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# Machine Learning (ML) Integrated Quadrant Gamma Detectors for Enhanced Safeguards, Security, and Real-time Inspection

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Dr Yannick Verbelen, Dr Dave Megson-Smith, Dr Freddie Russell-Pavier

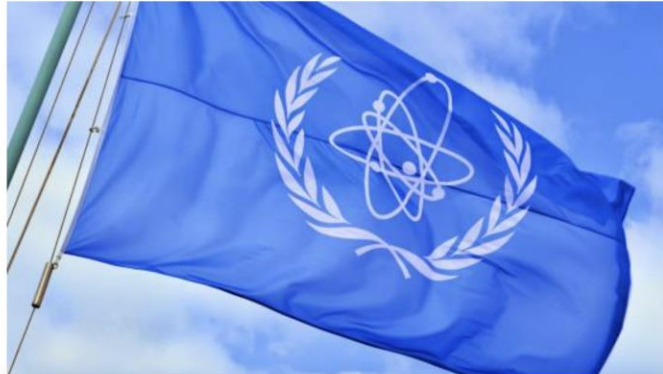
#SWNuclearHub

## IAEA Database Shows Continued Incidents of Trafficking and Loss of Control of Nuclear and Other Radioactive Material

6/2020

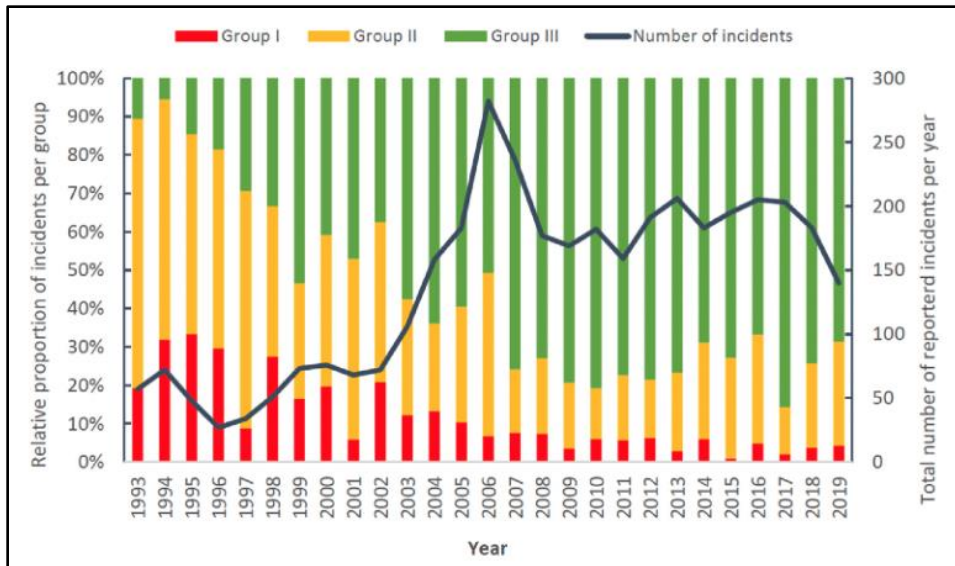
Vienna, Austria

FEB  
13  
2020



### Related resources

- [Incident and Trafficking Database \(ITDB\)](#)
- [2020 ITDB Fact Sheet](#)

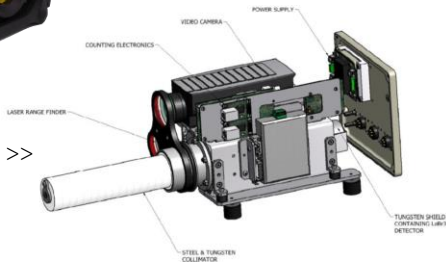


**Challenge:** How to rapidly locate gamma-emitting radioactive materials, moving within a complex environment.

## Gamma Cameras



<< iPIX, Mirion Technologies

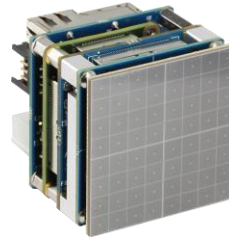


RadSearch, Antech Inc >>



<< CZT for SPECT, Kromek

## Compton Cameras



<< Prototype, Hamamatsu Photonics



^^ Prototype, Waseda University

iPIX - Manual Mode

Password Language Help

Ex CANBERRA

Information Imaging Spectro Dashboard

Number of frames  
23

Distance  
 Enable telemeter  
2.2 m

Enable multiple acquisition  
Number  
3

Step  
5 s

Panoramic

iPIX State

Highest

Lowest

## Prior NuSec Activities:

### Prototype RadICAL Detector for Nuclear Security

Christopher Mayhew, Jia Chuan Khong, Robert Speller and Robert Moss

Department of Medical Physics and Biomedical Engineering, University College London, London, UK



#### The Concept

The RadICAL (Radiation Imaging Cylinder Activity Locator) concept aims to enable the mapping of a 300° area in order to locate radioactive sources. To achieve this, RadICAL makes use of a specially-shaped rotating slab of scintillation material coupled to a photomultiplier tube (PMT). As a result, the ever-changing surface area and thickness of the scintillator, presented to a radioactive source, causes the PMT count rate of interacting photons to change as the scintillator is rotated about its central axis. This produces a Standard Response Curve (SRC) from which the direction of the source can be located as the minimum of the SRC.

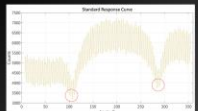


Figure 7: A RadICAL SRC of  $^{137}\text{Cs}$  observed during typical, steady rotating. The minimum of approximately 180° angle shows the RadICAL detector SRC profile. A source located and detected could be determined.

The location of the source observed by the rotating detector at various angles can be expressed through the following equation<sup>11</sup>:

$$\frac{I}{I_0} = e^{-\mu x} = I_0 e^{-\mu x} \quad (1)$$

#### Applications

RadICAL detectors have potential applications in four key areas:

- 1. Nuclear Decommissioning**  
During decommissioning of nuclear facilities, RadICAL has the potential to map regions of high and low radioactive contamination, reducing the potential of accidental exposure to people operating in these high risk areas.
- 2. Homeland Security**  
Multiple RadICAL detectors placed in stations, ports, etc. have the potential to detect, pinpoint and therefore help intercept the transportation of radioactive sources that may be used in the development of dirty bombs.

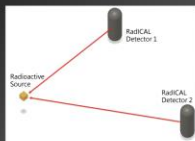


Figure 8: Two or more RadICAL detectors could be used to determine the location of radioactive sources. This could be used in the monitoring of ports and stations for homeland security.

- 3. Radioactive Contamination (CBRN, landfills, etc.)**  
A RadICAL detector, placed in areas with the potential for contamination, could be used to continuously scan for radioactive waste. This would negate the need for checks from

#### Design

A RadICAL detector is composed of the following key features:

- A scintillator - such as EJ-288 or EJ-276.
- A Photomultiplier Tube to establish a count rate at certain angles, and thus determine source location.
- A light-tight housing to reduce the photomultiplier tube's background noise.
- A Stepper Motor used to rotate the scintillator to the required angles.
- A control interface, such as MATLAB, to control the PMT and stepper motor, as well as record data.



NuSec Summer Project (2019)

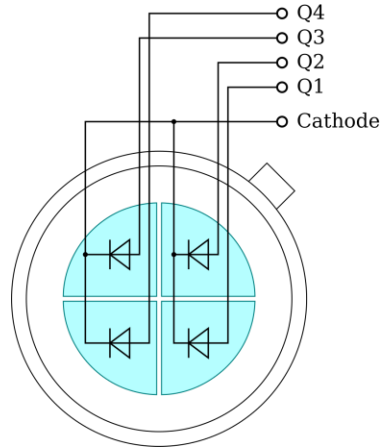
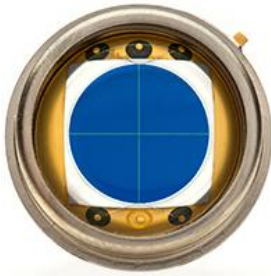
NuSec Summer Project (2022)

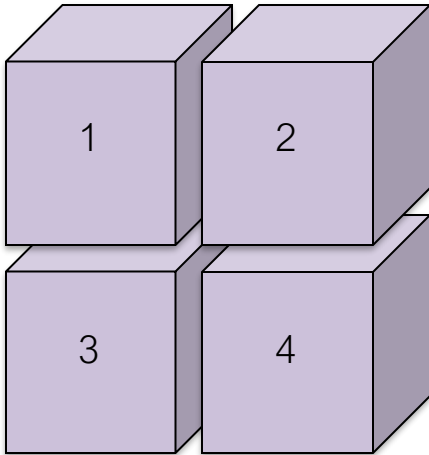
## Aims of NuSec Collaboration Project:

- Develop a **reduced cost gamma-imager**, with enhanced measurement efficiency/data acquisition rate.
- Construct a **field-deployable quadrant detector** system with initial 'coarse scan' results within seconds of scene exposure via progressive 'in-fill'.
- Produce an imaging system **capable of real-time photopeak** identification, negating the need for subsequent spectral post-processing – by human experts or automated processes.
- Enhance quadrant detector designs and validate performance using a **feedback-driven approach**.
- Develop a **'detector agnostic' system**, whereby the component quadrants could comprise any number of current or novel radiation sensor material type.
- Implement packet management and secure wireless data transmission to facilitate the next generation of 'decoupled' cloud-based real-time **high-speed data-stream processing**.
- Refine existing iterative projective deconvolution algorithm for **rapid and precise emitter localisation**; including the implementation of the "coarse infill" approach, whereby newly collected data continually contributes to the imaging resolution enhancement - building upon earlier results.



## Concept - Quadrant Photodiode:

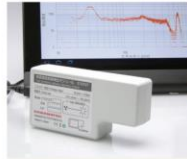




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## Radiation detection modules

C12137 series



### High accuracy, high sensitivity, compact radiation detection module

The C12137 series is a radiation detection module containing a scintillator and MPPC® (multi-pixel photon counter) designed to detect gamma rays from <sup>137</sup>Cs (Cesium-137) and the like. The scintillator converts incident gamma rays into visible light, and the MPPC detects the light down to extremely low light levels to measure low-energy gamma rays with high accuracy. The signal processing circuit and A/D converter are housed in a compact case. The modules provide a USB or RS-232C interface. The products include sample software with functions for setting measurement conditions, acquiring and saving data, and drawing graphs, etc.

#### Features

- Gamma ray energy discrimination
- Modular design for easy integration into devices
- Compact and lightweight

#### Applications

- Environmental monitoring and mapping
- Screening such as incoming and outgoing inspections at manufacturing sites
- Incorporation into portable, high-sensitivity detectors

#### Lineup

A total of eight types in four different sizes and two (USB and RS-232C) are available that you can choose according to your application.

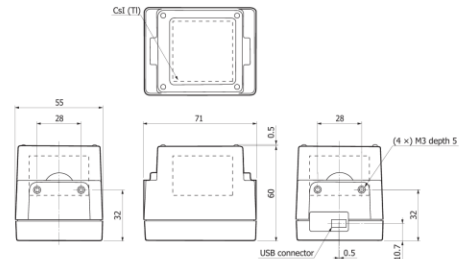
\* The characteristics are the same between the USB and RS-232C type (the software specifications are different).



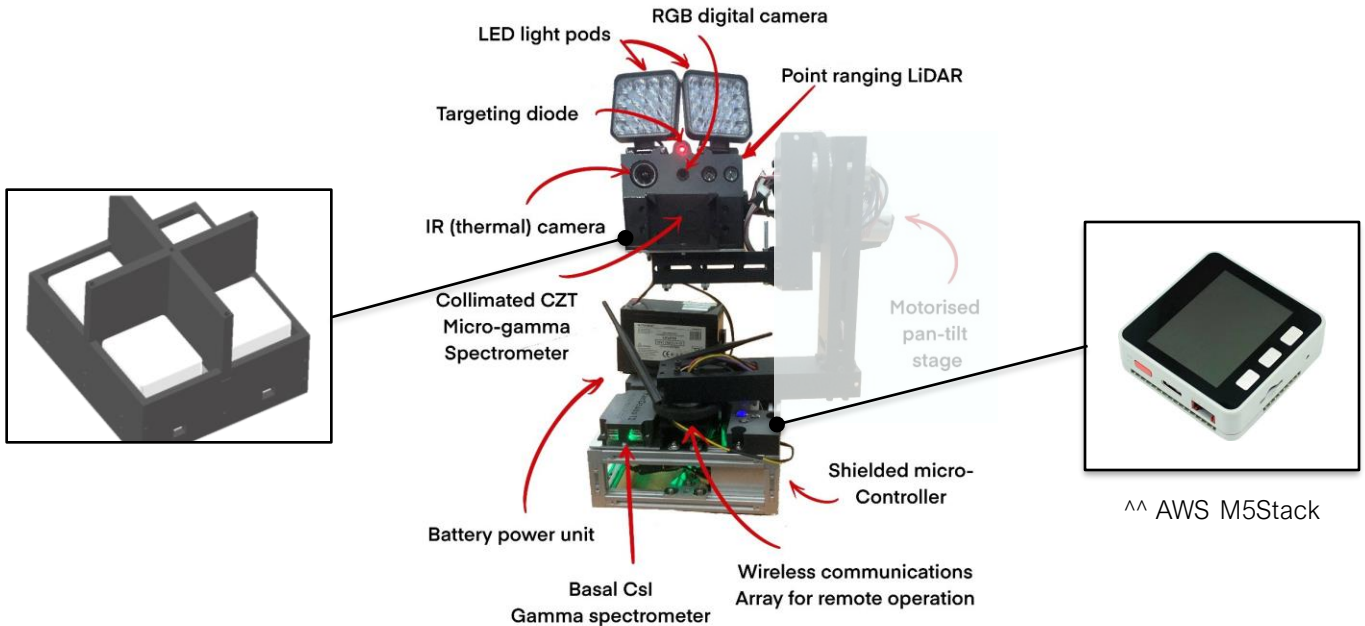
## Radiation detection modules

C12137 series

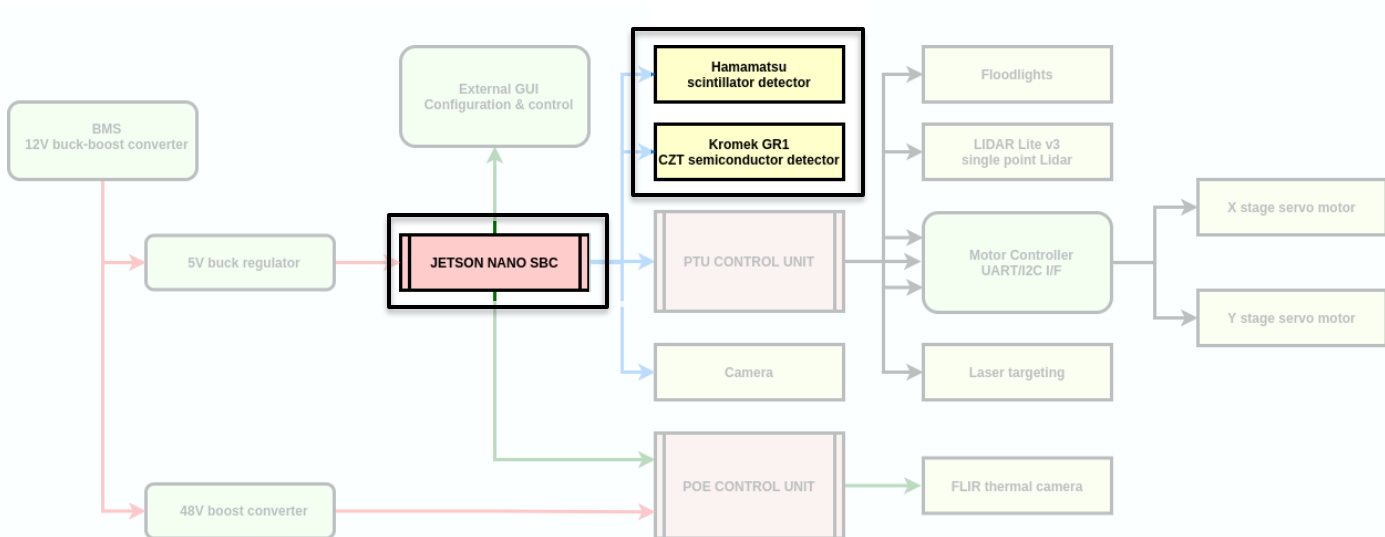
C12137-01



## Prototype Device - Overview:

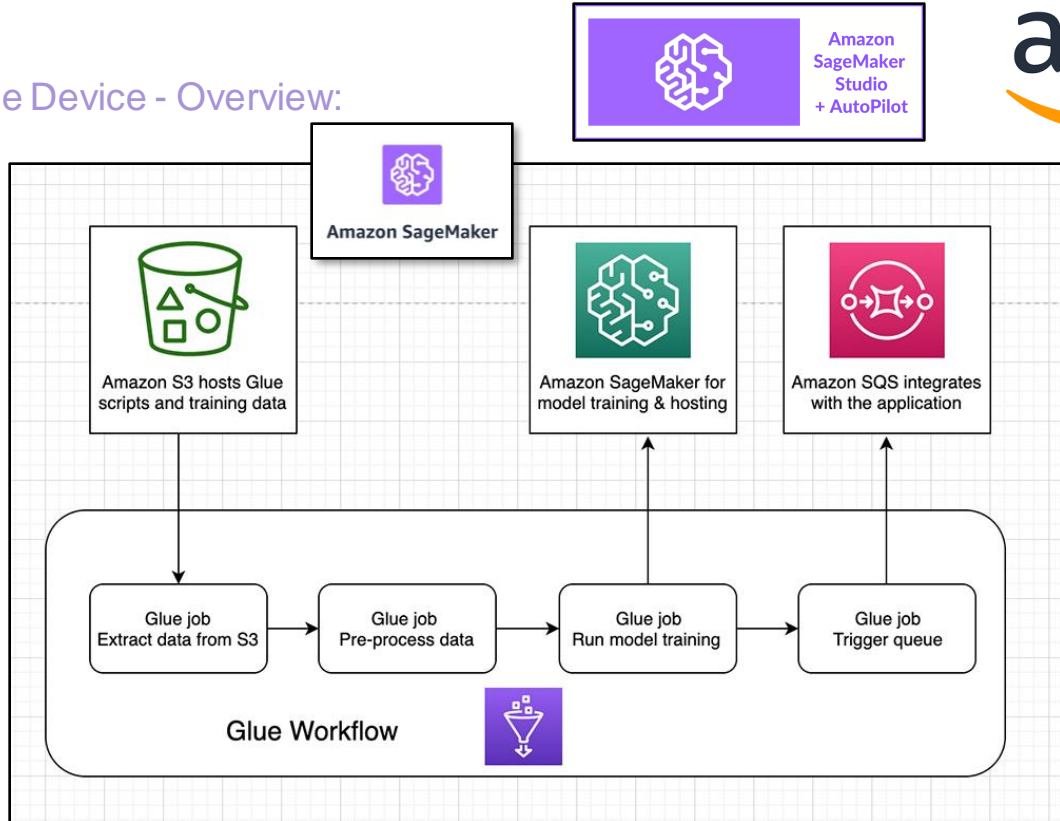


## Prototype Device - Schematic:

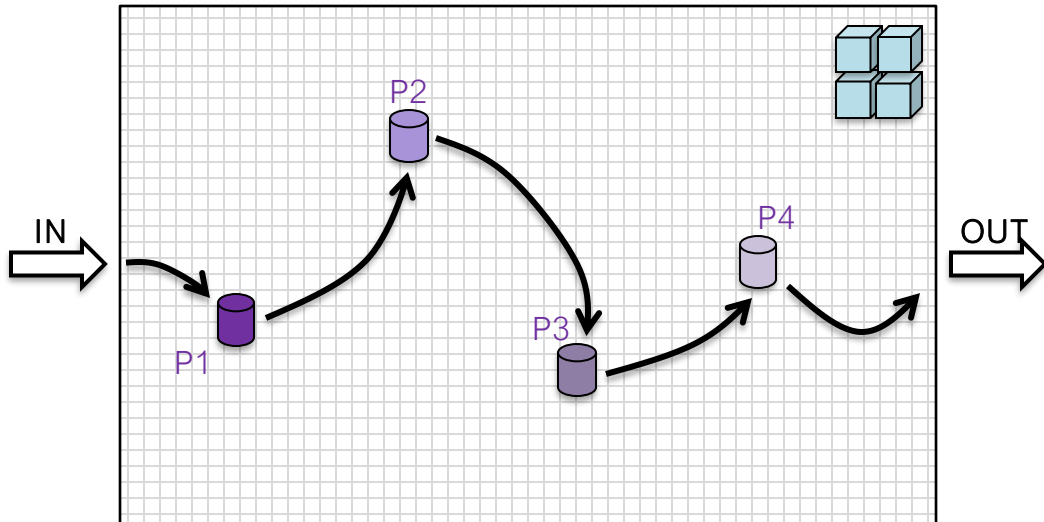




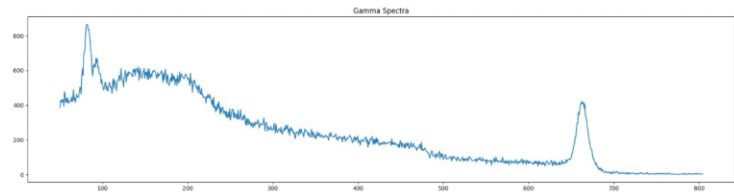
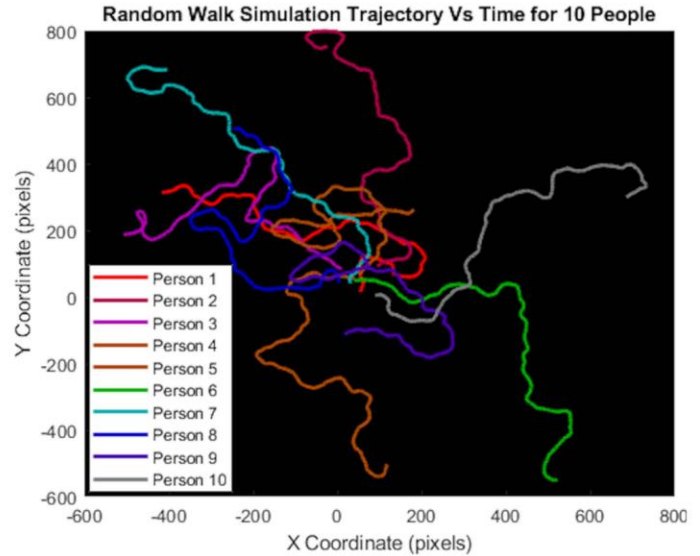
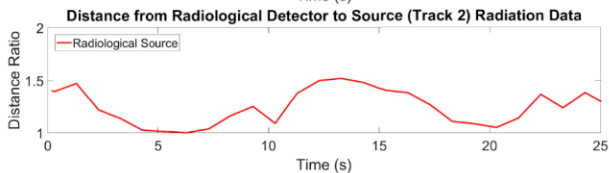
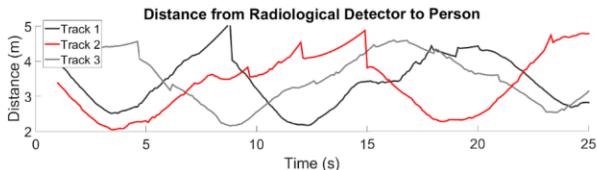
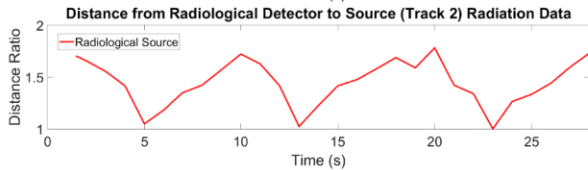
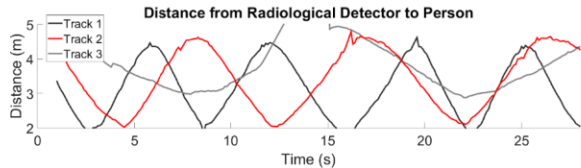
## Prototype Device - Overview:



## Modelling & Validation:



## Modelling & Validation:



Testing:

In-Progress...





## Testing:

