High-Resolution Aerial Radiation Mapping for Nuclear Decontamination and Decommissioning

Peter G. Martin

Interface Analysis Centre, University of Bristol, Bristol, United Kingdom

University of BRISTOL

SOUTH WEST NUCLEAR HUB

Abstract

Unmanned aerial vehicles are now widely employed for numerous applications including defence, search and rescue as well as within scientific fields such as high-altitude atmospheric sampling and remote sensing. However, their application to the high-resolution detection of radiation anomalies (specifically as part of the routine monitoring on nuclear sites) has been less well explored. In this work, we present the results of the radiation monitoring via a lightweight aerial platform on an active nuclear site (Sellafield Ltd.); having already deployed the device in the Fukushima-contaminated region. The system employed was able to detect regions of elevated radiation at the sub-meter scale as well as attributing the species responsible. Such a system presents an extremely powerful tool where it is not desirable, nor practical, to send human operators. Results presented show that the platform is easily capable of operating within the challenging and confined settings of a site such as Sellafield (or other similar sites worldwide).

Introduction

Whilst much of the world is currently experiencing a nuclear renaissance with the construction of fleets of new power-generation facilities, challenges still exist at numerous other sites associated with both the decommissioning and long-term on-site monitoring of contamination and radiation levels respectively.

Detection Payload

The standard radiation mapping platform consists of a lightweight gamma-ray spectrometer (weight 80 g) comprised of a single 1 cm³ crystal of cadmium-zinc-telluride (CZT) semiconductor material (GR1 from Kromek™ Ltd.), alongside a single-point laser rangefinder for determining the height of the unit above the ground. Both of these are side-by-side mounted onto a 3-axis gyroscopically stabilised gimbal to ensure they remained normal to the ground during the operation of the system - regardless of any instability of the air frame.

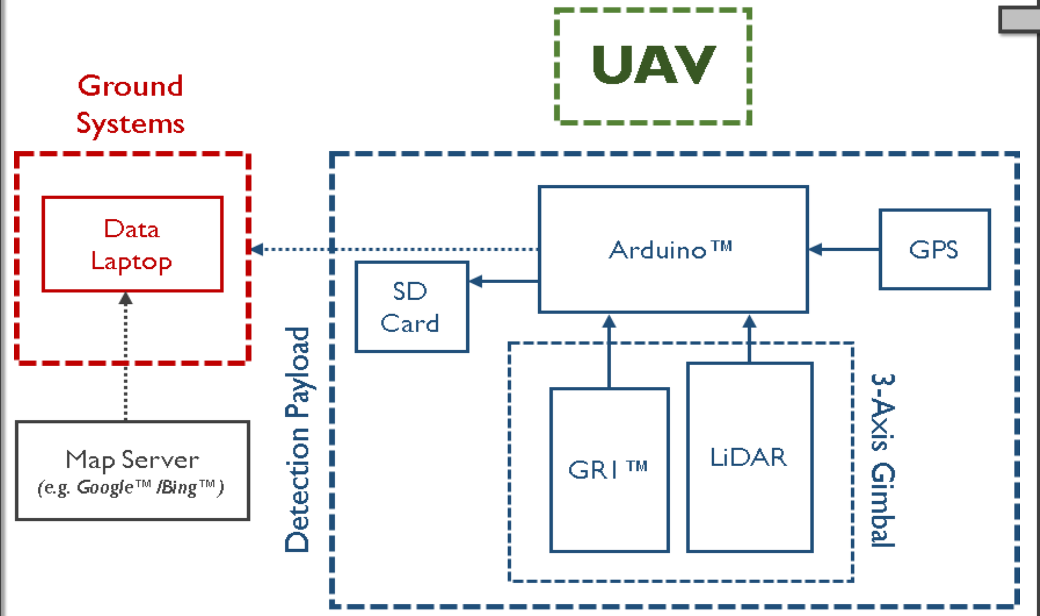


Figure 2: Schematic of the UAV system; consisting of the aerial (UAV) platform (green), detection payload (blue) and ground control system (red).

Unmanned Aerial Vehicle (UAV)

The UAV consists of an X8 configuration with motors and propellers mounted both above and below the platforms four arms. Operating on lithium-polymer (LiPo) batteries, the system, with a combined total mass of 7.0 kg, was capable of remaining airborne for approximately 30 minutes. During typical survey flights, an altitude of between 5 and 50 meters was maintained- depending on topography and local obstructions. The maximum attainable speed of the system is 50 km/hr, permitting the UAV to reach sites far from its initial position.

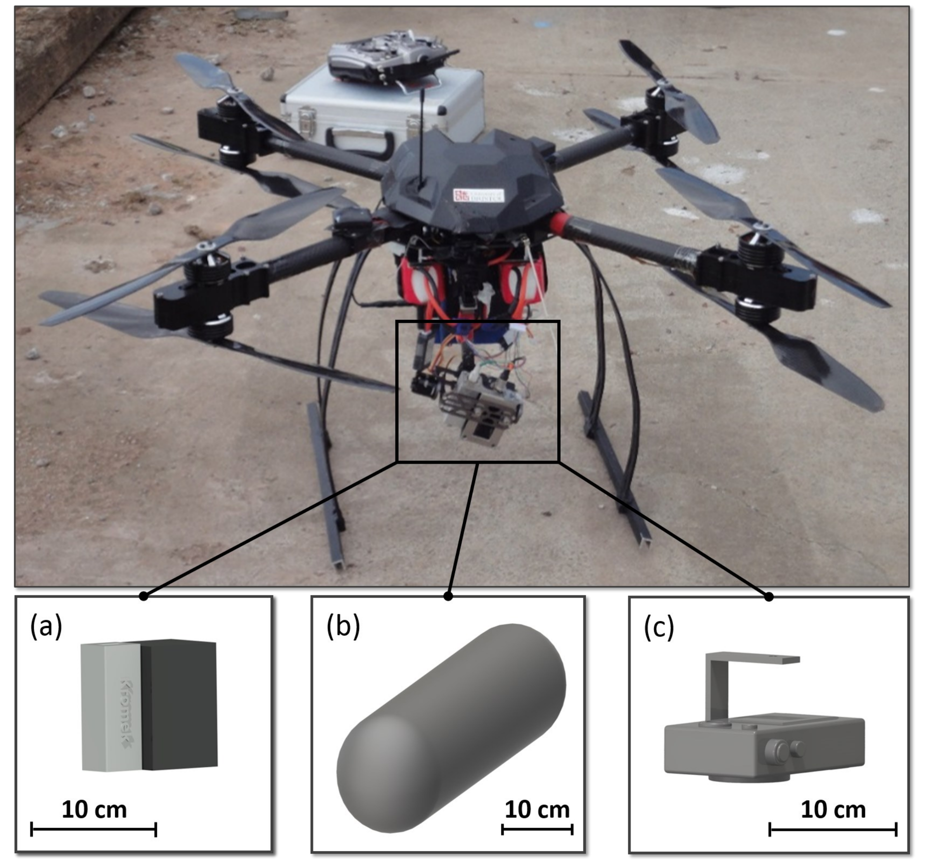


Figure 1: Schematic of the UAV system with interchangeable detection options of (a) combined gamma-spectrometer and laser rangefinder, (b) 3D-scanning LidarPod™, and (c) portable SLR camera.

Data Processing & Visualisation

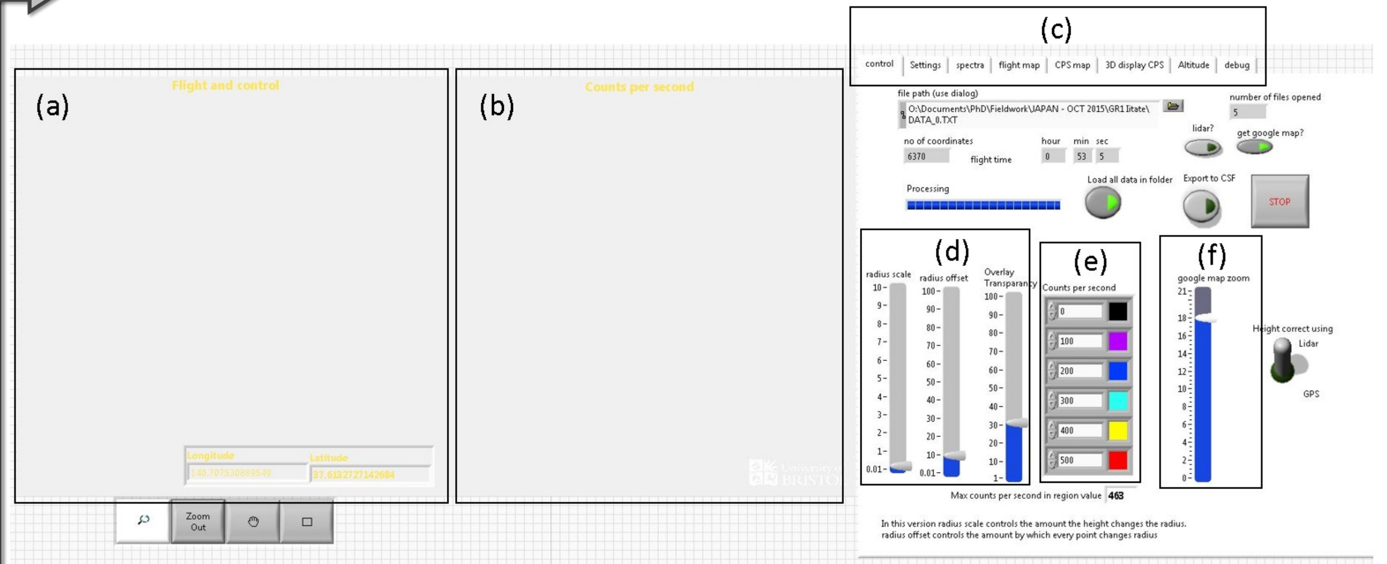


Figure 3: Screen-shot of the custom software produced; consisting of; (a) flight-path map, (b) radiation map overlain onto a base-map, (c) visualisation settings, (d) radius scaling options, (e) coloured scaling level and (f) 21-level map zoom level selection.

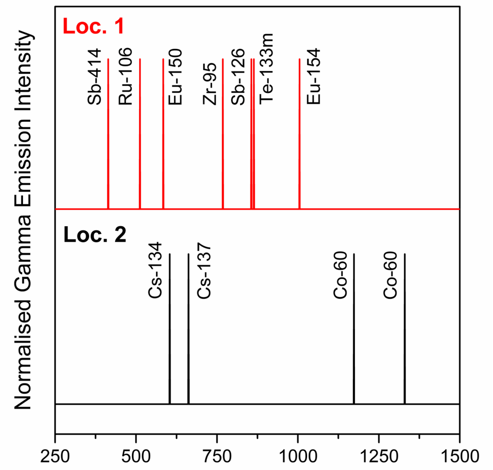
Software was produced to import the raw data, plotting the results as a scaled coloured overlay onto a georeferenced base-map. This software was also able to export the processed data to enable the results to be subsequently manipulated by third-party geospatial software platforms.

Study Site

Testing of the system took place at various locations on the Sellafield site. These locations included an Iso-Freight storage yard (**Loc. 1**) and a fission-product waste storage building (**Loc. 2**). Both represent a radiological hazard to those that would typically undertake routine monitoring.

Figure 4: The Sellafield Ltd. nuclear licensed site; a 6 km² area of the Cumbrian countryside which houses over 1,000 nuclear facilities on Europe's largest nuclear site.

Isotopic Fingerprinting



By employing gamma-ray spectrometers instead of Geiger-Muller based detectors, the contributing radionuclides can be identified by the over-flight of the UAV.

Figure 6: Gamma-ray spectra produced by the UAV from the radioactivity detected at the two locations.

Loc. 1

The radiation map of Loc. 1, the iso-freight storage compound, is shown in Figure 5 (a). At the time of the survey, five standard metallic containers were located at the centre of the site with their location illustrated below. As can be observed in the figure produced from the site; the location of the detected radiation is, as expected, seen to overlie the exact positon of the five containers. The dose-rate witnessed to be emitted from the top of the containers was calculated to be 25% greater than that detected by routine monitoring to come from the containers sides - a result of the packing strategy employed to limit potential radiation exposure.

Loc. 2

Similarly to Loc. 1, the radiation intensity map of Loc. 2 is shown below in Figure 5 (b). Again, the location of the structure containing the radiation source (the high-sided waste storage building) is marked. As can be seen within the figure, the radiation anomaly can be seen to exist, as expected, within the confines of the store. Alike to Loc. 1, care has been taken to ensure that the radiation level at the centre of the structure is greater than that around its perimeter. This is achieved through the placement of lower-activity material to induce 'self-shielding'. The detection of elevated activity over the roof of the building is a result of the lack of shielding.

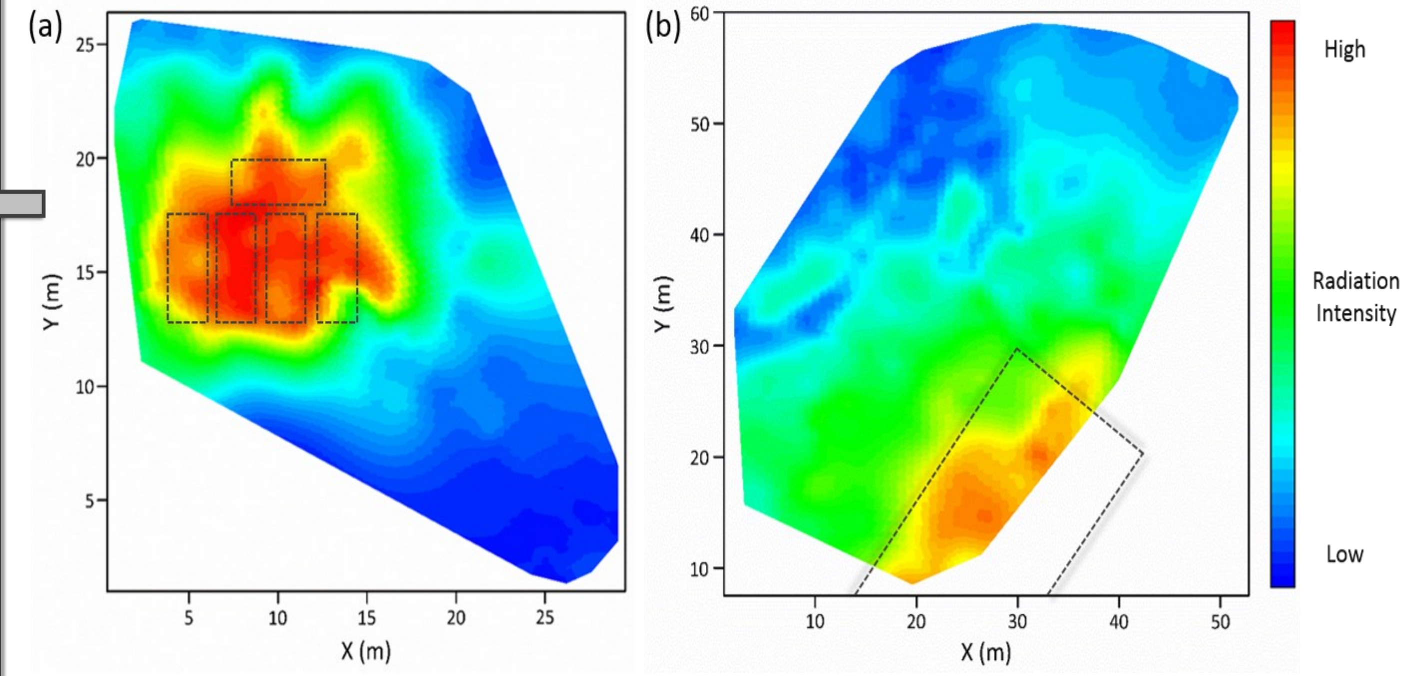


Figure 5: Radiation intensity maps produced of Loc. 1 (a) and Loc. 2 (b). The location of each of the contamination sources are evident from the heat-maps produced.

Conclusions

The demonstration of an unmanned aerial vehicle for autonomous radiation mapping has shown:

- *GPS positioning is not influenced by large buildings or structures on the site.*
- *Sub-meter resolution is attainable; comparable to that achievable via ground-based manual human surveys.*
- *The radioactive dose received by an operator is substantially reduced due to the need to not approach the active area.*
- *Difficult structures not easily accessible and locations with logistical issues can be assessed in a rapid period of time.*

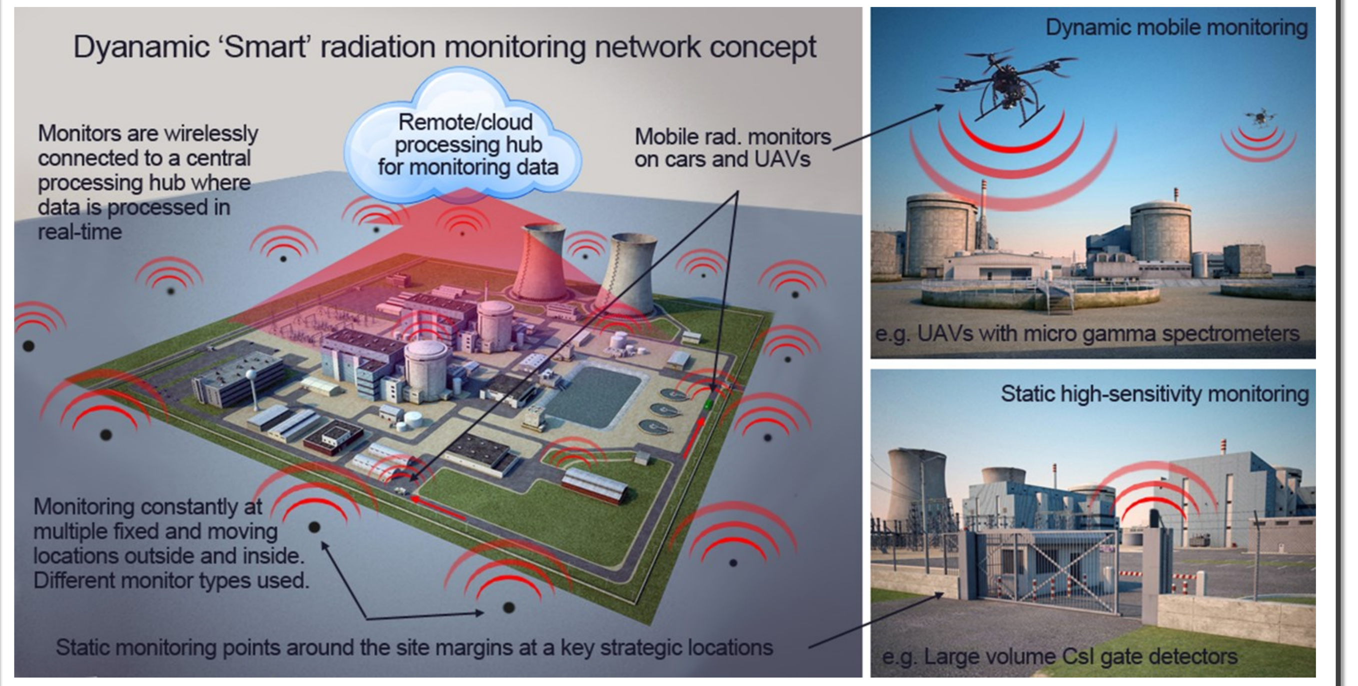


Figure 7: Potential application of UAV-based monitoring technology includes 'swarm' style systems whereby multiple aerial platforms operate fully autonomously to intelligently map an area without operator influence.

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