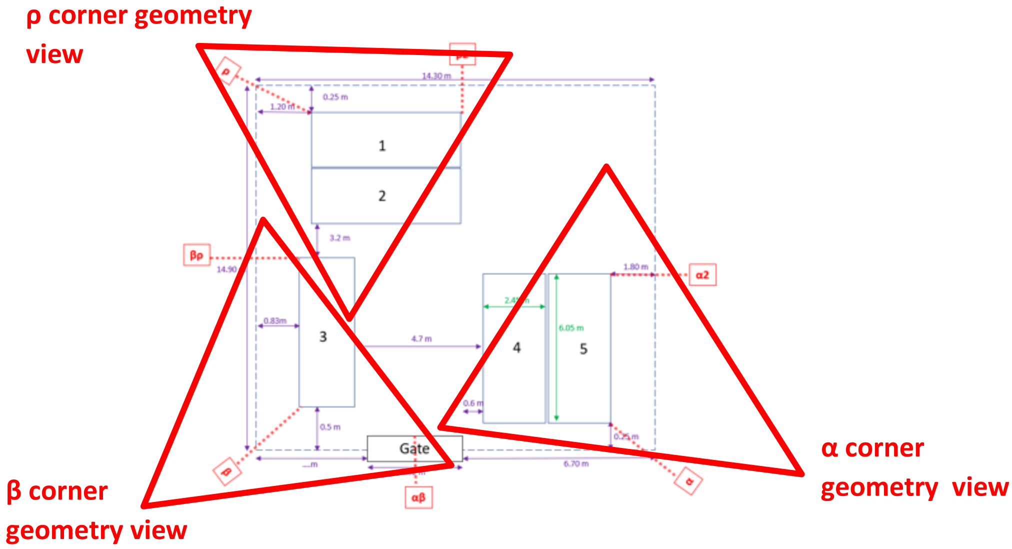

Figure 16. diagram showing the shipping containers were captured in the α, β and ρ detector side geometry views

When looking at the results in table 7, the corner spectrum ρ view (table 7, bold red text) is around 70% less activity for the uranium series than the α view corner spectrum (table 7, bold green text), despite having the same geometry model. The β view corner spectrum (table 7, bold purple text) also has a similar activity to the α view corner spectrum (3.29 ± 0.41 Bq/g and 2.92 ± 0.36 Bq/g respectfully) despite only having one shipping container in the geometry model as opposed to two. As in the case of the α2 view spectrum which had elevated activity estimates, the lower activity estimate for the ρ view is consistent with the dose rate maps around the site (refer to figure 4), where lower ambient dose rates were measured around the perimeter fence near containers 1 and 2.

The geometry for the αρ view, which includes containers 1, 2, and 3 in the geometry (refer to figure 13), was remodelled to have container #1 having approximately 30% of the activity compared to containers 2 and 3. The results are presented in Table 8, with the remodelled uranium series activity results in Bq/g now showing results that are closer in agreement with the α and β corner shots. These results could indicate that container 1 is shielding the contents of container 2 from the detector and the detector is only picking up the activity in the container 1, which is the container closest to it.

To test whether the shipping container closest to the detector was shielding the activity in the abutting shipping container, the ρ corner geometry and α corner geometry spectrums were remodelled with two different scenarios to have 100% of the activity and material in the shipping container closest to the detector line of sight, and 0% of the activity and material in the shipping container closest to the detector line of sight. Results are shown in table 9 along with the original ρ and α corner view results for ease of comparison. Results show there is a significant change in activity when 100% of the activity is placed in the shipping container furthest away from the detector line of sight. This indicates that there is considerable attenuation due to the contents of the shipping containers and the activity results reported are likely to be for the shipping container closest to the detector.

Table 8. Shielding sensitivity estimates of the remodelled βρ corner geometry view with ISOCS modelling adjusted to account for container 1 having 70% less activity.

Bq/g **k=2 for uncertainty**	**Uranium decay series activity**	**Thorium decay series activity**
	609 keV	911 keV
βρ view: spectrum k-betarho-20230614 – original analysis results	3.46 ± 0.44	0.209 ± 0.087
βρ view: spectrum k-betarho-20230614 reanalysis with 70% less activity in container 1 compared to container 2 and 3	2.95 ± 0.38	0.151 ± 0.049
α view: spectrum k-alpha-20230614	2.92 ± 0.36	0.151 ± 0.049
β view: spectrum k-beta-20230614	3.29 ± 0.41	0.209 ± 0.087

Table 9. Reanalysis of α2 view and k-rho-20230614 spectrum with ISOCS modelling adjusted to have either 100% or 0% of the activity in the shipping container 5or 1, which are the containers closest to the detector line of sight

Bq/g **k=2 for uncertainty**	**Uranium decay series activity**	**Thorium decay series activity**
	609 keV	911 keV
100% Activity in container 5 α view: k-alpha-20230614 Remodelled with 100% activity and material in container 5.	3.04 ± 0.38	0.156 ± 0.025
0% Activity in container 5 α view: k-alpha-20230614 Remodelled with 0% activity and material in container 5.	37.08 ± 4.60	1.78 ± 0.582
Original α view: spectrum k-alpha-20230614 original analysis with activity in both containers	2.92 ± 0.36	0.151 ± 0.049
100% Activity in container 1 ρ view: k-rho-20230614 Remodelled with 100% activity and material in container 5.	1.30 ± 0.16	0.164 ± 0.050
0% Activity in container 1 ρ view: spectrum k-alpha-20230614 Remodelled with 0% activity and material in container 1.	36.5 ± 4.6	4.2 ± 1.3
Original ρ view: spectrum k-alpha-20230614 original analysis with activity in both containers	1.25 ± 0.16	0.158 ± 0.049

2.7 Final Activity estimates

The mass of each shipping container is assumed to be 60 584 kg. This is likely to be a gross overestimate due to conservative assumptions made in modelling and activity calculations, stemming from limits on investigating the interior and contents of the containers.

A summary of the activities is presented in table 10. The remodelled data shows that the initial corner geometry models are reflective of activities in the corner shipping containers 1, 3 and 5 and can be used for reporting purposes. The activity concentration for shipping containers 2 and 4 is assumed to be similar to container 3.

The variation in activity for container 5 with the remodelled α corner spectrum and the αβ side view shows that the contents of the containers is not homologous and there is likely to be variations in activity within the shipping container contents for container 5, and the other containers. The dose rate mapping performed with AccuRad PRDs on the long sides of container 4 and 5 showed variations in dose rate measurements along the length.

Further in-situ spectral analysis and dose rate mapping on the sides of the containers would allow for more in depth characterisation and more accurate activity determination. Whether this would add any value is questionable. The highest dose rate recorded on the field trip was 23 µSv/Hr, measured along the side of container 5. A person standing next to this 'hot spot' for 40 hours would receive a radiation dose nearing the annual public dose limit of 1 mSv

Actinium decay series activities are calculated using gamma activity results for the ^{238}U decay series and the % weight composition of ^{235}U (0.711 %) to ^{238}U (99.284%) in naturally occurring uranium (IAEA, 2007)

Table 10. Final reported activities for shipping Containers Bq/g

<table>
<tr><th colspan="3">Final reported activities of shipping containers (Bq/g)
k=2 for uncertainty</th><th>Final reported activities of shipping containers (µBq/g)</th></tr>
<tr><td></td><td>Uranium decay series activity</td><td>Thorium decay series activity</td><td>Actinium decay series Activity</td></tr>
<tr><td colspan="3">Corner Spectrums (α, β, ρ)</td><td></td></tr>
<tr><td>Shipping container 1</td><td>1.25 ± 0.16</td><td>0.158 ± 0.049</td><td>0.148 ± 0.018</td></tr>
<tr><td>Shipping container 3</td><td>3.29 ± 0.41</td><td>0.209 ± 0.087</td><td>0.113 ± 0.014</td></tr>
<tr><td>Shipping container 5*</td><td>3.04 ± 0.18</td><td>0.156 ± 0.025</td><td>0.137 ± 0.017</td></tr>
<tr><td colspan="4">Shipping containers with no direct spectral analysis (average of shipping containers 3 and 5 used)</td></tr>
<tr><td>Shipping container 2</td><td rowspan="2">3.16 ± 0.30</td><td rowspan="2">0.183 ± 0.056</td><td rowspan="2">0.142 ± 0.018</td></tr>
<tr><td>Shipping container 4</td></tr>
</table>

* Remodelled α spectrum activity used for reporting

Table 11. Final reported activities for shipping Containers total per container based on contents of each shipping container weighing 60 584 kg

Final reported activities of shipping containers (MBq/container) k=2 for uncertainty			Final reported activities of shipping containers (Bq/g)
	Uranium decay series activity	Thorium decay series activity	Actinium decay series Activity
Corner Spectrums (α, β, ρ)			
Shipping container 1	152 ± 19	12.7 ± 5.3	6.84 ± 0.87
Shipping container 3	199 ± 25	19.1 ± 5.9	9.0 ± 1.1
Shipping container 5*	184 ± 23	9.5 ± 1.5	8.3 ± 1.0
Shipping containers with no direct spectral analysis (average of shipping containers 3 and 5 used)			
Shipping container 2	192 ± 24	11.1 ± 3.4	8.6 ± 1.1
Shipping container 4			

* Remodelled α spectrum activity used for reporting

2.8 Transport of Natural Uranium Ore

Radioactive material is classified as class 7 under the Dangerous goods code, but as movement and transport of the Koongarra shipping containers will not be transported on the same road vehicle or train as dangerous goods of other classes, deference for regulations should be made to ARPANSA's Radiation Protection Series C-2 Code for the Safe Transport (ARPANSA, 2019).

The object of this code is achieving safety and protection for people, property, and the environment. In this case special measures should be taken to ensure containment of the radioactive contents of the shipping containers and control of external radiation levels.

For the Uranium and Thorium decay chains, secular equilibrium is assumed, and exemption limits in the code are as follows

U-natural:

The parent nuclide (^{238}U) and it's progeny ^{234}Th, ^{234m}Pa, ^{234}U, ^{230}Th, ^{226}Ra, ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po, ^{210}Pb, ^{210}Bi, ^{210}Po are assumed to be in secular equilibrium

Activity concentration limit for exempt material = 1 Bq/g

Activity limit for an exempt consignment = 1000 Bq

Th-natural:

The parent nuclide (^{232}Th) and it's progeny ^{228}Ra, ^{228}Ac, ^{228}Th, ^{224}Ra, ^{220}Rn, ^{216}Po, ^{212}Pb, ^{212}Bi, ^{208}Tl (0.36), ^{212}Po (0.64) are assumed to be in secular equilibrium

Activity concentration limit for exempt material = 1 Bq/g

Activity limit for an exempt consignment = 1000 Bq

The uranium and thorium decay series nuclides listed above are above exemption limit for activity concentration, but below the limit for exempt consignment.

For the Actinium decay chain, we have assumed secular equilibrium, with the ^{235}U activity calculated based on the natural abundance to ^{238}U of 0.7% (World Nuclear Association, 2022). A specific activity of 12 439 Bq.g^{-1} for ^{238}U (Nucléide – Lara. 2023b) and 79 950 Bq.g^{-1} was used for ^{235}U(Nucléide – Lara. 2023b) to give the activity values in Table 10 and 11, the values of which are well below the exemption limits both for activity concentration and consignment, which are listed below:

^{235}U and it's progeny ^{231}Th are assumed to be in secular equilibrium

Activity concentration limit for exempt material = 10 Bq/g

Activity limit for an exempt consignment = 1000 Bq

^{231}Pa

Activity concentration limit for exempt material = 1 Bq/g

Activity limit for an exempt consignment = 1000 Bq

^{227}Ac and ^{223}Fr

Activity concentration limit for exempt material = 0.1 Bq/g

Activity limit for an exempt consignment = 1000 Bq

^{227}Th

Activity concentration limit for exempt material = 10 Bq/g

Activity limit for an exempt consignment = 10 000Bq

^{223}Ra, ^{219}Rn, ^{215}Po, ^{211}Pb, ^{211}Bi, ^{211}Po, ^{207}Tl

Activity concentration limit for exempt material = 10 Bq/g

Activity limit for an exempt consignment = 10 000 Bq

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Appendix 1: AccuRad calibration certificates (E102978)

SGS

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 2562
Corporate Site No. 18509
Accredited for compliance
with ISO/IEC 17025 - Calibration

Certificate of Calibration

Certificate No.: CAL-22-11400

Company Name: ARPANSA - South
Address: 619 Lower Plenty Road
Yallambie Vic 3085

Instrument Details:

Manufacturer: Mirion Technologies
Model No.: AccuRad PRD
Serial No.: 000232

Date of Calibration 8 July 2022

Test Conditions: The monitor was placed vertically in the beam. Refer to the calibration certificate appendix for additional test information.

Traceability: The results of the tests, calibrations and/or measurements included in this document are traceable to Australian standards. Refer to Section 2 of the calibration certificate appendix for further information.

Uncertainties: Refer to Section 3 of the calibration certificate appendix.

Calibration Summary

Test	Result
Dose Rate Response	Complies

Calibrated by: Edwin Okhamafe
Title: Health Physicist

Authorised by: Anthony Dyer
Title: Senior Technical Officer

Date: 8 July 2022

Date: 10 July 2022

Appendix 2: AccuRad calibration certificates (E102979)

SGS

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 2562
Corporate Site No. 18509
Accredited for compliance
with ISO/IEC 17025 - Calibration

Certificate of Calibration

Certificate No.: CAL-22-11397

Company Name: ARPANSA - South
Address: 619 Lower Plenty Road
Yallambie Vic 3085

Instrument Details:

Manufacturer: Mirion Technologies
Model No.: AccuRad PRD
Serial No.: 00028E

Date of Calibration 8 July 2022

Test Conditions: The monitor was placed vertically in the beam. Refer to the calibration certificate appendix for additional test information.

Traceability: The results of the tests, calibrations and/or measurements included in this document are traceable to Australian standards. Refer to Section 2 of the calibration certificate appendix for further information.

Uncertainties: Refer to Section 3 of the calibration certificate appendix.

Calibration Summary

Test	Result
Dose Rate Response	Complies

Calibrated by: Edwin Okhamafe
Title: Health Physicist

Authorised by: Anthony Dyer
Title: Senior Technical Officer

Date: 8 July 2022

Date: 10 July 2022

Appendix 3: AccuRad calibration certificates (E102981)

SGS

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 2562
Corporate Site No. 18509
Accredited for compliance
with ISO/IEC 17025 - Calibration

Certificate of Calibration

Certificate No.: CAL-22-11970

Company Name: ARPANSA - South
Address: 619 Lower Plenty Road
Yallambie Vic 3085

Instrument Details:

Manufacturer: Mirion Technologies
Model No.: AccuRad PRD
Serial No.: 0002BF

Date of Calibration 31 August 2022

Test Conditions: The monitor was placed vertically in the beam. Refer to the calibration certificate appendix for additional test information.

Traceability: The results of the tests, calibrations and/or measurements included in this document are traceable to Australian standards. Refer to Section 2 of the calibration certificate appendix for further information.

Uncertainties: Refer to Section 3 of the calibration certificate appendix.

Calibration Summary

Test	Result
Dose Rate Response	Complies

Calibrated by: Siu Chi Wong
Title: Health Physicist

Authorised by: Edwin Okhamafe
Title: Health Physicist

Date: 31 August 2022

Date: 2 September 2022

Appendix 4: AccuRad calibration certificates (E102982)

SGS

NATA

WORLD RECOGNISED ACCREDITATION

Accreditation No. 2562
Corporate Site No. 18509
Accredited for compliance
with ISO/IEC 17025 - Calibration

Certificate of Calibration

Certificate No.: CAL-22-12503

Company Name: ARPANSA - South
Address: 619 Lower Plenty Road
Yallambie Vic 3085

Instrument Details:

Manufacturer: Mirion Technologies
Model No.: AccuRad PRD
Serial No.: 00029B

Date of Calibration 14 November 2022

Test Conditions: The monitor was placed vertically in the beam. Refer to the calibration certificate appendix for additional test information.

Traceability: The results of the tests, calibrations and/or measurements included in this document are traceable to Australian standards. Refer to Section 2 of the calibration certificate appendix for further information.

Uncertainties: Refer to Section 3 of the calibration certificate appendix.

Calibration Summary

Test	Result
Dose Rate Response	Complies

Calibrated by: Elias Toza
Title: Technical Officer

Authorised by: Christian Curtis-Wilson
Title: Senior Health Physicist

Date: 14 November 2022

Date: 14 November 2022

Appendix 5: AccuRad calibration certificates (E102983)

SGS

NATA
Accreditation No. 2562
Corporate Site No. 18509
Accredited for compliance
with ISO/IEC 17025 - Calibration

Certificate of Calibration

Certificate No.: CAL-22-11971

Company Name: ARPANSA - South
Address: 619 Lower Plenty Road
Yallambie Vic 3085

Instrument Details:

Manufacturer: Mirion Technologies
Model No.: AccuRad PRD
Serial No.: 0002A4

Date of Calibration 31 August 2022

Test Conditions: The monitor was placed vertically in the beam. Refer to the calibration certificate appendix for additional test information.

Traceability: The results of the tests, calibrations and/or measurements included in this document are traceable to Australian standards. Refer to Section 2 of the calibration certificate appendix for further information.

Uncertainties: Refer to Section 3 of the calibration certificate appendix.

Calibration Summary

Test	Result
Dose Rate Response	Complies

Calibrated by: Siu Chi Wong
Title: Health Physicist

Authorised by: Edwin Okhamafe
Title: Health Physicist

Date: 31 August 2022

Date: 2 September 2022

Appendix 6: Source certificate for RSIN 1001 used for AGMS Energy calibration

Eckert & Ziegler
Analytics

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404-352-8677
Fax 404-352-2837
www.ezag.com

CERTIFICATE OF CALIBRATION
Standard Reference Source

SRS Number: 107216A
Source Description: 25.4 mm Diameter x 6 mm Thick Button
Product Code: MIX-GF-D
Customer: CTBTO RN39 Radionuclide Station
P.O. Number: 2015-1453 FRD No. 32, Item 1

This standard radionuclide source was prepared gravimetrically from calibrated master solutions. Radionuclide calibration and purity were checked by germanium gamma-ray spectrometry, liquid scintillation counting, and/or alpha spectrometry, as applicable. The nuclear decay rate and reference date for this source are given below. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology (NIST) through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 2, July 2007, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST."

Reference Date: 08-September-2017 12:00 PM EST

Isotope	Half-Life, d	Activity, Bq	Uncertainty			Calibration Method**
			u_A, %	u_B, %	U, %*	
Co-60	1.925E+03	3.437E+02	0.1	1.6	3.3	IC
Cs-137	1.099E+04	1.975E+02	0.1	1.7	3.5	IC
Eu-152	4.939E+03	1.648E+02	0.1	1.7	3.5	IC

***Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results." ****Calibration Methods:** 4π LS - 4π Liquid Scintillation Counting, HPGe - High Purity Germanium Gamma-Ray Spectrometer, IC - Ionization Chamber.

(Certificate continued on reverse side)

F-CR-32, Rev 0, 01 Nov 14

Corporate Office
24937 Avenue Tibbitts Valencia, California 91355

Laboratory
1380 Seaboard Industrial Blvd. Atlanta, Georgia, 30318

SRS Number: 107216A

Comments:

Diameter of active area 5 mm

Impurities:

Gd-153 1 17 Bq, Eu-154 1 38 Bq, other γ-impurities < 0 1%

Expiration Date: 08-September-2020

This sealed source was wipe tested in its inactive areas with leak test results < 185 Bq (5 nCi) of removable activity per ISO 9978:1992.

Source Prepared by: ______________________

K. Eardley, Radiochemist

QC Approved by: ______________________ Date: 07-SEP-17

J. Lahr, Spectroscopist

EZA Certificate Program Rev 0, 07-DEC-2015 Page 2 of 2

Appendix 7: Soil sample collection procedure

- Judgemental sampling will be performed using a clean, steel hand trowel.
- Field observations related to the sample description will be recorded in field sample log notes (refer to Table 2). Details may include the following:
    - A description of where the sample was taken at the site, this may or may not include geographical coordinates to aid in identifying the location the sample was taken from.
    - A visual description of the sample which may include descriptions related to colour, texture, fragment coarseness, moistness.
    - Photos of the sampling site.
    - Photos of the sample
- Sampled material will be deposited into a plastic zip-lock collection bag, sealed shut, and double bagged to prevent cross contamination
- Sampling details will be written on the collection bag and will include the following information:
    - Collectors name or initials
    - Date collected.
    - Sample number
- The sample number will be recorded on the site schematic (figure 6). This will correspond to a specific code indicative of the location and the project job (i.e. HPM23 NTK SC5-1 for health physics measurements 2023, Northern Territory Koongarra shipping container # 5, sample 1)
- After and between sample collections, the steel hand trowel will be cleaned with a isopropanol wipe and wiped dry with paper towel to minimise sample cross contamination of the trowel
    - The trowel may also be bagged with a plastic bag to prevent sample carryover and contamination if feasible

Appendix 8: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for Alpha2 Spectrum

```
Energy Calibration Report            26/10/2023 12:53:47 PM       Page  1

***************************************************************************
*****       E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
***************************************************************************

     Detector Name:   DET01
     Sample Title:    K-alpha2-20230614

       **************  ENERGY CALIBRATION COEFFICIENTS  **************

                 Energy Calibrate Performed on:  21/08/2023 11:45:46 AM
                         by:
                 Energy Calibrate Type:          POLY

   Energy(keV) =    -0.134 +     0.253*ch + -3.358E-08*ch^2 +  0.000E+00*ch^

       **************  SHAPE CALIBRATION COEFFICIENTS   **************

                 Shape Calibrate Performed on:  21/08/2023 11:45:46 AM
                         by:

                 FWHM     =     0.409  +   0.046*E^1/2

                 LOW TAIL =   4.67E+00 + -3.62E-04*E

       **************  ENERGY CALIBRATION RESULTS TABLE **************

                      Centroid      Centroid          Energy
                      Channel       error             (keV )
                        735.06        0.25             186.21
                       2405.04        0.05             609.31
                       3597.00        0.20             911.20
                       4422.70        0.14            1120.29
                       5767.53        0.16            1460.81
                       6968.10        0.19            1764.49

       **************  SHAPE CALIBRATION RESULTS TABLE  **************

             Energy     FWHM        FWHM          TAIL        TAIL
             (keV )     channels    error         channels    error
              186.21      5.43        0.58          12.90       1.00
              609.31      5.99        0.10          16.26       1.00
              911.20      7.27        0.44          32.69       1.00
             1120.29      7.83        0.30           6.37       2.53
             1460.81      8.63        0.32           8.34       1.00
             1764.49      9.28        0.37          16.54       1.00
```

Appendix 9: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for Alpha Spectrum

```
Energy Calibration Report            26/10/2023  1:47:48 PM       Page  1

**************************************************************************
*****      E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
**************************************************************************

     Detector Name:
     Sample Title:   k-alpha-20230614

       *************  ENERGY CALIBRATION COEFFICIENTS  *************

               Energy Calibrate Performed on:  21/08/2023  1:21:46 PM
                       by:
               Energy Calibrate Type:          POLY

   Energy(keV) =    -0.247 +     0.253*ch + -2.448E-08*ch^2 +  0.000E+00*ch^3

       *************  SHAPE CALIBRATION COEFFICIENTS   *************

               Shape Calibrate Performed on:  21/08/2023  1:21:46 PM
                       by:

               FWHM     =     0.302  +   0.055*E^1/2

               LOW TAIL =   1.31E+01 + -3.42E-03*E

       *************  ENERGY CALIBRATION RESULTS TABLE *************

                    Centroid      Centroid         Energy
                    Channel       error            (keV )
                      737.05        0.11            186.21
                     2409.39        0.06            609.31
                     4429.64        0.13           1120.00
                     4895.69        0.26           1238.11
                     5776.41        0.27           1460.81

       *************  SHAPE CALIBRATION RESULTS TABLE   *************

             Energy     FWHM       FWHM         TAIL        TAIL
             (keV )     channels   error        channels    error
              186.21      4.26      0.26          59.42       1.00
              609.31      6.47      0.12          10.33       1.00
             1120.00      8.58      0.25          95.86       1.00
             1238.11      9.00      0.55          14.86       1.00
             1460.81      9.25      0.57          16.72       1.00
```

Appendix 10: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for AlphaBeta Spectrum

```
Energy Calibration Report            26/10/2023  1:49:27 PM       Page  1

**************************************************************************
*****       E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
**************************************************************************

     Detector Name:
     Sample Title:   K-alphabeta-20230614

       *************  ENERGY CALIBRATION COEFFICIENTS  *************

                 Energy Calibrate Performed on:  21/08/2023  2:47:51 PM
                         by:
                 Energy Calibrate Type:          POLY

   Energy(keV) =     0.071 +     0.253*ch +  0.000E+00*ch^2 +  0.000E+00*ch^3

       *************  SHAPE CALIBRATION COEFFICIENTS   *************

                 Shape Calibrate Performed on:  21/08/2023  2:47:51 PM
                         by:

                 FWHM     =     0.286  +   0.050*E^1/2

                 LOW TAIL =   3.26E+00 +  5.96E-05*E

       *************  ENERGY CALIBRATION RESULTS TABLE *************

                      Centroid      Centroid         Energy
                      Channel       error            (keV )
                        736.35        0.22            186.21
                       2406.37        0.05            609.31
                       4424.64        0.13           1120.29
                       5769.69        0.19           1460.81
                       6969.91        0.22           1764.49

       *************  SHAPE CALIBRATION RESULTS TABLE  *************

               Energy     FWHM       FWHM         TAIL        TAIL
               (keV )     channels   error        channels    error
                186.21      5.65      0.56          2.10       0.71
                609.31      5.93      0.10         47.93       1.00
               1120.29      7.26      0.25          5.50       1.00
               1460.81      9.02      0.39          7.62       1.00
               1764.49     10.32      0.40         13.02       1.00
```

Appendix 11: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for Beta Spectrum

```
Energy Calibration Report              26/10/2023  1:45:48 PM       Page  1

**************************************************************************
*****      E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
**************************************************************************

     Detector Name:  DET01
     Sample Title:   k-beta-20230614

       *************  ENERGY CALIBRATION COEFFICIENTS  *************

                Energy Calibrate Performed on:  21/08/2023 11:42:54 AM
                        by:
                Energy Calibrate Type:          POLY

   Energy(keV) =     0.430 +     0.253*ch +  0.000E+00*ch^2 +  0.000E+00*ch^3

       *************  SHAPE CALIBRATION COEFFICIENTS   *************

                Shape Calibrate Performed on:  21/08/2023 11:42:54 AM
                        by:

                FWHM     =     0.072  +   0.059*E^1/2

                LOW TAIL =   7.99E-01 +  1.84E-03*E

       *************  ENERGY CALIBRATION RESULTS TABLE *************

                     Centroid      Centroid         Energy
                     Channel       error            (keV )
                       735.60        0.18            186.21
                      2407.23        0.02            609.31
                      4426.98        0.12           1120.29
                      4893.17        0.14           1238.11
                      6974.92        0.14           1764.49

       *************  SHAPE CALIBRATION RESULTS TABLE  *************

              Energy     FWHM       FWHM         TAIL         TAIL
              (keV )     channels   error        channels     error
               186.21       4.65      0.41          5.04        1.00
               609.31       5.98      0.05          8.89        1.00
              1120.29       7.81      0.24          9.37        1.00
              1238.11       7.87      0.29         10.15        1.00
              1764.49      10.76      0.27         18.16        1.00
```

Appendix 12: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for BetaRho Spectrum

```
Energy Calibration Report              26/10/2023  1:42:40 PM       Page  1

***************************************************************************
*****      E N E R G Y   C A L I B R A T I O N   R E P O R T        *****
***************************************************************************

     Detector Name:  DET01
     Sample Title:   K-betarho-20230615

       *************  ENERGY CALIBRATION COEFFICIENTS  *************

                Energy Calibrate Performed on:  17/08/2023  4:44:41 PM
                        by:
                Energy Calibrate Type:          POLY

   Energy(keV) =     0.150 +     0.253*ch + -2.467E-08*ch^2 +  0.000E+00*ch^3

       *************  SHAPE CALIBRATION COEFFICIENTS   *************

                Shape Calibrate Performed on:  17/08/2023  4:44:41 PM
                        by:

                FWHM     =     0.663  +   0.040*E^1/2

                LOW TAIL =   9.41E-01 +  8.75E-04*E

       *************  ENERGY CALIBRATION RESULTS TABLE *************

                     Centroid      Centroid         Energy
                     Channel       error            (keV )
                       734.85        0.13            186.21
                      3034.78        0.22            768.36
                      4425.64        0.14           1120.29
                      5771.65        0.22           1460.81
                      6972.63        0.16           1764.49

       *************  SHAPE CALIBRATION RESULTS TABLE  *************

              Energy     FWHM        FWHM          TAIL         TAIL
              (keV )     channels    error         channels     error
               186.21      4.93       0.24            3.64       1.00
               768.36      5.93       0.52            3.58       1.78
              1120.29      7.81       0.28           11.43       1.00
              1460.81      8.37       0.50            5.02       1.57
              1764.49      9.72       0.33            7.53       1.79
```

Appendix 13: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for Rho Spectrum

```
Energy Calibration Report          26/10/2023  1:46:40 PM       Page  1

**************************************************************************
*****      E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
**************************************************************************

     Detector Name:  DET01
     Sample Title:   K-rho-20230614

       *************  ENERGY CALIBRATION COEFFICIENTS  *************

               Energy Calibrate Performed on:  17/08/2023  3:17:24 PM
                       by:
               Energy Calibrate Type:          POLY

   Energy(keV) =     0.275 +     0.253*ch +  0.000E+00*ch^2 +  0.000E+00*ch^3

       *************  SHAPE CALIBRATION COEFFICIENTS   *************

               Shape Calibrate Performed on:  17/08/2023  3:17:24 PM
                       by:

               FWHM     =     0.839  +   0.032*E^1/2

               LOW TAIL =   2.20E+00 +  7.92E-04*E

       *************  ENERGY CALIBRATION RESULTS TABLE *************
```

Centroid Channel	Centroid error	Energy (keV)
735.06	0.00	186.21
2405.04	0.00	609.31
3032.00	0.00	768.36
4422.70	0.00	1120.29
5768.53	0.00	1460.81
6967.00	0.00	1764.49

************* SHAPE CALIBRATION RESULTS TABLE *************

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
186.21	5.43	0.00	12.90	0.00
609.31	5.43	0.00	16.26	0.00
768.36	6.83	0.00	4.12	0.00
1120.29	7.83	0.00	6.37	0.00
1460.81	8.63	0.00	8.34	0.00
1764.49	8.25	0.00	22.73	0.00

Appendix 14: Portable HPGe Energy and Peak Full Width Heigh Maximum (FWHM) calibration reports for Rho2 Spectrum

```
Energy Calibration Report          26/10/2023  1:44:39 PM       Page  1

*************************************************************************
*****      E N E R G Y   C A L I B R A T I O N   R E P O R T       *****
*************************************************************************

     Detector Name:
     Sample Title:   K-rhr2-20230614

       **************  ENERGY CALIBRATION COEFFICIENTS  **************

                 Energy Calibrate Performed on:  21/08/2023 12:57:05 PM
                         by:
                 Energy Calibrate Type:          POLY

   Energy(keV) =    -0.069 +     0.253*ch +  0.000E+00*ch^2 +  0.000E+00*ch^3

       **************  SHAPE CALIBRATION COEFFICIENTS   **************

                 Shape Calibrate Performed on:  21/08/2023 12:57:05 PM
                         by:

                 FWHM     =     0.497  +   0.042*E^1/2

                 LOW TAIL =   4.44E+00 + -1.28E-03*E

       **************  ENERGY CALIBRATION RESULTS TABLE **************
```

Centroid Channel	Centroid error	Energy (keV)
1390.98	0.09	351.90
2407.09	0.06	609.31
4425.41	0.17	1120.29
5771.36	0.15	1460.81
6972.42	0.28	1764.49

```
       **************  SHAPE CALIBRATION RESULTS TABLE  **************
```

Energy (keV)	FWHM channels	FWHM error	TAIL channels	TAIL error
351.90	5.03	0.18	23.88	1.00
609.31	6.03	0.12	5.16	1.00
1120.29	7.38	0.36	6.69	4.68
1460.81	8.16	0.30	8.15	1.00
1764.49	9.10	0.53	11.97	1.00

Appendix 15: Source site photos

Figure 17. Photo of the secured fenced source enclosure as first sighted. Points of note include the right corner fence damage (bent corner pole) and the tree branches on the right side of the fence.

Figure 18a. Close of the damage to corner pole and tree branches on right side of fence. Fallen tree branches can also be seen on top of the shipping containers #4 and #5

Figure 18b. Close of the corner pole damage and tree branches on the right side of fence, side view of the right side of the fenced enclosure. The fallen branches on the fence could be attributed to the broken tree on the inside the enclosure

Figure 19. Photo showing gate secured with chain and padlock, restricted area and radiation warning signage. Note damage to the fence to the left of the gate with a buckled pole and fencing leaning inwards (circled in red).

a)  b) 

Figure 20a. Grass growth inside the fenced enclosure being pushed out of the way when the gate was opened. A fallen tree growing inside the enclosure can be seen in the background. **b)** close up of the central fallen tree which has a branch fallen on container #4. Movement through the enclosure does a great job of quickly flattening the overgrown grass.

a)  b) 

Figure 21a. Debris inside the enclosure - old broken chairs inside the enclosure near shipping container #3 and old oil can near door of container #4. **b)** The ground in front of shipping container #4 and #5 appears to have burnt debris in front of it – refer to pictures for shipping container 4 and 5 for close up details

Figure 22. Photo showing what appears to be mining core samples, boot included for size comparison. Found outside shipping container 4 and 5 door. The ground is elevated in a slight mound outside the door of shipping container #5 with what appears to be discarded sample debris. Dose rate measurements on AccuRad PRD read 0.360 μSv.

Appendix 16: Shipping container #1 photos

Figure 23. Photo showing chain and lock on the middle of shipping container #1 door and radioactive material warning label.

Figure 24. Photo showing condition of fence side view of shipping container #1, The other long side of shipping container #1 abuts onto shipping container #2 so photos are unavailable of the other long side

Figure 25. Photo showing condition of end view of shipping container #1

a)  b) 

Figure 26b. Photo attempting to show the slight lean of shipping container #1, at the top of the fence line the shipping container is much closer to it than it was at the bottom**. b)** Photo showing positioning of shipping containers #1 and #2 next to each other.

Appendix 17: Shipping container #2 photos

Figure 27. Photo showing chain and lock on shipping container #2 and radioactive material label.

Figure 28. Photo showing some degradation round the bottom door of container #2 and potential sample spill out

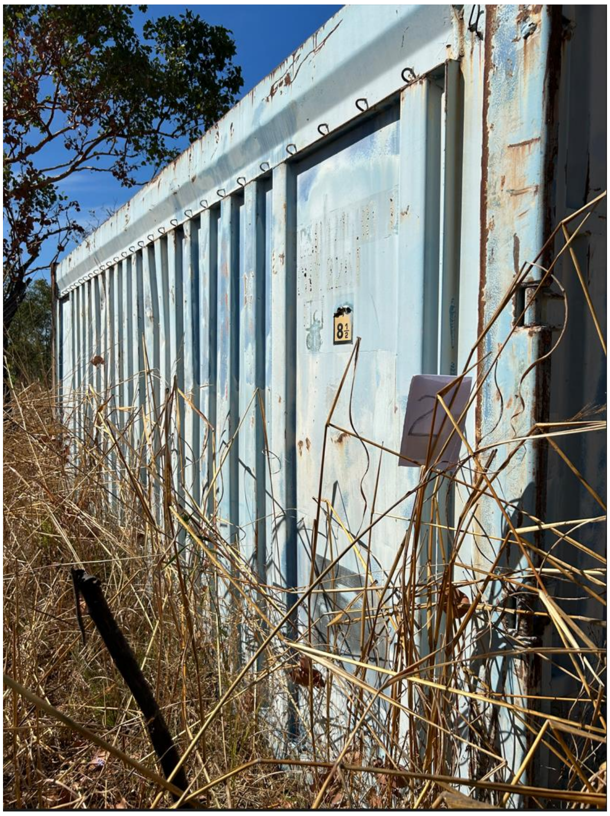


Figure 29. Photo showing condition of long side shipping container #2, looking towards the end of the container. The other long side of shipping container #2 abuts onto shipping container #1 so photos are unavailable of the other long side

Figure 30. Photo showing condition of end view of shipping container #2

Figure 31. Photo showing some degradation round the bottom door of container 2 and potential sample spill out

Appendix 18: Shipping container #3 photos

a) 

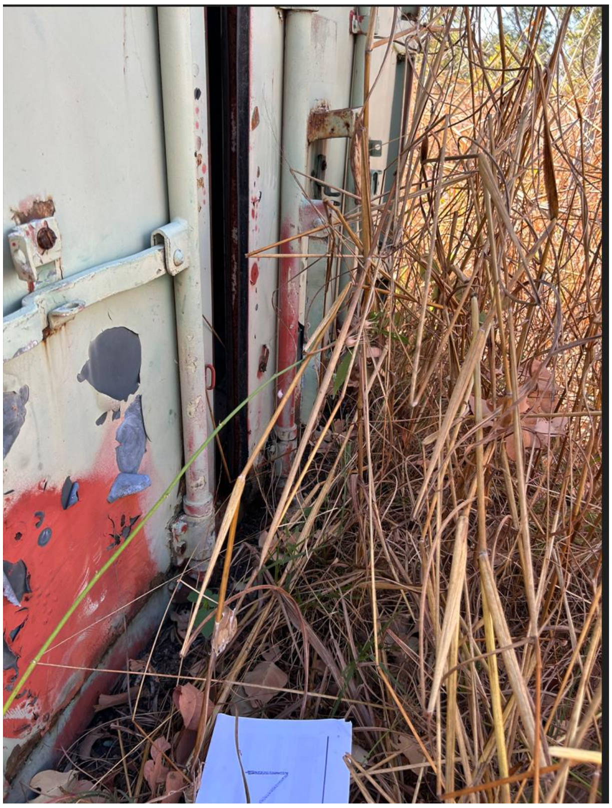
b) 

Figure 32a. Photo showing shipping container #3 door. The radioactive materials labels can be seen affixed to the door. The door has not been chained or locked due to difficulties doing this (likely due to door mechanisms seizing due to rust and environmental conditions). **b)** There is a gap where the 2 doors meet of about 5cm or less.

Figure 33. Photo showing closeup of some rust degradation of shipping container door #3.

Figure 34. Close up of degradation along inside long side of container #3, where samples are potentially spilling out

Figure 35. Photo showing condition of fence side view of shipping container #3

Figure 36. Photo showing condition of end view of shipping container #3

Figure 37. A person can fit their hand in the door gap in container #3 and take a photo of the inside of the container. There appears to be small holes in the roof of the container letting light in

Appendix 19: Shipping container #4 photos

Figure 38. Photo showing shipping container 4 door and radioactive material warning label. The door has not been chained or locked due to difficulties doing this (likely due to door mechanisms seizing due to rust and environmental conditions). Rust degradation can be seen along the top and bottom edges of the door

Figure 39. Close up photo showing degradation along bottom of container 4 door. Burnt looking debris is present and a old, rusted oil can is nearby. Broken core samples can be seen in the foreground.

Figure 40. Photo of long side of shipping container 4. A fallen dead tree branch can be seen resting on the top of the container

Figure 41. Photo showing condition of end view of shipping container #4

Appendix 20: Shipping container #5 photos

Figure 42. Photo showing radioactive material label and chain and lock on the top of shipping container 5 door. The door of shipping container 5 can't close properly and there is a gap of about 5-10cm where the doors close. Burnt material can be seen in front of the door of shipping container on the ground.

a) 

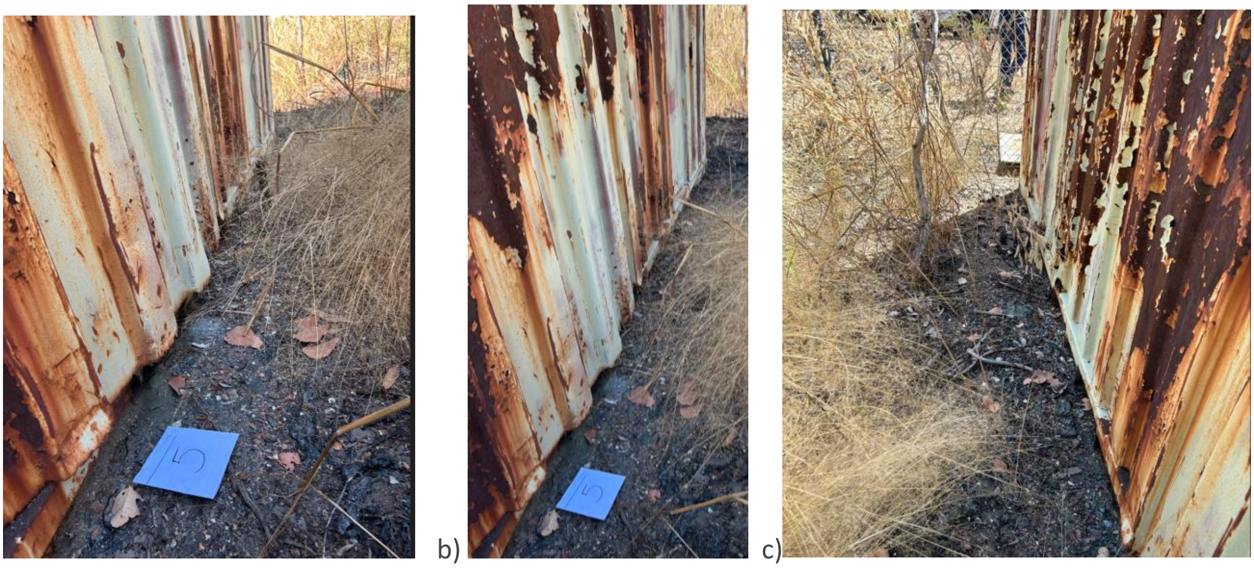
b) 

Figure 43a. Close up of the ground in front of shipping container 5. Two core samples can be clearly seen on the ground and the gap of 5-10cm can be seen in the second photo, along with considerable rust. **b)** The two wooden bits of wood are not doing much to hold the door in position, but their positioning suggests the wooden bits of wood may be have put there to do that.

Figure 44. Close up of the door gap on container 5

Figure 45. A person can fit their hand in the door gap in container #5 and take a photo of the inside of the container. There appears to be holes in the roof of the container letting light in

Figure 46. Photo of long side of shipping container #5.



a) b) c)

Figure 47a. Buckling of the side wall on container 5, integrity of the container has been breached along the bottom. **b)** and side **c)** Close up of rust along the wall looking towards the end of the container.

Figure 48. Photo showing condition of end view of shipping container #5. Rust is clearly visible.

a)  b) 

Figure 49a. and **b)** Photo showing condition of side view of shipping container #5 on the fence side. Rust is clearly visible. The other side of container #5 abuts onto shipping container 4 so no photos of the other long side are possible.

a) 

b) 

Figure 50a. and **b)** Close up of the rust on shipping container 5, long fence side, towards the door end, and end side next to shipping container 4

Appendix 21: Site photos – sheds

a) 
b) 
c) 

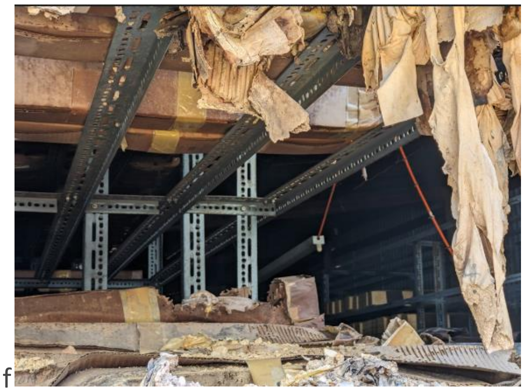
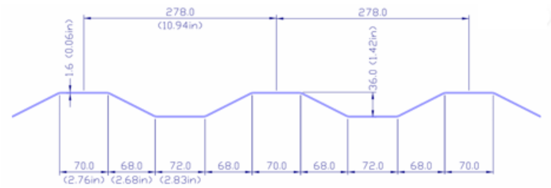
d) 
e) 
f 

Figure 51a. The sheds are readily accessible due to missing wall and roof panels and are not secured in anyway. **b)** Photo of inside of shed one showing trays of what appears to be mining cores or samples laid out on the ground. **c)** Dose rate measurements using a Accurad PRD inside the shed showed reading of 1.55 μSv/h. **d)** to **f)** Shed stacked of sample trays can be seen in shed 2 with trays also seen on the ground in the left of the photo.

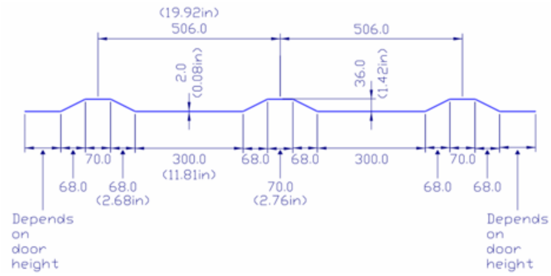
Figure 52a. and **b)** Photo of inside of shed 3 showing empty racks for sample trays and some boxes in the top left hand corner of the shed.

Figure 53. Members of the HPM field team in discussion with Che Doering, site RSO.

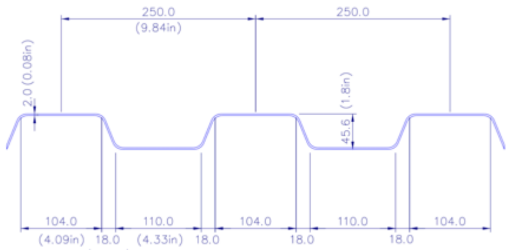
Appendix 22: Data and information on standard Shipping container specifications used for ISOCS models



Shipping container side corrugation dimensions



Shipping container door corrugation dimensions



Shipping container end corrugation dimensions

		20' container	
		imperial	metric
external dimensions	length	20' 0"	6.096 m
	width	8' 0"	2.438 m
	height	8' 6"	2.591 m
interior dimensions	length	18' 10 5⁄16"	5.758 m
	width	7' 8 19⁄32"	2.352 m
	height	7' 9 57⁄64"	2.385 m
door aperture	width	7' 8 ⅛"	2.343 m
	height	7' 5 ¾"	2.280 m
volume		1,169 ft³	33.1 m³
maximum gross mass		66,139 lb	30,400 kg
empty weight		4,850 lb	2,200 kg
net load		61,289 lb	28,200 kg

Figure 54. Standard shipping container dimensions, physical characteristics and dimensions, pictures and table reproduced from Discover Containers (2023) and TECC|EAST (2003).

Table 11. Summary of shipping container specifications used in ISOCS models

	Dimensions mm
Side wall thickness*	1.6
Door thickness*	2
End wall thickness*	2
Length**	5758
Width**	2352
Height**	2385
Fill height***	2000

*Assumes uniform thickness of walls. Corrugations have not been considered in the model

** using inner dimensions of shipping container, used in ISOCS geometry

***Refer to figure 37 and 45. Assumes all shipping containers filled to same height

Table 12. Koongarra shipping container contents (material library name: koon2.8), density 2.31 g/cm³

	% compositions
Koongarra Dirt (material library name: koon), density 2.7 g/cm³ (95.81% total composition)	
$Al_2Si_2O_5(OH)_5$	7.67
$Mg_3(AlSi_3O_{10})$	0.88
Fe_2O_3	12.49
SiO_4	44
Uranium	3.83
Steel (material library name: corten), density 7.8 g/cm³ (4.19% total composition)	

Table 13. Shipping container and steel scaffolding composition (material library name: corten), density 7.8 g/cm³

	% compositions
Carbon	0.12
Silicon	0.75
Manganese	0.50
Phosphorus	0.15
Sulphur	0.03
Chromium	1.25
Copper	0.55
Nickle	0.65
Iron	96

Table 14. Calculations for amount of core sample in shipping container

Aspect	Cubic volume (cm³)	Assumptions made to arrive at cubic volume in cm³
Volume of a core sample	2 355 cm³	Assumes core is 120 cm long, radius of 2.5 cm
Number of core samples per tray	14 230 cm³	Assumes 6 core samples per tray
18 trays per tray rack	254 340 cm³	Refer to figure 8a, the number of 18 is based on number of trays seen in the shipping container picture. This number also assumes the racking system is 2m high not inside container height.

13 trays long	3 306 420 cm^3	Refer to figure 8a, the number of 13 is based on number of racks seen in shipping container picture
Multiply by 2 If racking system down both lengths of container	6 612 840 cm^3	This converts to 6.61 m^3
Multiple by 3	19 838 520 (or 19.9 m^3)	The total volume a shipping container with 2 m fill height is 26.2 m^3 (2 m x 2.3 m x 5.7 m - refer to Table 11). 6.61 m^3 seems a little conservative as 26.2 m^3 of material can fit into this space. Multiplying it by 3 brings it up to a much more feasible number, also considering how packed in the trays are
Multiple by density of soil		53 564 004 g This is equal to 53560 kg or 53.6 Tonnes of dirt in each container

Table 15. Calculations for amount of steel tray material in shipping container

Aspect	Weight in grams (g)	Assumptions made to arrive at cubic volume in cm^3
Weight of steel tray	5 000	Assumes tray dimensions of 124 cm x 29 cm
Weight of 18 trays per rack	90 000	Refer to Table 14
13 trays down length of shipping container	1 170 000	
Multiply by 2 if down both sides	7 020 000	

Table 16. Calculations for total weight percent and density in container

Aspect	value	Assumptions made
Total weight of shipping container contents	60 584 004 g	7 020 000 g of steel + 53 564 004 g of core sample
Koongarra core steel density	2.3 g/cm^3	Total weight of shipping container contents divided by filled volume: 60 584 004 g ÷ 26 220 000 cm^3
Core sample amount	95.81 %	Assumes tray dimensions of 124 cm x 29 cm

Appendix 23: Rho2 ISOCS model data

Geometry Composer Report

CANBERRA

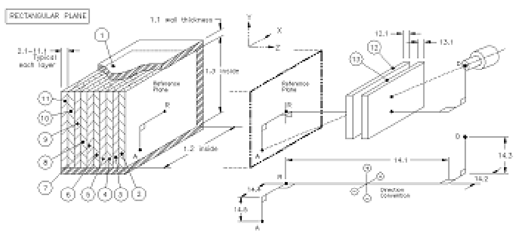
Date: Friday, October 27, 2023 - 14:09:47
Description: rho2 rectangle plane 2m high
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\rho2 12 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (mm)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel. Conc.
1	Side Walls	2	5758	2000				corten	7.8	
2	Layer 1	2352						koon2.8	2.3	100.00
3	Layer 2	2						corten	7.8	
4	Layer 3	144						dryair	0.0013	
5	Layer 4	2						corten	7.8	
6	Layer 5	2352						koon2.8	2.3	100.00
7	Layer 6	0						none		
8	Layer 7	0						<none>		
9	Layer 8	0						<none>		
10	Layer 9	0						<none>		
11	Layer 10	0						<none>		
12	Absorber1									
13	Absorber2									
14	Source-Detector	10950	-2879	160	-2879	160				

List of energies for efficiency curve generation

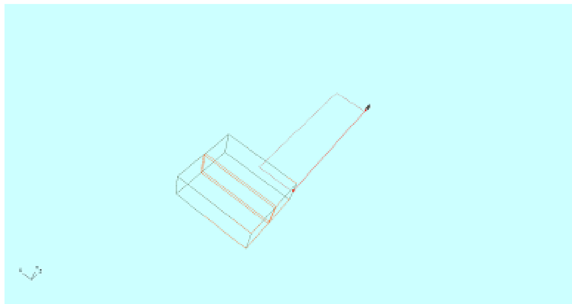
45.0	60.0	80.0	100.0	150.0	200.0	300.0	500.0
700.0	1000.0	1400.0	2000.0				



Geometry Composer Report

CANBERRA

Date: Friday, October 27, 2023 - 14:09:47
Description: rho2 rectangle plane 2m high
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\rho2 12 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)



Appendix 24: AlphaBeta ISOCS model data

Geometry Composer Report

CANBERRA

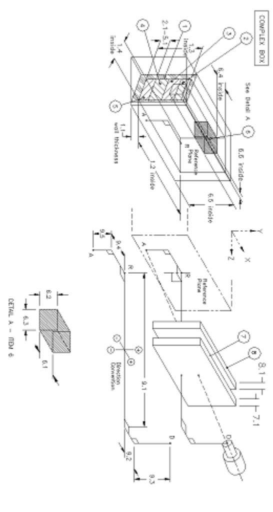
Date: Friday, October 27, 2023 - 14:20:42
Description: Koongarra alpha beta
Comment: Long shot for containers 3/4/5 in single model
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alphabetabox345view.geo
Software: ISOCS
Template: COMPLEX_BOX, Version: (default)
Detector: Falcon
Collimator: FALCON CAP (none)
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (m)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel.
1	Box	0.002	2.385	11.756	5.758			csteel	7.9	
2	Source - Top Layer	2.352						koon2.8	2.3	100.00
3	Source - Layer 2	4.7						dryair	0.0013	
4	Source - Layer 3	2.352						koon2.8	2.3	100.00
5	Source - Bottom Layer	2.352						koon2.8	2.3	100.00
6	Source - Concentrated	0	0	0	0	0	0	<none>		
7	Absorber1									
8	Absorber2									
9	Source-Detector	9.25	0	-0.478	0	-0.478				

List of energies for efficiency curve generation

45.0	60.0	80.0	100.0	150.0	200.0	300.0	500.0
700.0	1000.0	1400.0	2000.0				



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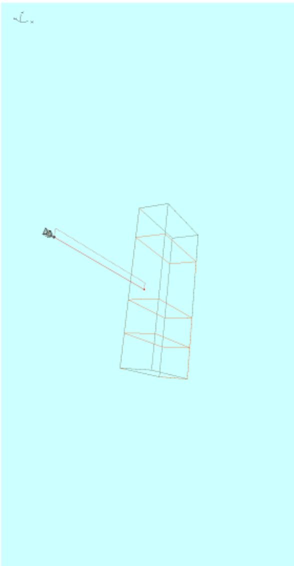
Geometry Composer Report

CANBERRA

Date: Friday, October 27, 2023 - 14:20:42
Description: Koongarra alpha beta
Comment: Long shot for containers 3/4/5 in single model
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alphabetabox345view.geo
Software: ISOCS
Template: COMPLEX_BOX, Version: (default)



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Appendix 25: Beta ISOCS model data

Geometry Composer Report

CANBERRA

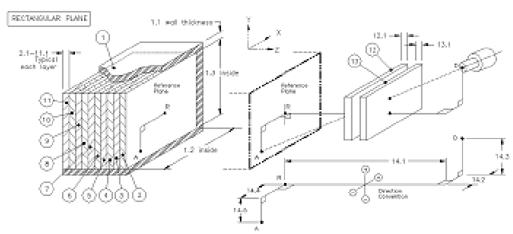
Date: Friday, October 27, 2023 - 14:11:22
Description: beta rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\beta 3view only.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (mm)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel. Conc.
1	Side Walls	2	5758	2000				corten	7.8	
2	Layer 1	2352						koon2.8	2.3	100.00
3	Layer 2	0						none		
4	Layer 3	0						none		
5	Layer 4	0						none		
6	Layer 5	0						none		
7	Layer 6	0						none		
8	Layer 7	0						<none>		
9	Layer 8	0						<none>		
10	Layer 9	0						<none>		
11	Layer 10	0						<none>		
12	Absorber1									
13	Absorber2									
14	Source-Detector	1998	4525	250	2879	250				

List of energies for efficiency curve generation

45.0 60.0 80.0 100.0 150.0 200.0 300.0 500.0
700.0 1000.0 1400.0 2000.0



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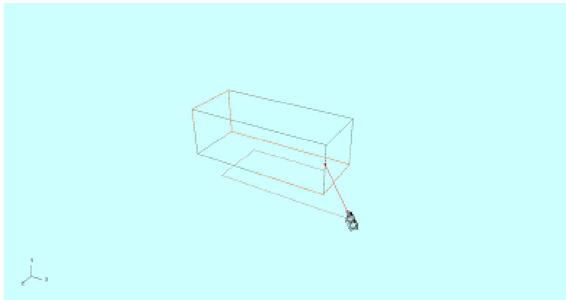
Geometry Composer Report

CANBERRA

Date: Friday, October 27, 2023 - 14:11:22
Description: beta rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\beta 3view only.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)



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Appendix 26: Rho ISOCS model data

Geometry Composer Report

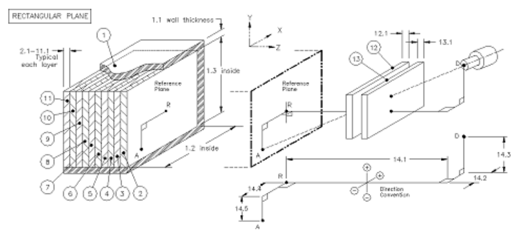
CANBERRA

Date: Friday, October 27, 2023 - 14:15:44
Description: rho rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\rho12 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

No.	Description	Dimensions (mm) d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel.
1	Side Walls	2	5758	2000				corten	7.8	
2	Layer 1	2352						koon2.8	2.3	100.00
3	Layer 2	2						corten	7.8	
4	Layer 3	144						dryair	0.0013	
5	Layer 4	2						corten	7.8	
6	Layer 5	2352						koon2.8	2.3	100.00
7	Layer 6	0						none		
8	Layer 7	0						<none>		
9	Layer 8	0						<none>		
10	Layer 9	0						<none>		
11	Layer 10	0						<none>		
12	Absorber1									
13	Absorber2									
14	Source-Detector	1050	3859	150	2879	150				

List of energies for efficiency curve generation

45.0 60.0 80.0 100.0 150.0 200.0 300.0 500.0
700.0 1000.0 1400.0 2000.0



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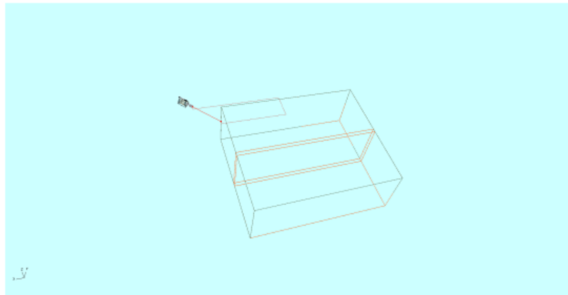
Geometry Composer Report

CANBERRA

Date: Friday, October 27, 2023 - 14:15:44
Description: rho rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\rho12 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)



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Appendix 27: Alpha ISOCS model data

CANBERRA

Geometry Composer Report

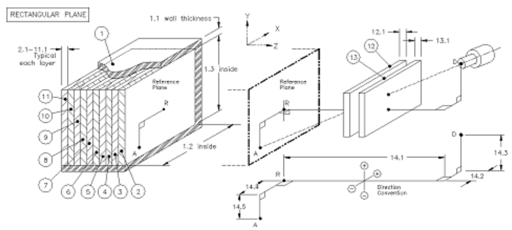
Date: Friday, October 27, 2023 - 14:17:42
Description: alpha rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alpha45 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (mm)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel.
1	Side Walls	1.6	5758	2000				corten	7.8	
2	Layer 1	2352						koon2.8	2.3	100.00
3	Layer 2	2						corten	7.8	
4	Layer 3	144						dryair	0.0013	
5	Layer 4	2						corten	7.8	
6	Layer 5	2352						koon2.8	2.3	100.00
7	Layer 6	0						none		
8	Layer 7	0						<none>		
9	Layer 8	0						<none>		
10	Layer 9	0						<none>		
11	Layer 10	0						<none>		
12	Absorber1									
13	Absorber2									
14	Source-Detector	2949	-4278	170	-2879	170				

List of energies for efficiency curve generation

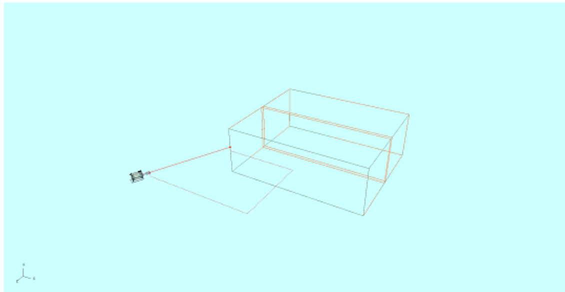
45.0	60.0	80.0	100.0	150.0	200.0	300.0	500.0
700.0	1000.0	1400.0	2000.0				



CANBERRA

Geometry Composer Report

Date: Friday, October 27, 2023 - 14:17:42
Description: alpha rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alpha45 view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)



Appendix 28: Alpha2 ISOCS model data

CANBERRA

Geometry Composer Report

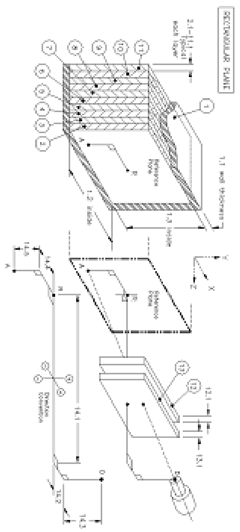
Date: Friday, October 27, 2023 - 14:08:43
Description: alpha2 rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alpha2 rect 45view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (mm)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel. Conc.
1	Side Walls	2	5758	2000				corten	7.8	
2	Layer 1	2352						koon2.8	2.3	100.00
3	Layer 2	2						corten	7.8	
4	Layer 3	144						dryair	0.0013	
5	Layer 4	2						corten	7.8	
6	Layer 5	2352						koon2.8	2.3	100.00
7	Layer 6	0						none		
8	Layer 7	0						<none>		
9	Layer 8	0						<none>		
10	Layer 9	0						<none>		
11	Layer 10	0						<none>		
12	Absorber1									
13	Absorber2									
14	Source-Detector	11670	2879	170	2879	170				

List of energies for efficiency curve generation

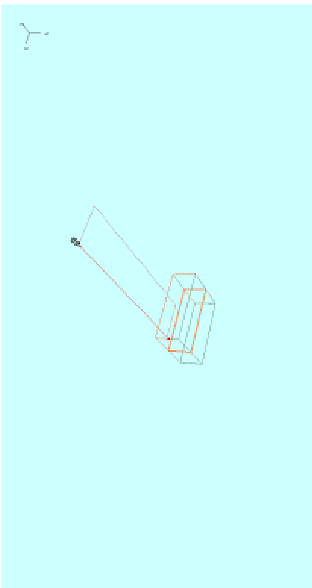
45.0	60.0	80.0	100.0	150.0	200.0	300.0	500.0
700.0	1000.0	1400.0	2000.0				



CANBERRA

Geometry Composer Report

Date: Friday, October 27, 2023 - 14:08:43
Description: alpha2 rectangle plane
Comment:
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\alpha2 rect 45view.geo
Software: ISOCS
Template: RECTANGULAR_PLANE, Version: (default)



Appendix 29: betaRho ISOCS model data

Geometry Composer Report

CANBERRA

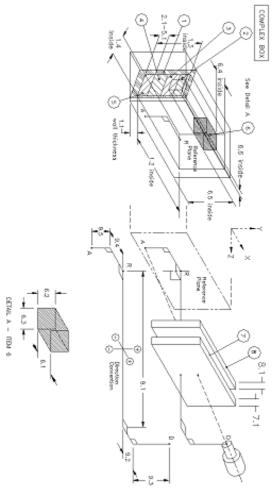
Date: Friday, October 27, 2023 - 14:22:29
Description: Beta Rho containers - 1,2,3 2m height
Comment: Contains 3 containers to the depth of container 3
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\betarhobox123ship2.geo
Software: ISOCS
Template: COMPLEX_BOX, Version: (default)
Detector: Falcon
Environment: Temperature = 22 °C, Pressure = 760 mm Hg, Relative Humidity = 30%
Integration: Convergence = 1.00%, MDRPN = 2^4 (16), CRPN = 2^4 (16)

Dimensions (m)

No.	Description	d.1	d.2	d.3	d.4	d.5	d.6	Material	Density	Rel.
1	Box	0.002	2	13.662	5.758			corten	7.8	
2	Source - Top Layer	2.352						koon2.8	2.3	100.00
3	Source - Layer 2	2.352						koon2.8	2.3	100.00
4	Source - Layer 3	3.2						dryair	0.0013	
5	Source - Bottom Layer	5.758						dryair	0.0013	
6	Source - Concentrated	2	5.758	2.352	0	0	0	koon2.8	2.3	100.00
7	Absorber1									
8	Absorber2									
9	Source-Detector	9.08	0	-1.073	0.152	-1.073				

List of energies for efficiency curve generation

45.0	60.0	80.0	100.0	150.0	200.0	300.0	500.0
700.0	1000.0	1400.0	2000.0				



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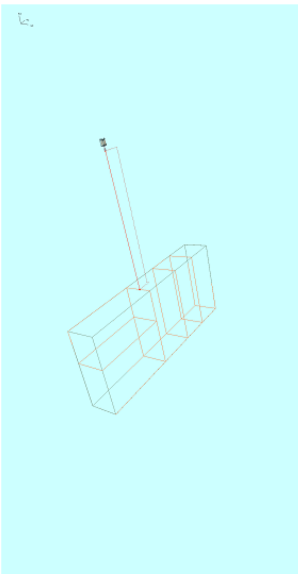
Geometry Composer Report

CANBERRA

Date: Friday, October 27, 2023 - 14:22:29
Description: Beta Rho containers - 1,2,3 2m height
Comment: Contains 3 containers to the depth of container 3
File Name: C:\GENIE2K\isocs\data\GEOMETRY\In-Situ\koonship2\betarhobox123ship2.geo
Software: ISOCS
Template: COMPLEX_BOX, Version: (default)



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