MIRION TECHNOLOGIES

Radiation Safety. **Amplified.**

A: A CZT In-Situ Quantitative Spectroscopic Measurement Tool

B: A Device for Continuous Repeating Real-time Assay of HPGe or CZT Gamma Spectra

FRAZIER BRONSON CHP
MIRION-TECHNOLOGIES [CANBERRA]
MERIDEN CT

Obligatory Disclosure

1. These are my personal comments.

2. Neither my company nor my mother nor my wife has said they agree with them.

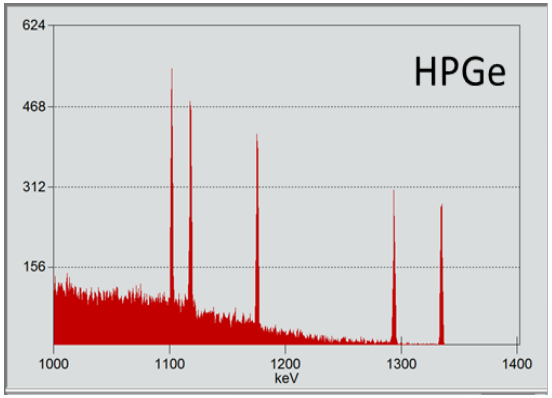
3. Other opinions are OK, as long as accompanied by a Margarita – with salt and extra limes

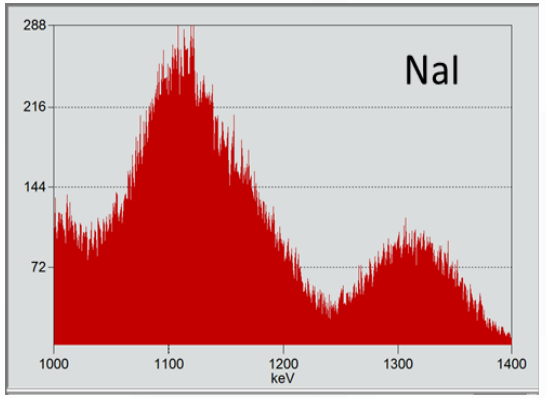
Quantitative In-Situ Gamma Spectroscopy – evolution

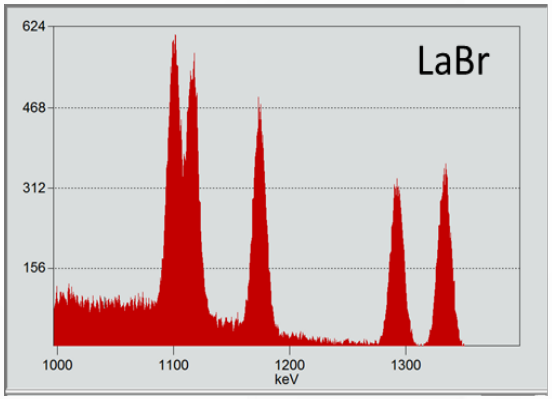
- Timeline of in-situ gamma spec instruments
  - Detector on tripod; NaI 60's source+math cals by user
  - Ge detector on tripod; '70s; '90 factory MCNP cals
  - Ge+shield with ISOCS mathematical cal; '96 user cals
  - InSpector1000 '03; NaI > LaBr > small CZTs
    - 5 20 60 500 mm3
- Common Characteristics of all
  - Nuclide Identification and Activity computations
  - Better resolution that NaI
  - Allow ISOCS efficiency calibrations
  - Reasonably portable but pretty expensive
- How can we do it better, and make a more affordable device for Radiation Protection use in the field ?

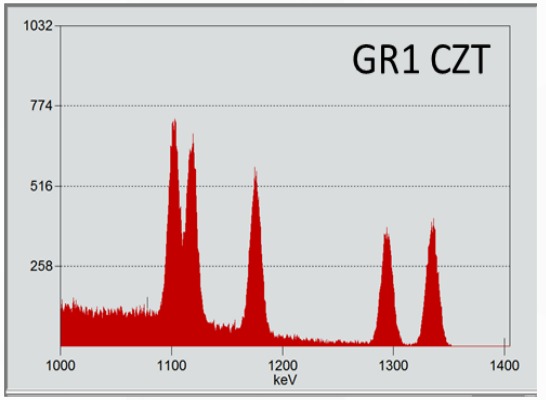
Why we chose large CZT detector with integrated MCA

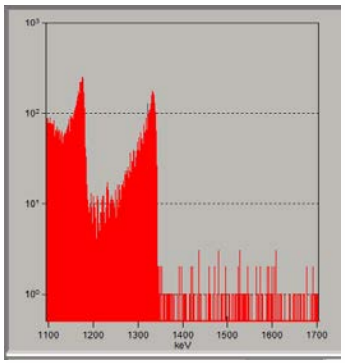
- Small physical size
  - Lower cost/weight shield
- Good peak shape and energy resolution; Gaussian peak shape
  - Better gamma spec results
- Better efficiency than CZTs with InSpector1000



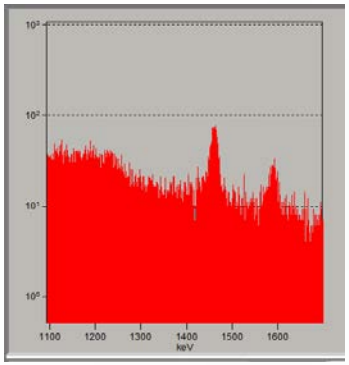








Small In1K CZT



1cc GR1

- Energy resolution <2% at Cs-137
- Gain stability good up to ~1 mSv/hr [100 mR/hr]
- Resolution stable to ~40 degC; only 4% at 50 degC

Add a PC and shield to make the rest of the InSitu Measurement System

- Detector low power – runs off of PC via USB
- Small size – 1” square to go in small places
  - Inside pipes
  - In in holes in concrete or soil
  - Inside thin tubing for below-water
- Shield can be small and light because the detector and integrated MCA is very small
  - Unlike previous HPGe systems
- Versatile shield for InSitu applications
  - 2cm thickness Tungsten standard
  - Attenuation factor: 25 Co58; 6.6 Co60
  - 8.4kg (19lbs) with maximum collimator
  - 5 collimation arrangements – 9.1kg total
- More Tungsten is easy for custom units
  - 3cm = 18kg [40 lbs]; 4cm = 28 kg [70 lbs]
- Quick and easy deployment
  - Light weight, no cooling-down time
- Add efficiency calibration and get immediate quantitative results in the field,

Collimator configurations, accessories.

180 deg collim with base shield

front plate with 35mm opening

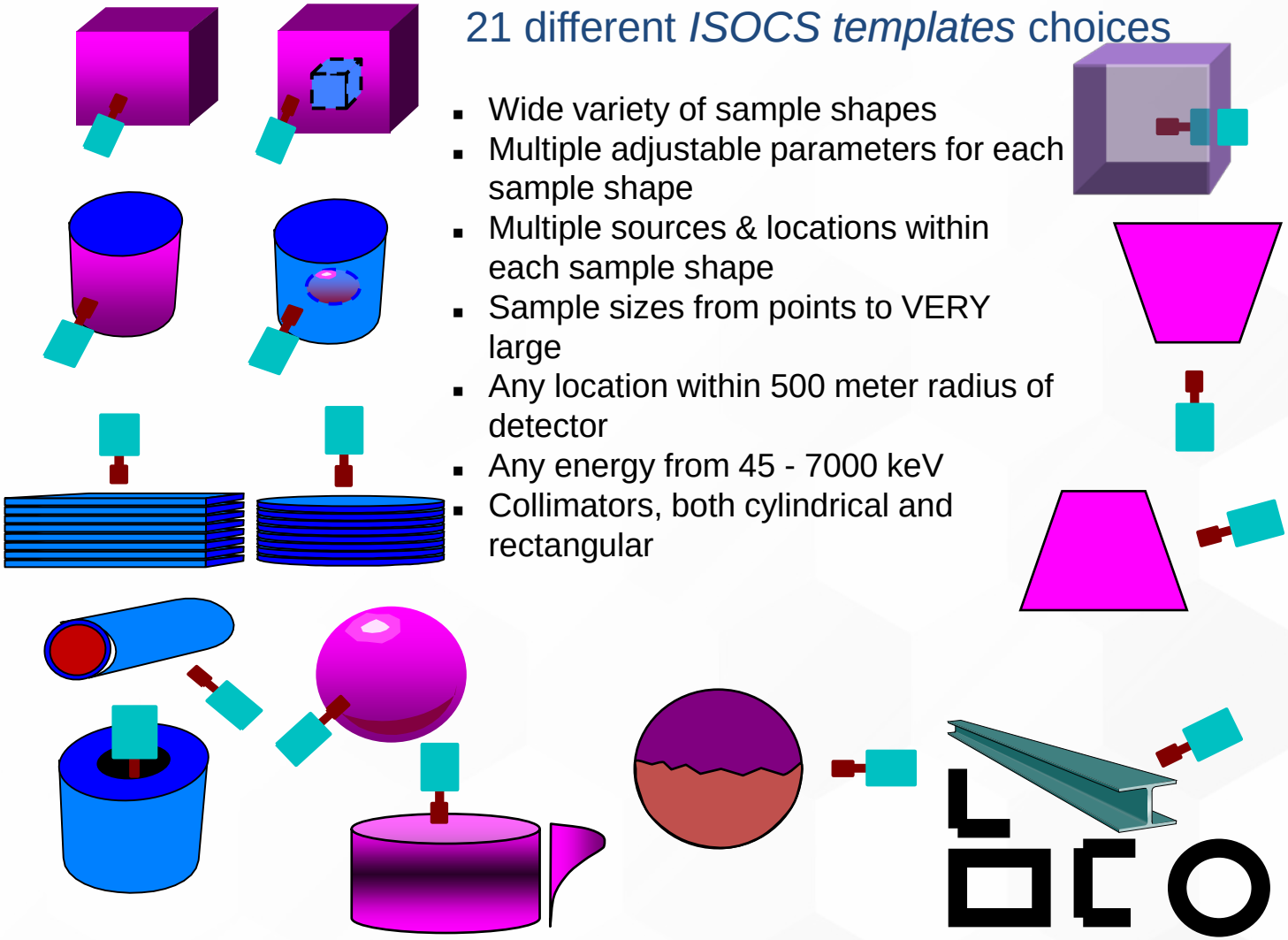
Inserts of 8mm, 2mm, and 0mm

Can also be used to assay samples in the field

Heavy duty carbon fiber tripod

Pelican sturdy waterproof transportation and storage case holds all items plus PC

The ISOCS mathematical efficiency calibration software allows for quick and accurate Quantitative Results – by the user, in the field

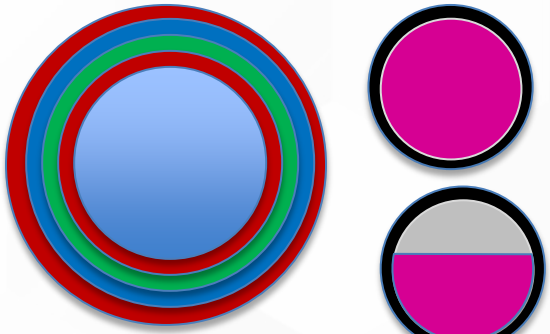


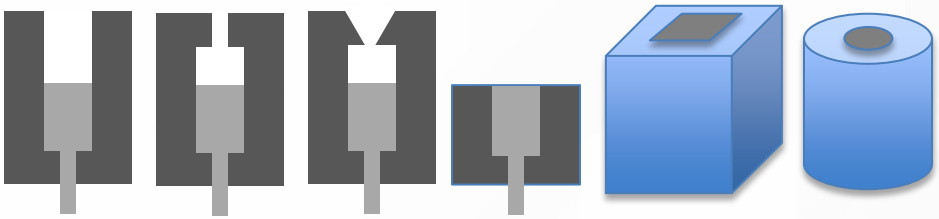
21 different *ISOCS templates* choices

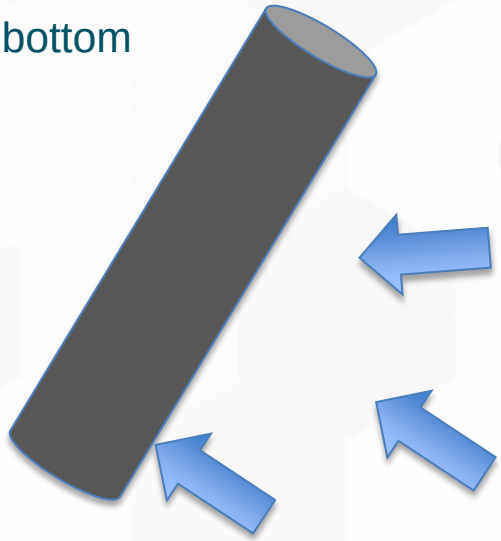
- Wide variety of sample shapes
- Multiple adjustable parameters for each sample shape
- Multiple sources & locations within each sample shape
- Sample sizes from points to VERY large
- Any location within 500 meter radius of detector
- Any energy from 45 - 7000 keV
- Collimators, both cylindrical and rectangular

Example of ISOCS flexibility – many different ways to model a pipe

- Pipes can be any diameter, any length, and any thickness of any material [any = <several hundred meters]
- Pipes can have 1-6 layers to easily model various insulation and protection layers
- Any layer can be radioactive or an absorber
  - Internal or external contamination
- The pipe can be filled with radioactive or non-radioactive material
- The pipe can be partially filled, or the source can be on the bottom
- The detector can be close, or far, or at any angle
- Most any collimator can be added







As they say on late-night infomercials

But wait !! There's More !!!

An accessory for continuous measurements

Data Archiver – a Black Box [literally] to allow continuous spectroscopy

Autonomous portable field assay kit

- CZT detector
- Tungsten shield and collimator set
- Wide-range EcoGamma doserate probe

Works with wide variety of detectors

- Germanium for best quality
- NaI LaBr and CeBr scintillation for good sensitivity and low cost
- CZT for low cost and maximum portability

Data Archiver Design and Capabilities

Base Device

- DA module
- POE power supply
- Wi-Fi and GPS antennas

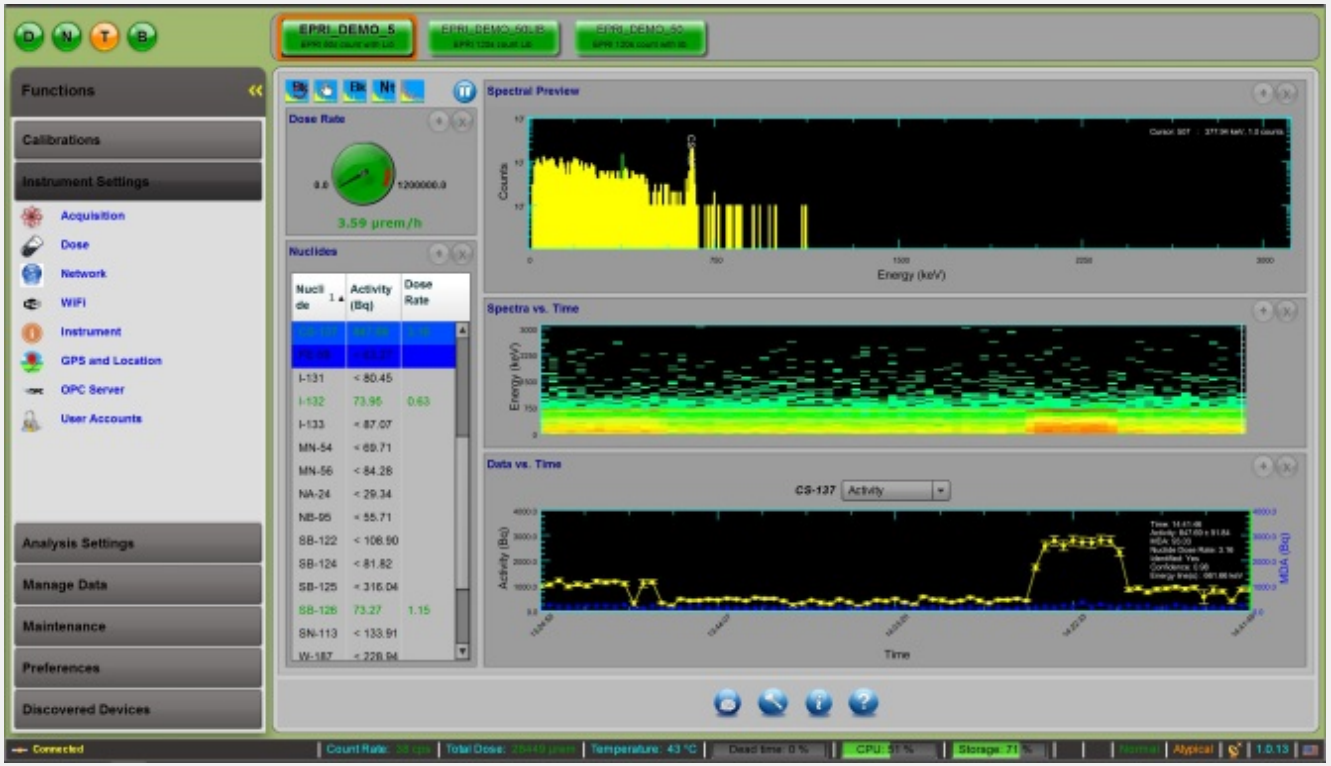
Specifications

- Power via POE
- 3 watts
- 13 x 6 x 17cm
- Integral SoM computer
- Autonomous operation
- Generates nuclide-specific alarms
- Local LED alarm lights
- External start/stop inputs
- External Alarm signal outputs
- External PC for setup and readout
- Full standard Genie spectral analysis
- Runs multiple simultaneous Workflows; each can have different count times, libraries, and analysis parameters

Requires addition of PC, MCA, and Detector

- PC used to setup sequences, view current results, and download archives of data
- MCA can be internal with detector unit [CZT shown here] or external Osprey or Lynx MCA with detector.

Data Aggregator Design and Capabilities



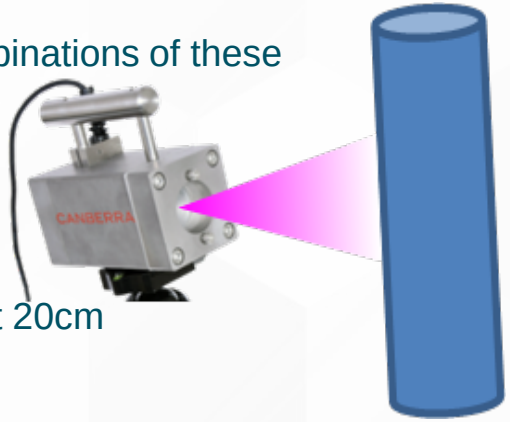
Main Screen of User Interface

- Time sequence for doserate
- Time sequence for each individual nuclide
- Waterfall spectral time sequence
- Spectra for each incoming time period, or for the selected previous assay

Applications relevant to Nuclear Power Plants

Measurement of radioactive contamination inside pipe with CZT.

- NPPs have MANY pipes and various contamination situations
  - Clean, radioactive liquid or gas, internal or external contamination, combinations of these
  - All can be modeled with ISOCS and quantitatively assayed
- Is the liquid in the pipe radioactive ?
  - 15cm [6”] diameter pipe, 5mm wall thickness
  - Detection Limit for 100% gamma yield, 15min measurement, detector at 20cm



CZT MDA

keV	60	100	300	600	1000	1500	3000
Bq/kg	54488	1180	412	748	1116	1489	3951

x 0.03 ~uCi/ml
~ same as EPA and European food limits
what level of radiation protection required ?

- Is the inside of the pipe contaminated ?
  - Example – planning repair work involving opening the pipe
  - Pipe is known to be empty, but wall contamination not known
  - Detection limit for 100% gamma yield, 15min measurement, detector at 20cm

CZT MDA

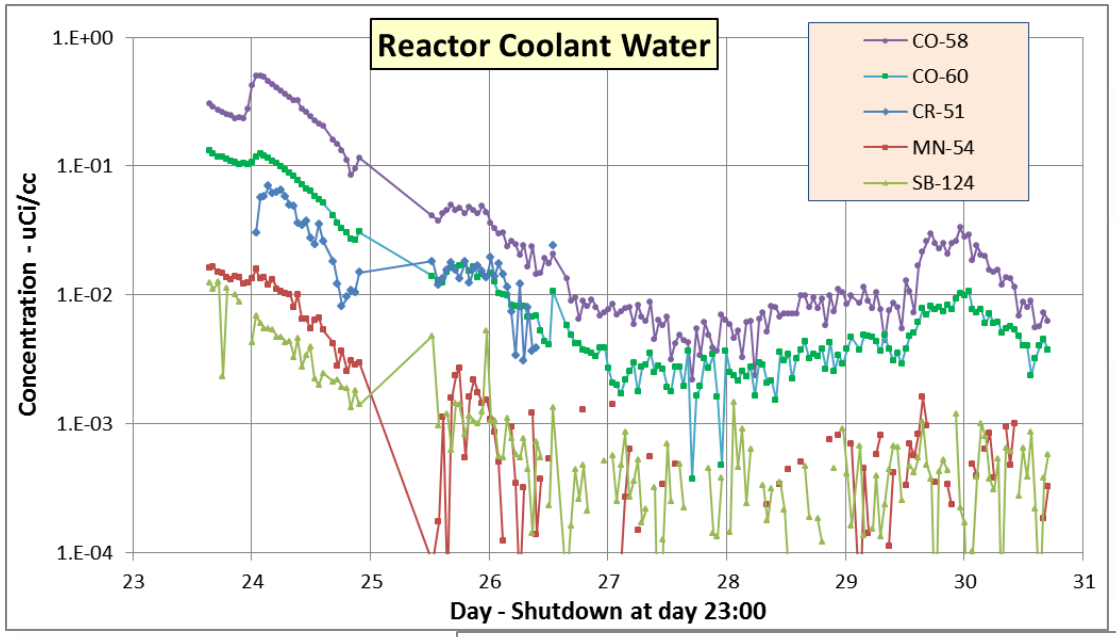
keV	60	100	300	600	1000	1500	3000
Bq/100cm2	11769	245	91	182	292	414	1198

~15000 dpm/100cm2 Cs134/137, Co58/60
what level of radiation protection required ?

- Knowing the contamination nuclides and level allows the most Reasonable procedures to be used [R in ALARA = Reasonable]

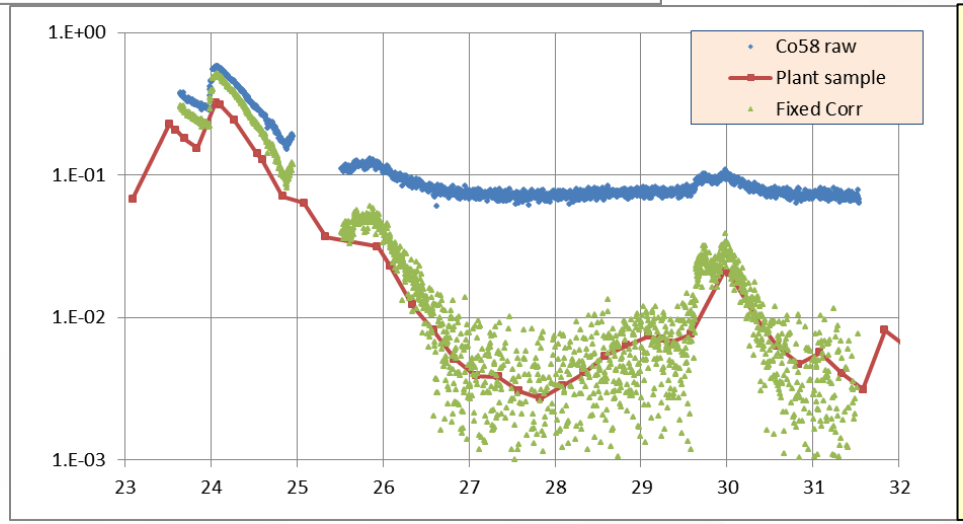
First Field Deployment – at Nuclear Power Plant immediately after shutdown

joint Plant, Electric Power Research Institute, and Mirion project



Other nuclides reported

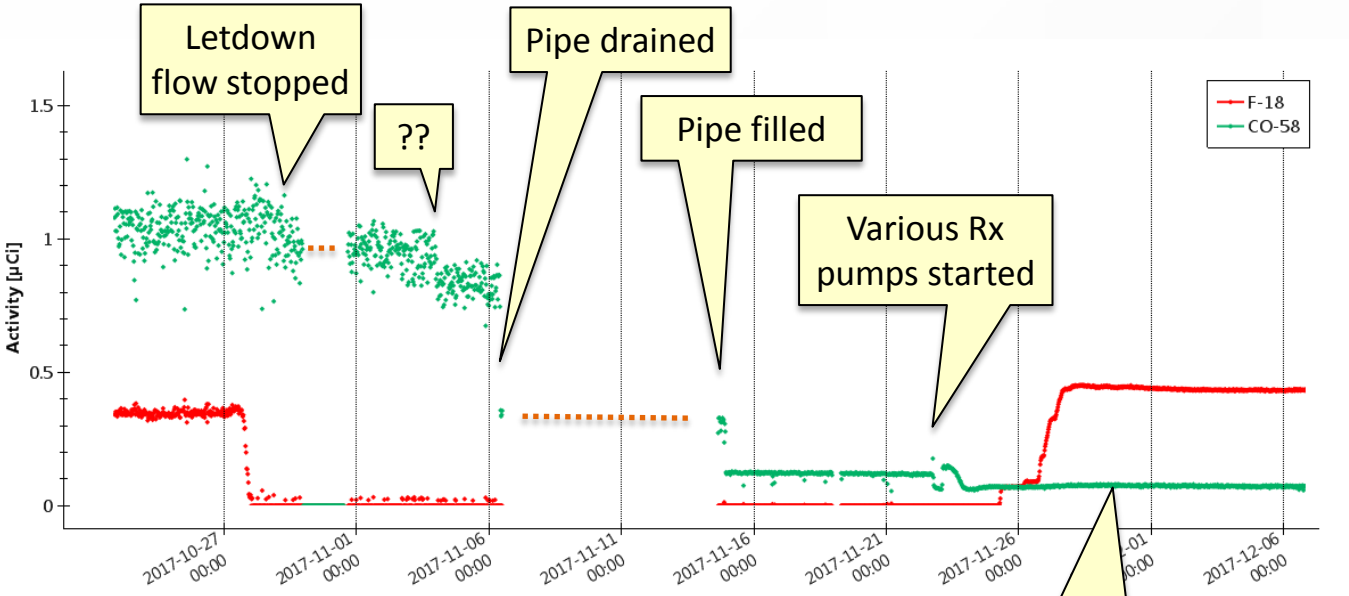
- Fe-59
- Sn-113
- Zr-95
- Nb-95
- Ag-110m
- Zn-69m
- A-41
- Na-24



- Detector measures water plus pipe activity
- Pipe activity assumed to be fixed
- Results mirrored plant water activity when 0.18 uCi/cm2 subtracted

Second Reactor Deployment - very preliminary data

joint Plant, Electric Power Research Institute, and Mirion project

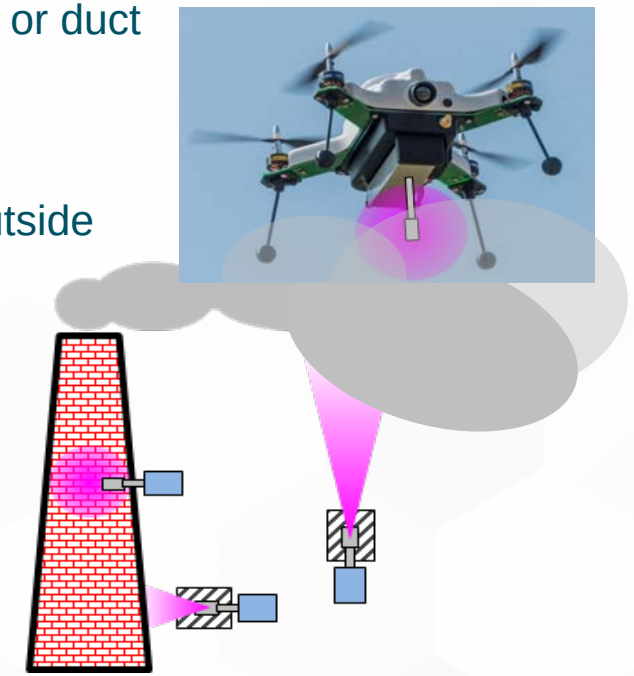


- Detector aimed at letdown pipe
- Pipe isolated during outage, therefore does not show transient activity like previous slide
- F-18 shown to illustrate reactor power level
  - Steps at startup mirror plant power startup process
- Deployment also includes EcoGamma probe for accurate doserate
- Will be left in for full fuel cycle

Primary system water lower activity than fill tank water and much lower than before shutdown

Radioactive gas effluent – with CZT detector

- A. Unshielded detector could be inserted into the stack or duct
  - Stack is 2m inside diameter and 8m tall
  - Detector in middle of stack
- B. Collimated detector could be aimed at stack from outside
  - Stack has 5mm thick steel walls
  - Detector shield in near-contact with stack
- C. Collimated detector could be aimed at the effluent plume from the ground
  - Plume 50 m in diameter, very long, with midline at 50m from ground
- D. Un-collimated detector could measure plume in air from UAV [drone]
  - Plume 50 m in diameter, detector in center of plume
- All of these are good candidates for use with the DA for continuous repeating measurements



CZT 15min MDA

keV	60	100	300	600	1000	1500	3000
A Bq/m^3	2033	1378	1426	2965	5031	6395	17607
B Bq/m^3	357414	8595	3829	7819	12627	18072	52796
C Bq/m^3	402	300	320	670	1091	1553	4431
D Bq/m^3	123	79	74	144	235	289	761

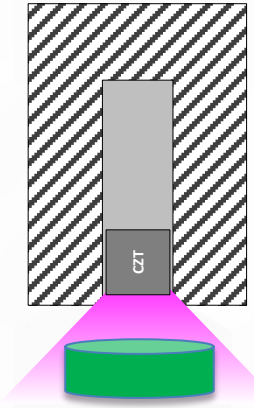
Measuring gas effluent with HPGe detector and Data Archiver

- Sample extracted from stack
- Pre-filter to remove particulates and Iodine
  - Could be monitored separately for P-I-NG
- Assay container 17 Liter Marinelli Beaker
  - Stainless steel; easily exchangeable
  - Pressure sensors read by DA and used to compute sample volume
  - Stack flow rate used to compute effluent rate
- Inside modified 747 shield
  - 10.16 cm of lead
  - Copper lining to reduce lead x-rays
- HPGe detector [30% RE] and Lynx MCA
  - Electrically cooled with CP-5
- MDA about 100x lower than previous example of bare CZT in middle of stack
- DA set for 3 different simultaneous count times

MDC (Bq/m^3)			
Nuclide	600 sec acquisition	3600 sec acquisition	14400 sec acquisition
Kr-85	6.91E+04	2.50E+04	1.19E+04
Kr-85m	1.85E+02	6.77E+01	3.25E+01
I-131	2.20E+02	7.67E+01	3.61E+01
Xe-131m	7.41E+03	2.72E+03	1.31E+03
Xe-133	5.74E+02	2.10E+02	1.01E+02
Xe-133m	1.56E+03	5.66E+02	2.70E+02
Xe-135	1.87E+02	6.77E+01	3.24E+01
Xe-135m	2.46E+02	8.25E+01	3.82E+01

Measuring airborne activity – CZT detector

- Air sampled is 1000 liters; 1 cfm (28 liters/minute) for 35 minutes
- Sample counted for 15 minutes
- 100% collection efficiency
- Filter paper is 20 cm^2 area
- Iodine cartridge is 20 cm^2 area and 2cm thick
- Filter media 1cm from shielded detector.
  - A. Filter paper
  - B. Iodine cartridge

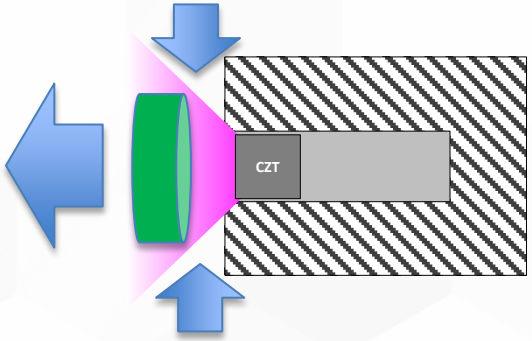


Field assay of filter

CZT MDA 15min

keV	60	100	300	600	1000	1500	3000
A Bq/m^3	6	6	9	22	42	67	222
B Bq/m^3	11	9	14	37	69	109	360

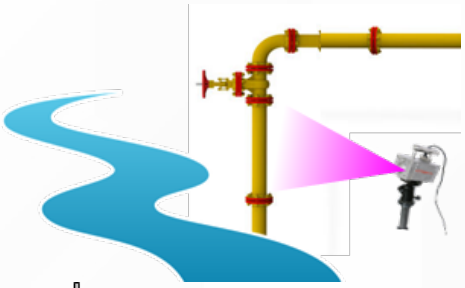
Goal – MDA = 40 DAC-hrs
I-131: 35min sampling time, 35 min count time
Co-60: 100min sampling time, 100min count time

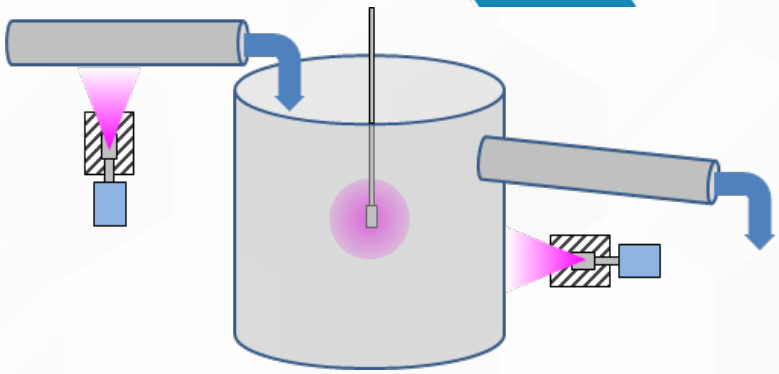


Add Data Archiver to make quantitative gamma spec CAM

Liquid in tanks, pipes, inlets, discharges

- A. Aim shielded detector at intake or discharge pipe
  - Detector 2cm from 15cm [6”] diameter pipe, 5mm wall thickness, 2m long [as before but detector closer]
- B. Aim shielded detector at tank
  - Tank is 2m diameter, 2m high, and filled with water
  - Tank walls are 5mm steel
- C. Insert unshielded detector into well in tank

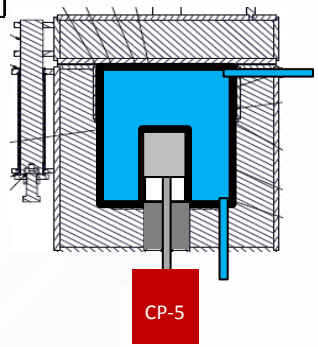




CZT MDA 15 min

keV	60	100	300	600	1000	1500	3000
A Bq/kg	19699	424	152	272	404	542	1427
B Bq/kg	13083	270	88	136	174	203	413
C Bq/kg	61	34	25	39	52	54	104

- System we designed for Japan seawater
  - Like Gas monitor but water
  - 100% RE HPGe, 17 liter MB
  - 0.15 Bq/kg Cs134, Cs135, 15 minutes; 200x better

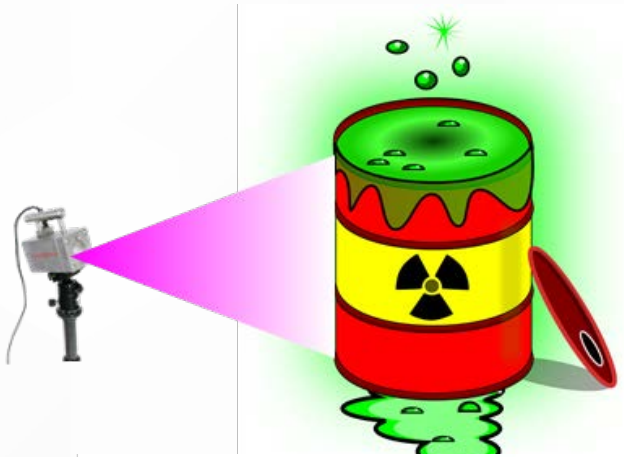


HPGe strongly recommended for installed on-line coolant assay
- **Better resolution**
- **Better stability**
- **Wider dynamic range**

- In-situ for tanks, filters, resin columns
- Add Data Archiver for continuous assays – resin sluicing, discharges, chemical decon progress

Radioactive Waste Assay – CZT detector and shield

- A. 200 liter drum filled at 0.5 g/cc density [111 kg]
  - Shielded detector at 1 meter
  - 2mm Fe walls
- B. Box [1m x 2m x 1m] at 0.5 g/cc density [1000 kg]
  - Shielded detector at 1 meter
  - 3mm Fe walls

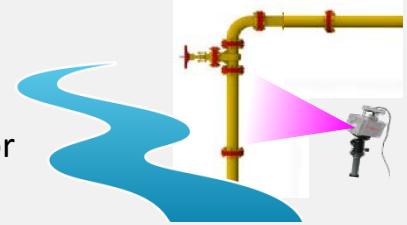


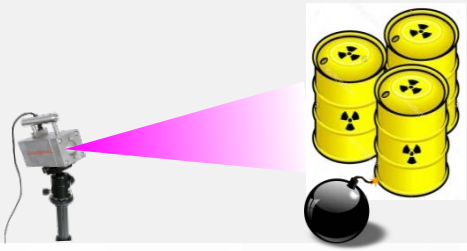
CZT	keV	60	100	300	600	1000	1500	3000
MDA	A Bq/kg	6183	859	562	1157	1881	2599	7334
15 min	B Bq/kg	3563	276	152	293	449	601	1565

Emergency Response or D&D Applications

Emergency response applications

- Municipal water intakes
- Unstable situations with potential for liquid or airborne releases



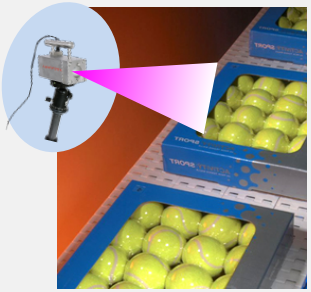


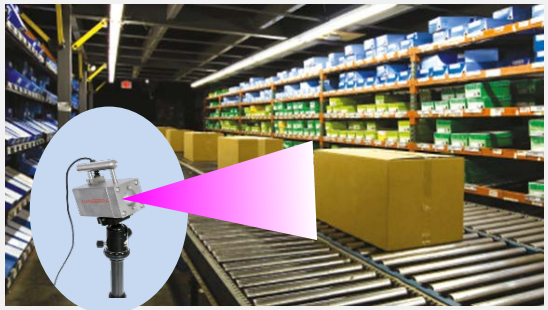
Detector on moving platform

- Radioactivity on the ground, along with GPS coordinates
- In UAV for radioactivity in plumes or on ground

Conveyor monitoring applications – nuclide-specific screening and sorting

- Excavated soil
- Crushed concrete
- Containers of food
- Ad Hoc screening applications





Summary and Conclusion

- The CZT detector and shield has adequate sensitivity for most HP NPP applications
- The CZT/shield/tripod/LaptopPC highly portable for quick deployment in complicated areas
  - <20 lbs and no external power
- The addition of the ISOCS efficiency software makes quantitative results easy and accurate.
  - Calibrations can be quickly made by user for very wide range of situations
  - Calibration method acceptable by USNRC in RG 1.21
- Addition of Data Archiver turns InSitu measurement system into Continuous Spectroscopy System
  - Works with CZT detector, with HPGe detector and Lynx, and with Scintillation detectors and Osprey
  - EcoGamma probe can be added for wide-range accurate doserate measurements
- Deployment in measurement area very easy – set equipment in place and apply power; then everything happens automatically
- Results instantly available at the end of each measurement period
  - Multiple measurement periods and assay scenarios can happen simultaneously
  - Results transmitted over WiFi, Ethernet, USB, and Mirion WRM dosimetry network.


THANK
YOU!
STOP
935