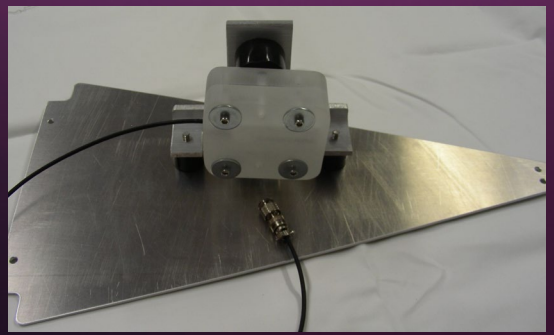
SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

CTBTO
PREPARATORY COMMISSION

PNNL-SA-162591

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA



POSTER

P3.1-309

Pacific Northwest
NATIONAL LABORATORY

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

ABSTRACT

A novel first-look cadmium zinc telluride (CZT) detector is being developed by Pacific Northwest National Laboratory (PNNL, USA) in collaboration with General Dynamics – Mission Systems (GD-MS, USA). The compact gamma-spectrometer is designed to be installed within the air intake plenum of the Radionuclide Aerosol Sampler Analyzer (RASA) design of International Monitoring System (IMS) radionuclide stations. It provides real-time measurements of the radionuclides collecting on the filters in advance of the standard High-Purity Germanium (HPGe) measurement made 48 – 72 h after sample collection. These measurements are made every 15 minutes, and may provide an early indication of radionuclides relevant for Treaty monitoring purposes, supporting nuclear event discrimination and atmospheric transport modelling (ATM) projections. During the high-activity conditions that might be expected during a nuclear accident, it would also provide a measurement of dose rate useful for protecting the station operator and other personnel (including the dose expected from activity collected on the filters). The first-look detector would also safeguard against contamination of the RASA, and may be used to trigger reduced air flow and collection time, to limit the activity being collected onto the filters, and measured by the HPGe.

The GR1A CZT detector

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

BACKGROUND

- A novel first-look cadmium zinc telluride (CZT) detector is being developed
  - Collaboration between Pacific Northwest National Laboratory (PNNL) and General Dynamics – Mission Systems (GD-MS)
- It is designed to be installed onto the Radionuclide Aerosol Sampler Analyzer (RASA)
  - Provides real-time measurements of the radionuclides collecting on the RASA filters
  - Measurements in advance of the standard High-Purity Germanium (HPGe) measurement made 48 – 72 h after sample collection
- Provides measurements useful for nuclear explosion monitoring, dose assessments and protecting against RASA contamination

Evaluation of gamma-spectrometry equipment for on-site inspection

Performance characterization of the Radionuclide Aerosol Sampler/Analyzer air sampler during a high-activity release event

Earlier work [1,2] demonstrated the utility of the CZT first-look detector

[1] Burnett J. and Miley H. (2021). Nuclear Instruments and Methods A 985
[2] Burnett J. et al. (2017). Journal of Radioanalytical and Nuclear Chemistry 312

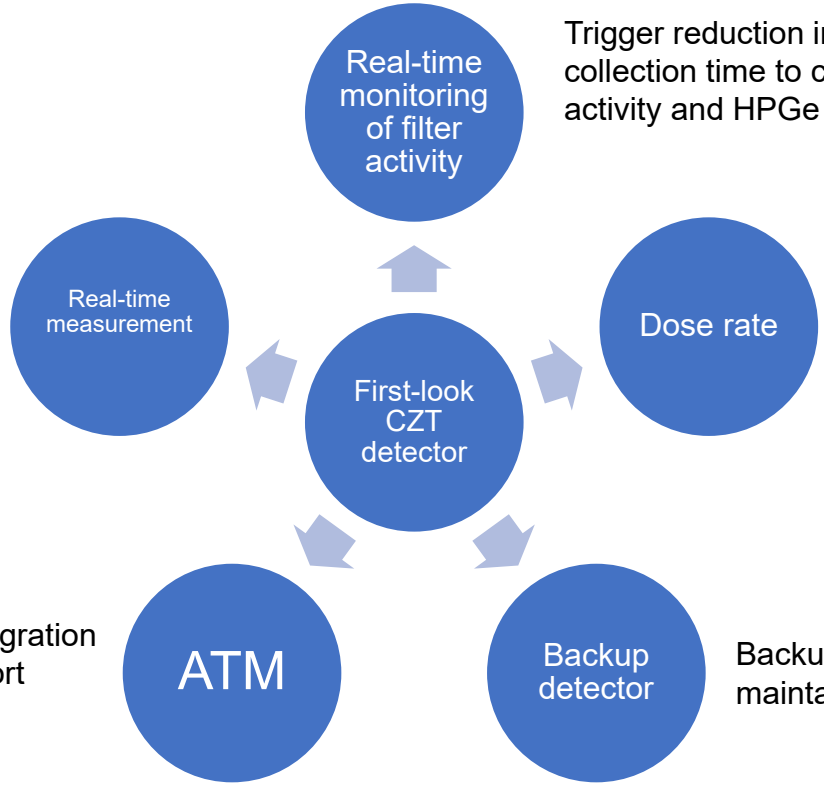
SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

ROLES



Trigger reduction in air flow or collection time to control sample activity and HPGe dead-time

Nuclear event monitoring

Provide real-time dose rates to protect station operator and other personnel

Understanding plume migration and atmospheric transport modelling

Backup detector for critical HPGe failure to maintain station capability

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

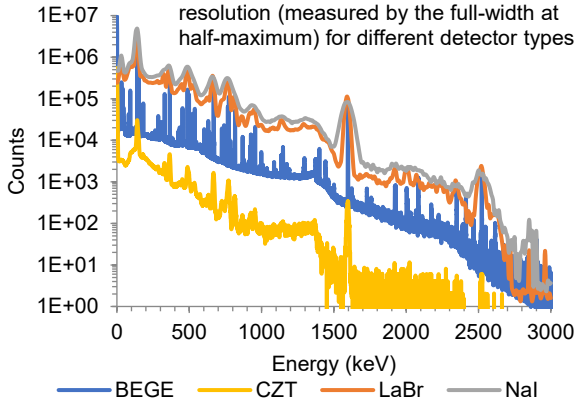
J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

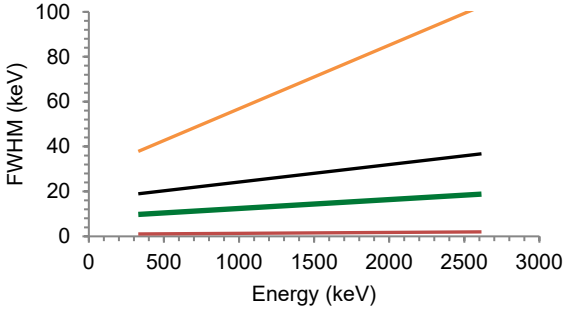
CTBTO PREPARATORY COMMISSION

Why use a CZT?

- Previous work [1] demonstrated utility of medium-resolution CZT for detection of radionuclides indicative of a nuclear explosion
  - Compared performance to high-resolution HPGe and low-resolution sodium iodide and lanthanum bromide detectors
  - Demonstrated that 11/17 relevant radionuclides were detectable using the CZT for a 1 kT nuclear explosion
  - CZT resolution (2% at 662 keV) is better than a NaI or LaBr for improved radionuclide identification
- CZT provides a cost effective (<$20k), compact (3 in), low-power (250 mW) solution that can easily be installed into the RASA air intake plenum
- Stable operation with no thermal drift and no cooling required
- Tolerance to count rate for a contamination event (> 30K cps)

A comparison of spectra response and resolution (measured by the full-width at half-maximum) for different detector types





SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

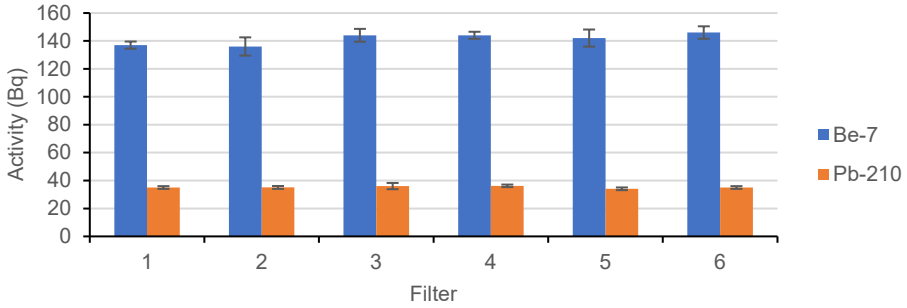
Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

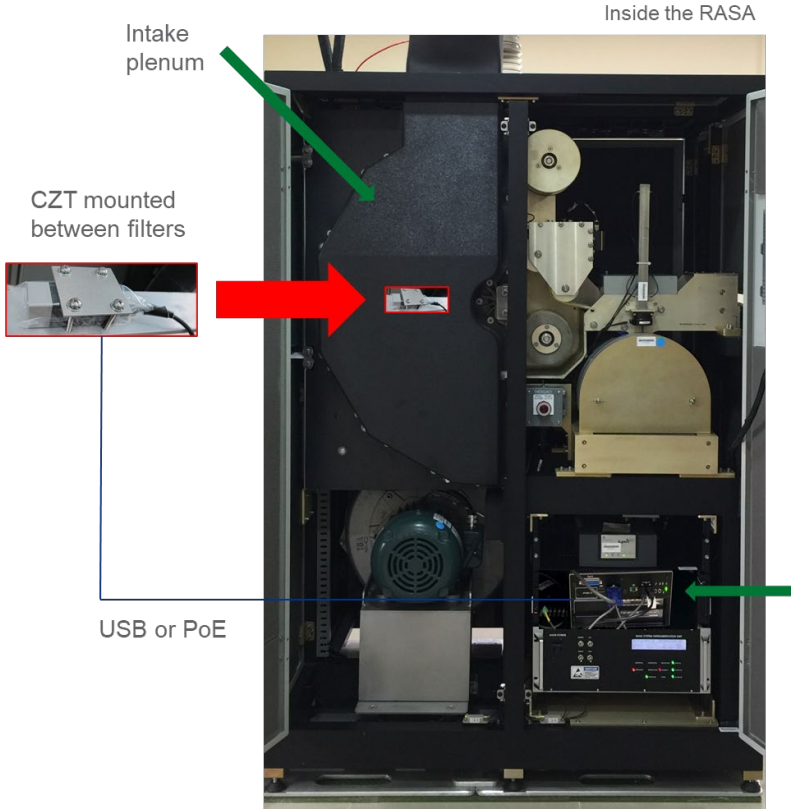
CTBTO PREPARATORY COMMISSION

PLACEMENT

- The CZT is positioned between the center filters in the RASA intake plenum
- Laboratory experiments have shown that particulates are collected equally amongst all 6 filters



Activity collected on each filter in the intake plenum for a 7-day collection



SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

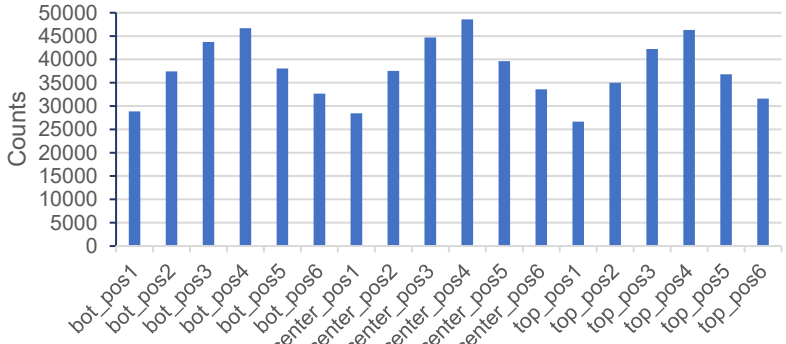
J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

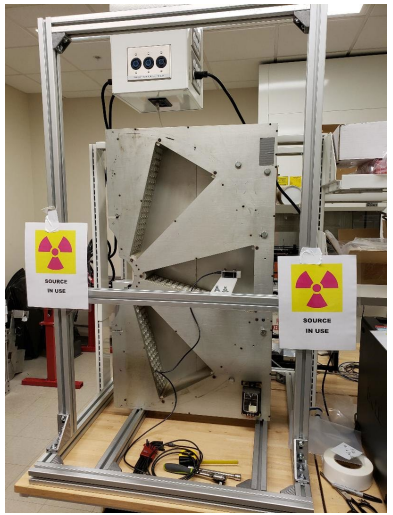
CALIBRATIONS

- Efficiency calibrations performed for different CZT positions within the intake plenum
- Calibration rig constructed containing 6 spiked filters and 18 CZT placement locations evaluated
  - Optimum placement of the CZT determined

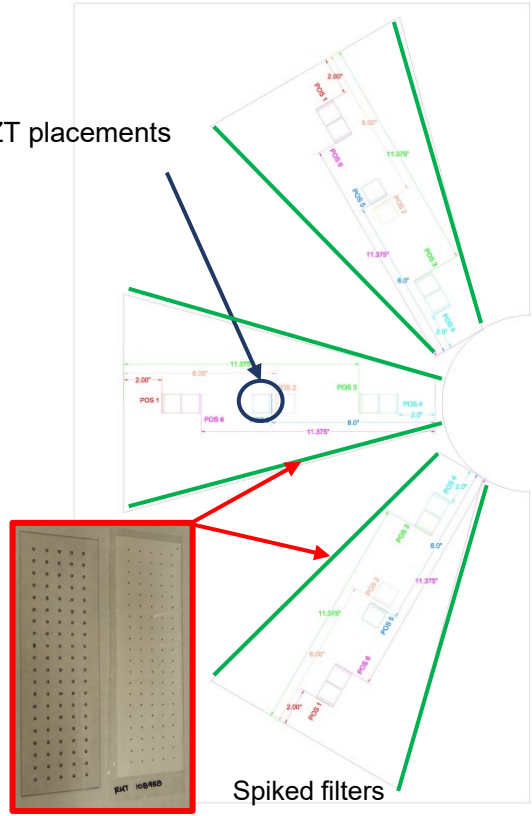
Determination of the optimum positioning of the first-look detector



Calibration rig



CZT placements



Spiked filters

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

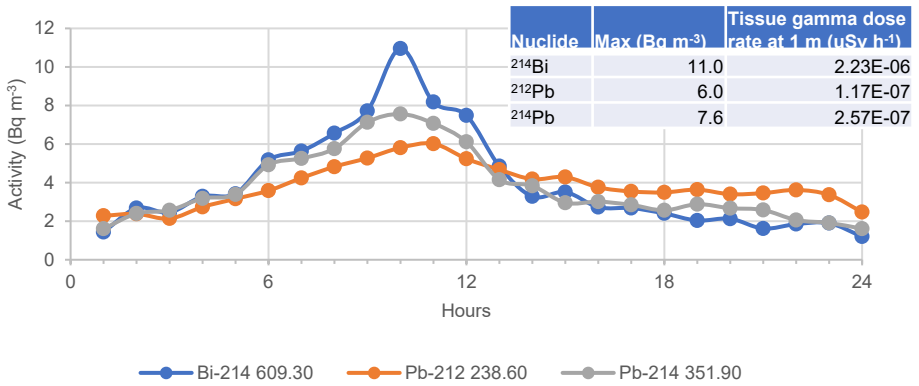
J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

MEASUREMENT

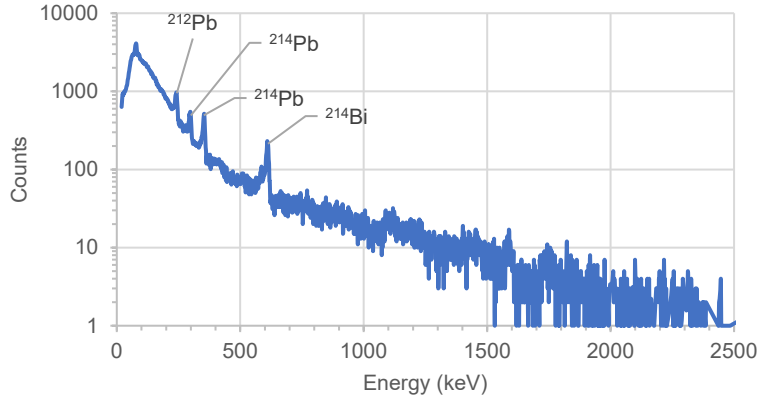
- CZT detector installed onto PNNL test-bed RASA at PNNL
  - Performed 1 h measurements during 24 h air sampling
  - Efficiency calibrations enable activity measurements and dose rate
- Measurement of radon progeny accumulating on filter with hourly fluctuations as atmospheric concentrations change

First-look CZT measurements during 24 hour collection



Nuclide	Max (Bq m^{-3})	Tissue gamma dose rate at 1 m (uSv h^{-1})
^{214}Bi	11.0	2.23E-06
^{212}Pb	6.0	1.17E-07
^{214}Pb	7.6	2.57E-07

First-look CZT measurement (24 hour collection)

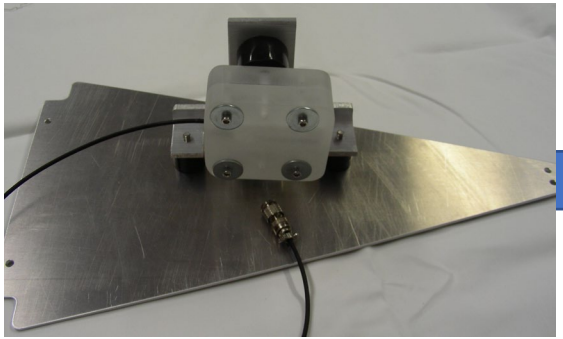


Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

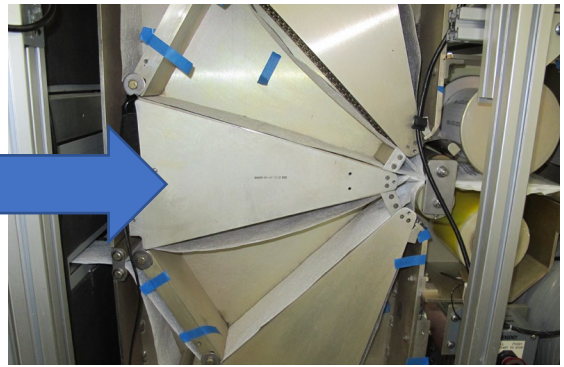
J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

INSTALLATION

- Installation between the RASA filters is relatively easy
  - The detector is mounted on a panel within the intake plenum positioning it between the center air filters
  - It is then connected to the RASA computer by a USB cable
  - No additional electronics or components are required



The first-look detector mounted on a panel



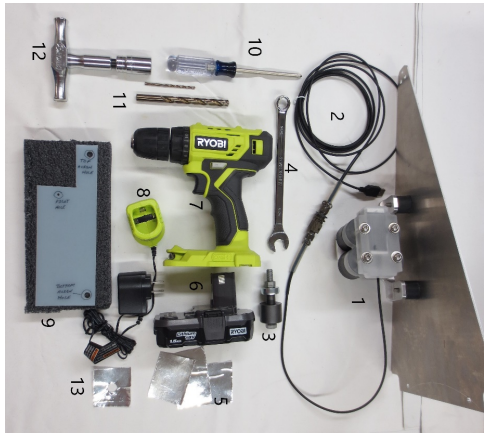
RASA intake plenum

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

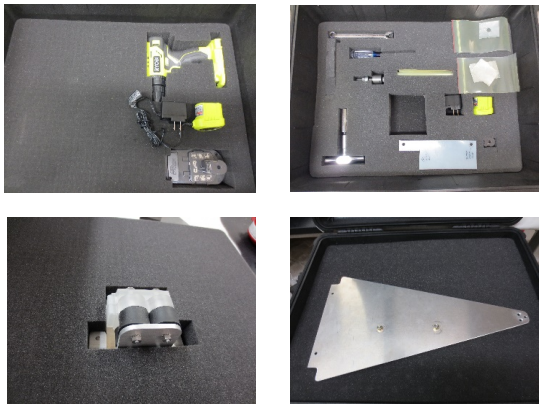
UPGRADE KIT

- A complete first-look detector upgrade kit has been developed for installation of the first-look detector onto the GD-MS test-bed RASA
  - The upgrade kit includes everything needed for the installation - the CZT detector, detector mounting panel and bracket, USB cable and connectors, installation tools and instructions



Contents of the first-look detector upgrade kit

All components are contained within a protective plastic case



Within the case, components are packed in layers

SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
Poster No.: P3.1-309

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CTBTO PREPARATORY COMMISSION

TESTING

- The first-look detector has been installed onto the GD-MS test-bed RASA for testing and development
  - Aims to evaluate performance under operational conditions and determine integration requirements
  - Includes additional software development, calibrations, testing and QA monitoring
- Supported by a first-look detector/HPGe at PNNL for calibration purposes using higher activity samples
  - Experiments will determine the relationship between CZT and HPGe count rate
  - This is needed to determine alarm thresholds to prevent system contamination

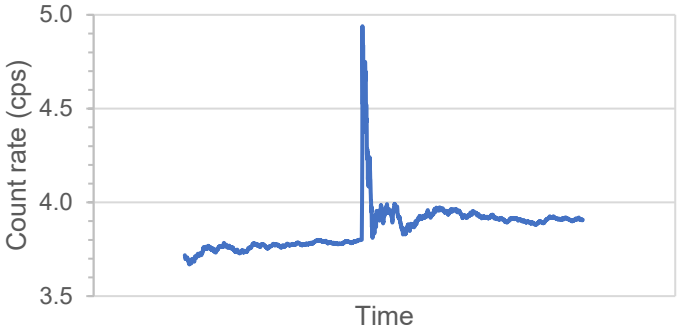
The first-look detector upgrade kit next to the GD-MS test-bed RASA

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

SOFTWARE

- C++ acquisition software has been developed by PNNL
  - To facilitate integration into GD-MS pipeline for testing purposes
- Saves spectra every 15 m (SPHDP) and 24 h (SPHDF) in IMS2.0 format
  - Analogous to HPGe spectra transmitted for automated analysis using GD-MS pipeline
- Monitors and records count rate every 2 second
  - Alarms if thresholds exceeded – could be used to trigger contamination protection



Real-time measurements using the first-look detector

```
First-Look Detector Console Software Version 1.20
Pacific Northwest National Laboratory 2021
************************************************
First-Look Detector Found
GR1A ID: 1185314814
Manufacturer: Kromek
************************************************
Enter the number of acquisition days:
1
************************************************
Enter the flow rate (m3/h):
1000
************************************************
SPHDP flow volume of 250 m3
************************************************
Enter the alarm threshold (counts/second):
300
************************************************
SPHDP Acquisition cycle: 1
MSG_ID: 197
Start time: 2021/05/12 23:22:53
Stop time: 2021/05/12 23:37:53
************************************************
SPHDP Acquisition information
Total counts = 3216
Count rate (counts/s) = 3
Real time (s) = 900
Live time (s) = 899
************************************************
```

SPHDF_CZT_20210414_234333 - Notepad

File Edit Format View Help

```
#g_Spectrum
4096
0     0     0     0     0     0
5     0     0     0     0     0
10    0     0     0     0     0
15    0     0     0     0     0
20    0     0     0     0     0
25    0     0     2     3     14
30    43    66    92    115   121
35    107   114   133   151   131
40    146   136   161   149   158
45    156   180   154   130   95
50    104   148   172   226   300
55    257   206   183   153   134
60    155   153   172   173   216
65    182   189   214   202   214
70    266   251   223   252   247
75    230   232   255   267   254
80    253   253   258   257   296
85    281   271   284   294   288
90    327   331   320   320   272
95    325   304   315   305   329
100   331   343   349   342   360
105   317   382   344   350   327
110   348   345   339   349   362
115   343   374   386   354   354
120   402   364   364   361   395
```

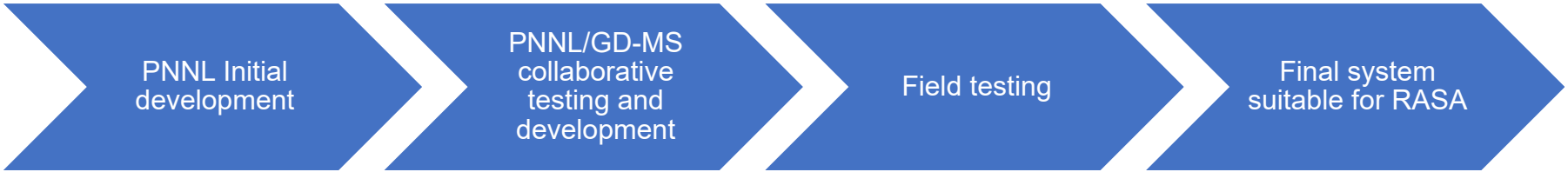
First-look detector control software and data saved in IMS2.0 format

Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

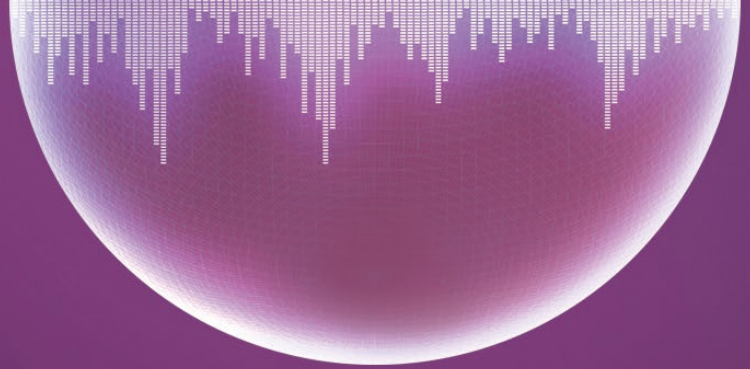
J. L. Burnett[1], A. Myers[1], I. Cameron[1], S. Little[2], T. Ly[2], M. Wright[2]
[1]Pacific Northwest National Laboratory, USA; [2]General Dynamics – Mission Systems, USA

CONCLUSIONS

- A novel first-look cadmium zinc telluride (CZT) detector is being developed
  - Designed to be installed onto the Radionuclide Aerosol Sampler Analyzer (RASA)
  - Provides real-time measurements of filter activity useful for nuclear explosion monitoring, dose assessments and protecting the against RASA contamination
- Further testing and development is ongoing at GD-MS and PNNL to develop a system suitable for implementation at IMS stations



The first-look detector roadmap



Thank you

Funding for this research effort was provided by the Defense Threat Reduction Agency, USA

For additional comments or questions….
Dr Jonathan L Burnett
Pacific Northwest National Laboratory
jonathan.burnett@pnnl.gov