Application of the Imitec AARM radiation mapping system to mapping contaminated marshland areas

Imitec specialises in the manufacture of advanced radiation mapping solutions for the nuclear and mining industries with its Autonomous Airborne Radiation Monitoring (AARM) system representing the most advanced gamma-spectrometry based UAV mapping system in the world that is used over numerous US and UK nuclear sites on a regular basis and has been extensively deployed in the Chernobyl Exclusion Zone (CEZ).

The AARM system is an award winning and patented technology (**GB2511754**) that has several key defining technical features that together are unmatched by other competitors. The AARM system is more than just a radiation detector fixed to the bottom of a drone but instead is an advanced sensor system, integrating numerous radiation and positional sensors, powered by an intelligent internal battery management system and secure data transmission functionality to allow near real-time observation of radiation data as it is measured. The AARM solution developed to be agnostic of drone platform is a novel high sensitivity unit, that relays radiological information via cellular and local wifi connections between the AARM unit and the ground operator.

In the past 12 months the AARM has been used for survey work conducted by the University of Bristol with Sellafield and the UK National Nuclear Laboratory to map contaminated marshland areas to the south of Sellafield's Seascale site in Cumbria UK.

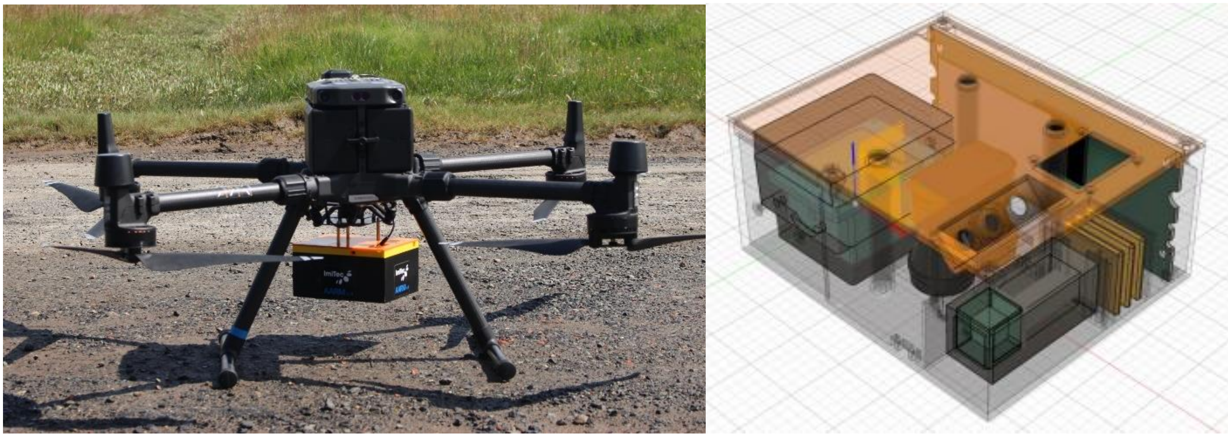

Figure 1. (left) The AARM unit mounted on a DJI M350 multirotor drone unit; (right) A 3D representation of the AARM unit, with its two gamma spectrometer sensor modules.

The AARM unit used for this task (**Figure 1**) was fitted with two gamma spectrometers in order to provide a large range of measurement and sensitivity. The first spectrometer was a Kromek GR1 module with 1 cm^3 CZT crystal, providing excellent energy resolution and ability to operate without saturation at higher dose levels. The second spectrometer was a Hamamatsu C12137-01 module with 36 cm^3 CsI crystal, providing enhanced detection sensitivity due to its larger detection crystal. The AARM was mounted on a DJI M350 multirotor drone unit, capable of flight times with the attached AARM of unit 40-45 minutes.

Surveys of the Ravenglass Salt Marshes

Sellafield Ltd have a duty to assess the off-site environment at locations where radioactivity legally discharged from legacy operations, could reside or accumulate due to continually changing natural processes. Currently, ground-based methods such as personal probe surveys or vehicle mounted platforms are utilised for monitoring mapping and sampling of sites like beaches and estuaries. While low-cost, simple to operate and fast to deploy, these approaches are time-consuming and inefficient when compared to now well-established aerial techniques such as unmanned aerial systems (UAS) equipped with radiation detectors.

When equipped with modern detector technology such as large volume solid-state scintillator detectors, this highly automated approach allows for regular repeat surveys and collection of monitoring data to be performed with little or no user input and with rapid transfer into geospatial tools for visualisation and processing.

Given the remote and difficult-to-access nature of the monitoring sites an opportunity to trial enhanced surveying methods, such as the AARM, would validate the potential for benefit to Sellafield Ltd., it's regulators, and to enhance public awareness of environmental assurance activities.

In collaboration with the University of Bristol the Sellafield mapping project sought to pilot the AARM monitoring approach at the Esk Estuary, over the Ravenglass Salt Marshes where radioactivity distributions have been identified as requiring further investigation. The successful implementation of this approach did not only yield the desired data at the estuary but demonstrated that it will save time and resource is in the future, by reducing the time, cost and complexity for the data collection process.

Additionally, the successful outcome from the mapping exercise further informs Sellafield future decisions regarding the adoption of UAS surveying systems across the organisation potentially replacing manual data collection entirely.

This work was reported in the Sellafield Ltd. annual R&D report for 2024, providing a substantial endorsement for the AARM technology (**Figure 2**).

Off-site environmental gamma monitoring

Sellafield Ltd have a duty to assess the off-site environment at locations where radioactivity, legally discharged from legacy operations, could reside or accumulate due to continually changing natural processes. Currently, ground-based methods such as personal probe surveys or vehicle-mounted platforms are utilised for monitoring, mapping, and sampling at sites like beaches and estuaries. While low-cost, simple to operate and fast to deploy, these approaches are time-consuming and inefficient when compared to now well-established aerial technologies, such as Unmanned Aerial Systems (UAS) equipped with radiation detectors.

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Given the remote nature of the monitoring sites, an opportunity to trial enhanced surveying methods could be of benefit to Sellafield Ltd, its regulators/ stakeholders, and enhance public awareness of environmental assurance activities.

In collaboration with the University of Bristol, this project seeks to pilot the UAS data monitoring approach at the Esk Estuary, where radioactivity distributions have been identified as requiring further investigation through analysis of data produced by the statutory Sellafield environmental monitoring programme.

Successful implementation of this approach would not only yield the desired data at the estuary, but also save time and resources in the future by reducing the need for manual input in the data collection process. Additionally, a successful outcome will further inform future decisions regarding the adoption of such systems across the organisation, potentially replacing manual data collection entirely.

Project
Environmental monitoring for public and stakeholder reassurance

Benefits
UAS monitoring allows improvements to radioactivity mapping within publicly accessible areas of West Cumbria. Such data is reported to the EA and reviewed by West Cumbria site stakeholder group and COMARE contaminations working group.

The use of a UAS provides significant safety and resource benefits over traditional manned surveys of the estuarine mudflats.

Current Status
This project is ongoing with initial surveys planned for Summer 2024.

Delivery Partners
University of Bristol

Contact Details
Dr Richard Hill, Dr Laura Newsome
innovation.team@sellafieldsites.com

NDA Grand Challenge Alignment

1. UAS equipped with radiation detector
2. Survey over the Ravenglass Estuary

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Figure 2. Research article from the Sellafield Ltd. annual R&D report 2024.

Numerous different areas over the saltmarshes were surveyed over the course of three days with the survey altitudes kept below 20m with a similar line spacing. This enabled the capture of very high spatial resolution data, to provide a very accurate representation of the distribution of radioactivity. **Figures 3** and **4** provide examples of some of the data collected.

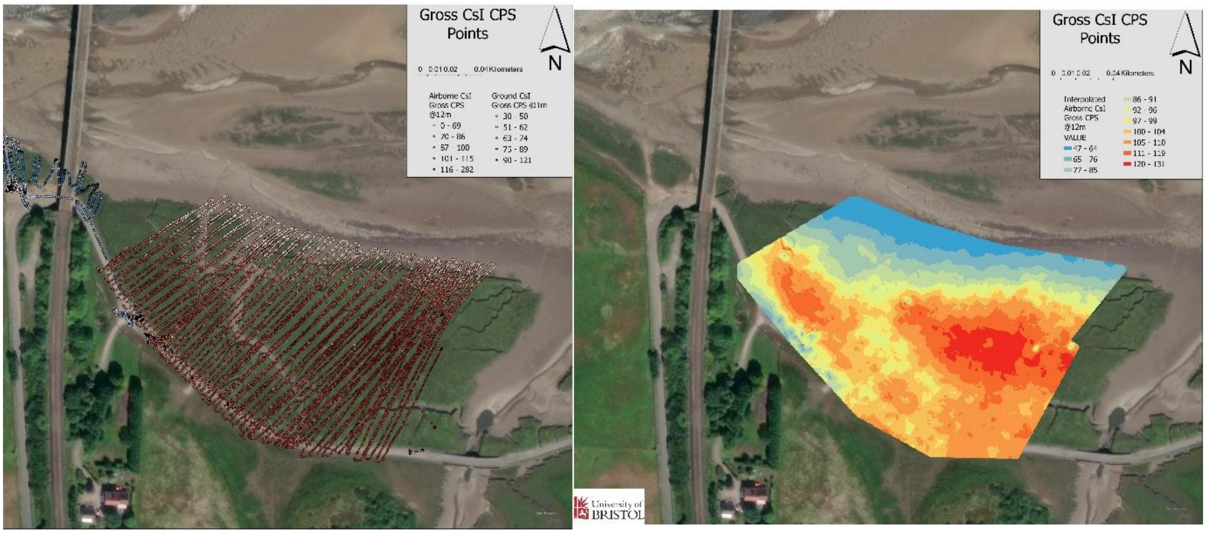

Figure 3. (left) Flight path for the AARM over an area of the saltmarsh, and (right) the corresponding counts-per-second interpolated radiation map.

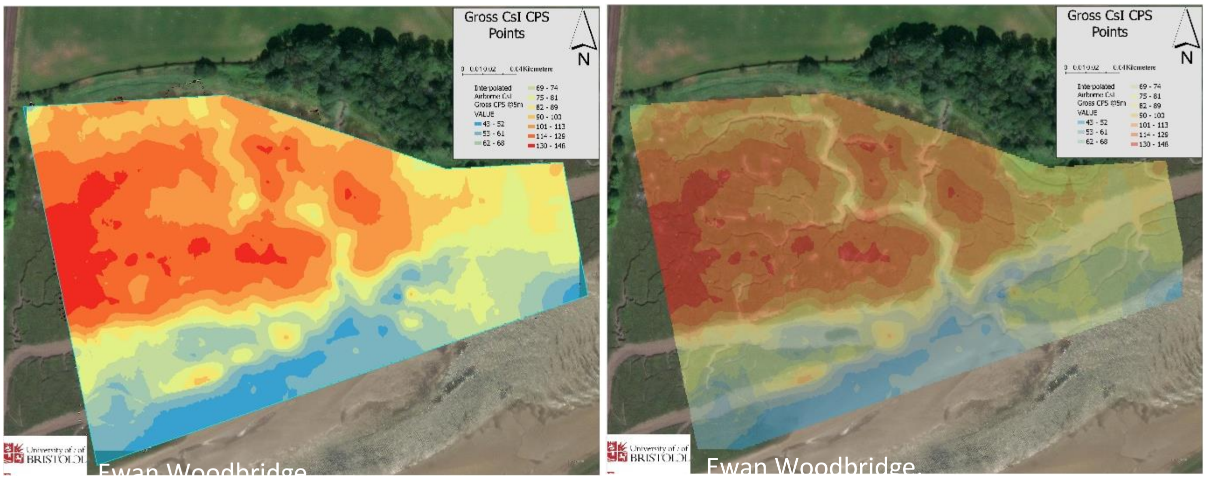

Figure 4. (left) Radiation map of an area of the saltmarsh, and (right) a modified transparency overlay showing the coincidence of low radiation areas with outlet channels.

The recorded data was processed using ArcGis Pro, utilising the software's Empirical Bayesian Kriging method to produce a series of interpolated radiation distribution maps. When compared with aerial photos (figures 3 and 4), it can be seen that lower levels of radioactivity correspond with channel areas and sandy margins.

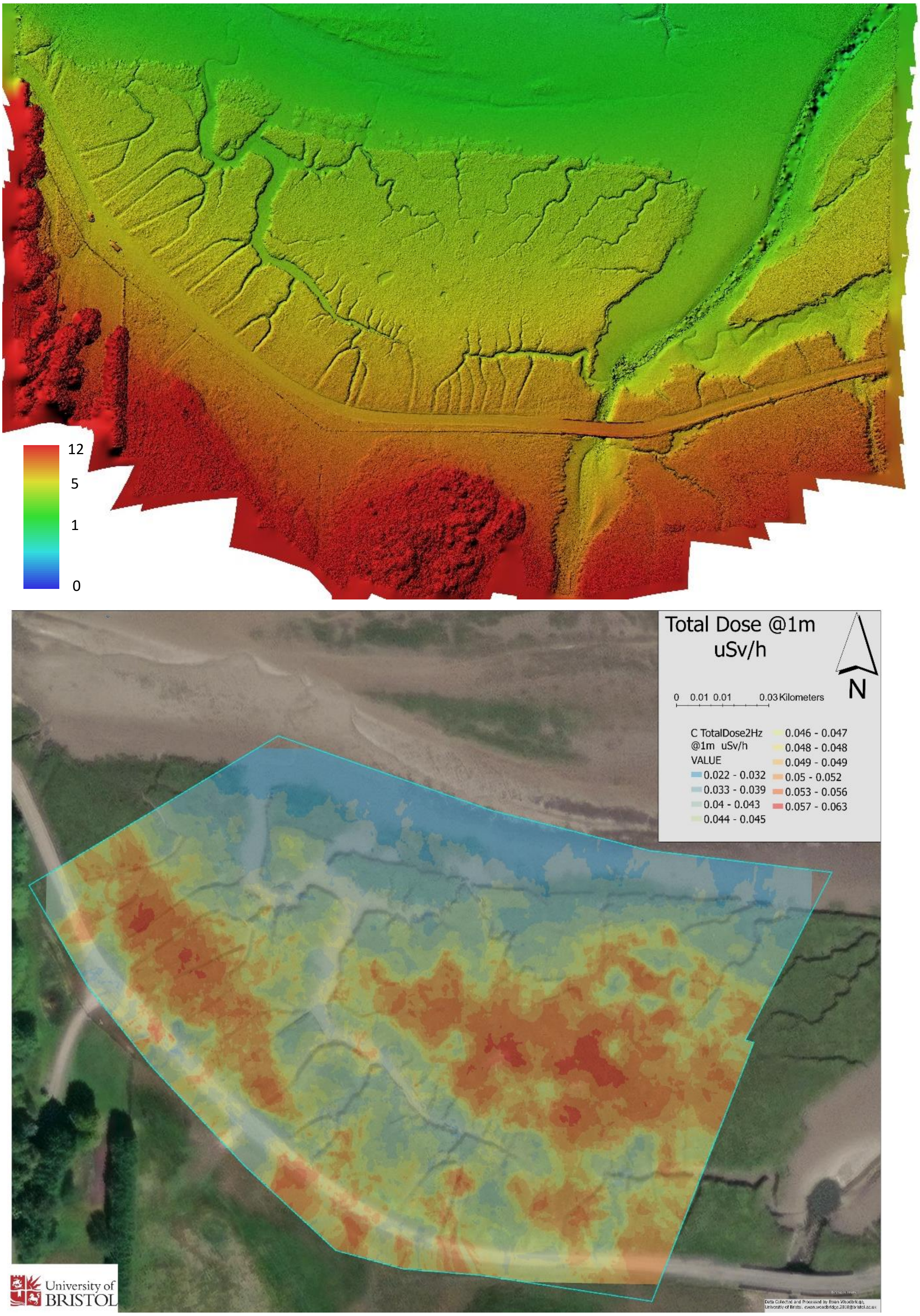

Figure 5. (top) DEM terrain model and (bottom) corresponding radiation dose map.

In conjunction with the aerial radiation mapping survey, photogrammetry flights were also conducted to create an image stack which was subsequently compiled and processed to form a 3-4 cm accurate digital elevation model (DEM). This terrain model, as shown in **Figure 5**, enabled the topographic structure of the saltmarsh areas to be analysed in detail, specifically highlighting the distribution of channels and outlets.

The summed spectral data for each flight was visualised and showed that the primary responsible gamma emitter was Cs-137, which is an anthropogenic fission product, and therefore not naturally occurring. The naturally occurring isotope K-40 was also detected in the collected spectral data, which is considered common for a saltmarsh where there are large amounts of evaporite salts present. **Figure 6** shows an example of the summed spectral data for one of the saltmarsh areas.

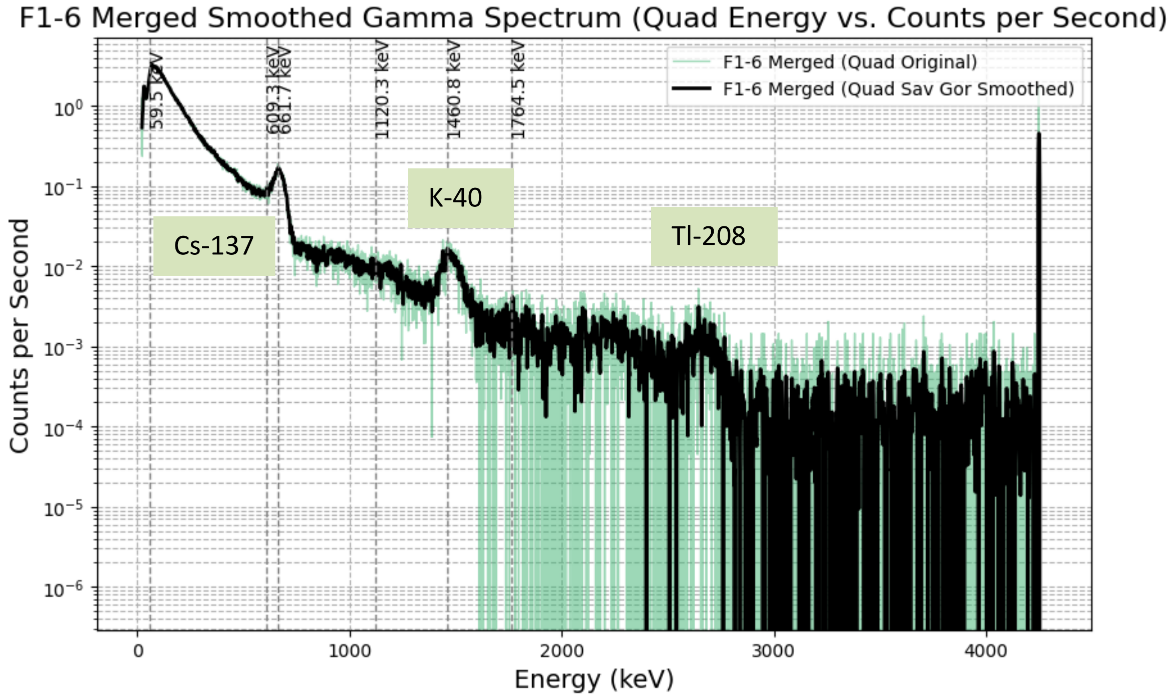

Figure 6. Area gamma spectrum collected from the saltmarsh area, showing the presence of Cs-137 and K-40 as the primary gamma photopeaks recorded up to 4MeV..

The maximum airborne detected dose in this study was 0.097 µSv/hr which closely agrees with values from recent ground studies, which recorded a maximum value of: 0.098 µSv/hr. This shows the excellent sensitivity of the AARM unit and its close comparability with equivalent on-the-ground monitoring.

When combined with the radiation data, it could be clearly identified that the major majority of the Cs-137 contamination was associated with elevated areas of the marsh rather than the discharge channels themselves. This was not an unexpected result given the historic releases from Sellafield site.

Advantages of the AARM versus other commercial offerings.

A number of key features stand the AARM system apart from the competition:

1) **Positional accuracy to enable accurate radiation dose determinations.**
In order to calculate on-the-ground radiation dose levels from measurements taken in the air it is essential that the height of the sensor system above ground is accurately known for each radiation measurement. The AARM achieves this using a downwards pointing laser ranging (LiDAR) system, with 120m range and centimetre accuracy. This allows real-time reporting of dose to the ground control stations.
Other positioning tools e.g. GPS and Barometry are unable to determine accurate height above ground for the sensor and hence, systems without a downwards facing LiDAR simply cannot (and do not) enable conversion of radiation counts-per-second (CPS) data into dose. Additionally, dose conversions can only be reliably made when a full gamma spectrum is recorded to determine the spectrum of gamma photon energies incident at any mapped location. Without gamma spectrometry the dose may only be crudely calculated from a series of energy assumptions.

2) **Real-time data viewing**
The AARM payload for the M300 transmits radiation data in real-time and allows visual association of radiation hotspots and anomalies with specific objects on a digital map or satellite image such as buildings or terrain features. This is very useful for situational awareness in the event of a nuclear incident. The AARM software provides live counts per second (CPD) data to the pilot (see section below on software) but can also be configured to transmit data to a central secure server for other responders and decision-makers to use. The software can also be switched to provide live dosimetry data, which is calculated based on an algorithms which combines the CPS with height-above-ground data received by the on-board LiDAR.

3) **Telling natural from man-made radiation**
The use of radiation mapping drones for routine monitoring and emergency response, ideally requires that the sensor system can distinguish between naturally occurring gamma radiation, such as that given off by rocks and minerals, versus radiation give off from man-made radiation sources which are typically distinctly different. This requires a gamma spectrometry system with a sufficiently wide gamma energy measurement range to capture both natural and anthropogenic gamma photons emitted from the ground. This is why the AARM system specified herein contains a spectrometer with an energy range from 30 KeV to 3.0 MeV, a range capability which is essential for such discrimination and not matched by alternative technology offerings. The substantial detector volume of the environmental-specific AARM units is x10 that used for nuclear industry surveys, enabling differentiation of naturally emitted gammas, which in turn enables fingerprinting of different rock types.

We understand that one of the specific requirements for the current training project is a system which has sufficient sensitivity and energy measurement range capability to discern natural from man-made radiation sources. Accordingly, we are pleased to offer an AARM version solution with integrated twin Hamamatsu CsI gamma spectrometers capable of measuring gamma photons of up to 3.0 MeV in energy and operable at temperatures up to 40 centigrade. This bespoke system includes a compact PCB design with RoHS and FCC certification, integrated LiDAR with increased 120m range, battery management, longer operating time and encrypted 4G GMS cellular data transmission.

Summary

The Imitec's AARM radiation mapping technology is ideally suited to both small- and large-area radiation mapping applications, including marshland areas. For applications in environmental and minerals mapping, the larger detector units required for mapping are readily available as part of the AARM offering and recommended for maximising detector sensitivity.

When advanced photogrammetry or LiDAR (laser) scanning is used in conjunction with the AARM, highly accurate and detailed 3D models of the terrain can be captured and integrated with the radiation data, to provide an enhanced understanding of radiation distribution and the location of any specific interest areas that can subsequently be studied in more detail.