Low-altitude unmanned aerial vehicles for the rapid and high-resolution determination of contamination.

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Abstract

The 2011 events at the Fukushima Daiichi Nuclear Power Plant (FDNPP) as a result of the Great Eastern Japan Earthquake and ensuing tsunami released considerable quantities of highly-radioactive material into the global environment. This catastrophic release of radioactivity highlighted the need for a rapid and highly-spatially accurate means by which to determine the distribution of such contamination – not only in response to disaster-release scenarios but also for the potential application to wider monitoring following a nuclear dispersion incident, illicit material trafficking or as part of routine site monitoring. This work from the University of Bristol, launched in direct response to the incident at Fukushima, is the combined low-altitude multi-rotor unmanned aerial vehicle coupled with a lightweight radiation detection and mapping system. Via this system, it was possible to determine the spread of contamination with sub-meter resolution as well as attributing the species responsible. The use of UAVs represents an important tool in the remote sensing toolkit, with applications in areas in addition to radiological monitoring.

Introduction

In order to carry out radiological monitoring following contamination events, it has previously been necessary to undertake either the slow and labour intensive manual surveying of an area using humans on the ground or by utilising manned helicopters operating at high-altitudes. The former has the drawback of exposing those conducting the work to potentially significant levels of dose, although achieving the greater spatial resolution, whereas the manned helicopter surveys – despite exposing the operators to a lower dose, are only capable of achieving much lower spatial resolution at a much greater monetary cost of upkeep. The application of low-altitude unmanned aerial vehicles, as described in this work, represents a powerful surveying method within the "toolkit" for the analysis of contaminated environments alongside existing techniques – with a number of significant advantages *(Table 1)*.

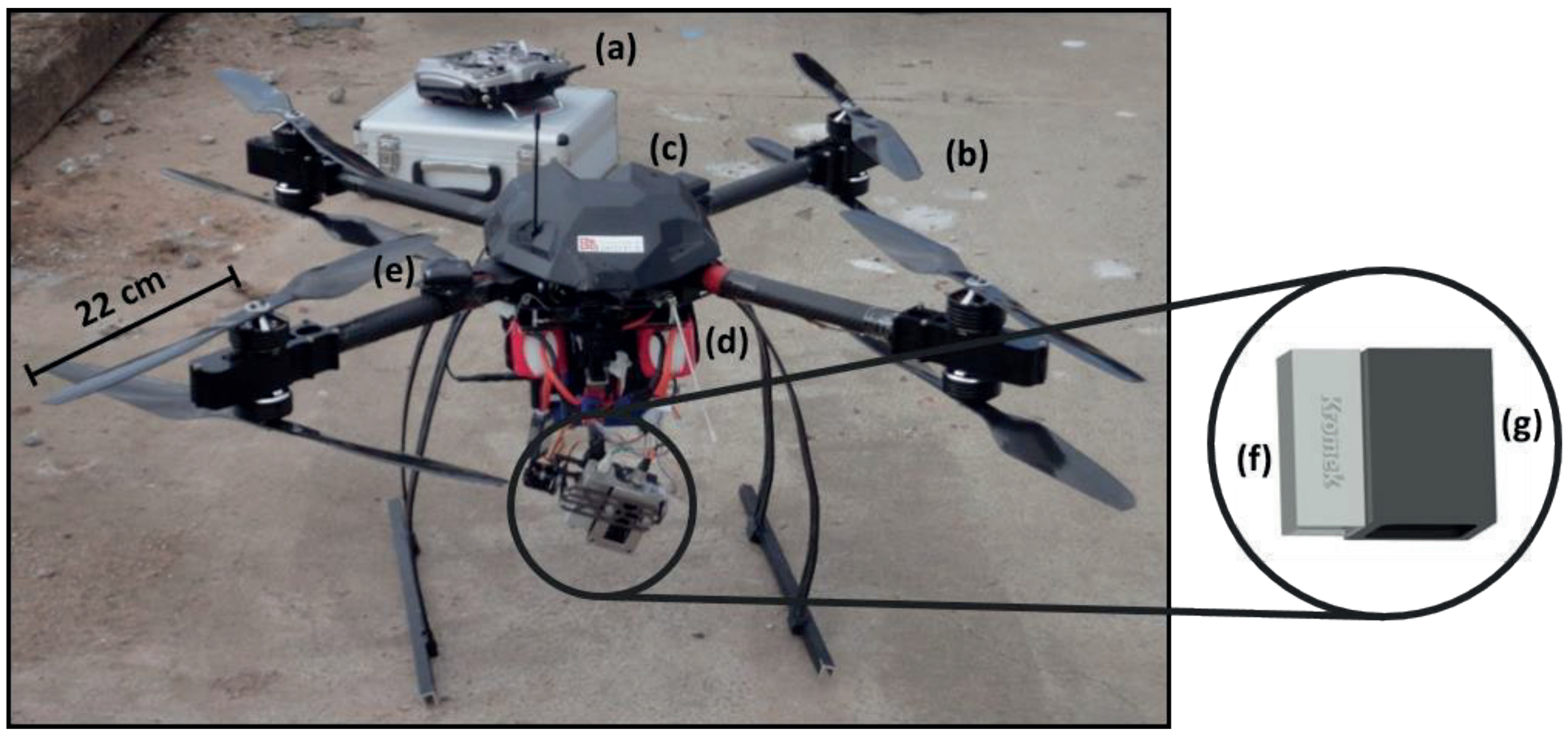

Fig. 1. (above) The UAV developed at the University of Bristol, as deployed at the Sellafield Ltd. site and in the area surrounding the FDNPP, consisting of (a) radio-controls, (b) counter-rotating propellers, (c) flight control electronics under protective cover, (d) LiPo batteries, (e) high-accuracy GPS unit, (f) micro gamma-spectrometer and (g) range-finder unit [both (f) and (g) are mounted on an actively stabilised gimbal].

Platform:	Cost	Dose to Operator	Spatial Resolution	Coverage	Data Availability
Manned Helicopter	High	Low -> Moderate	Low	High	Rapid
Ground-based	Low	High	High	Low	Slow
UAV	Moderate	Very Low	High	Moderate	Rapid

Table 1. Comparison of the different radiological survey platforms currently available.

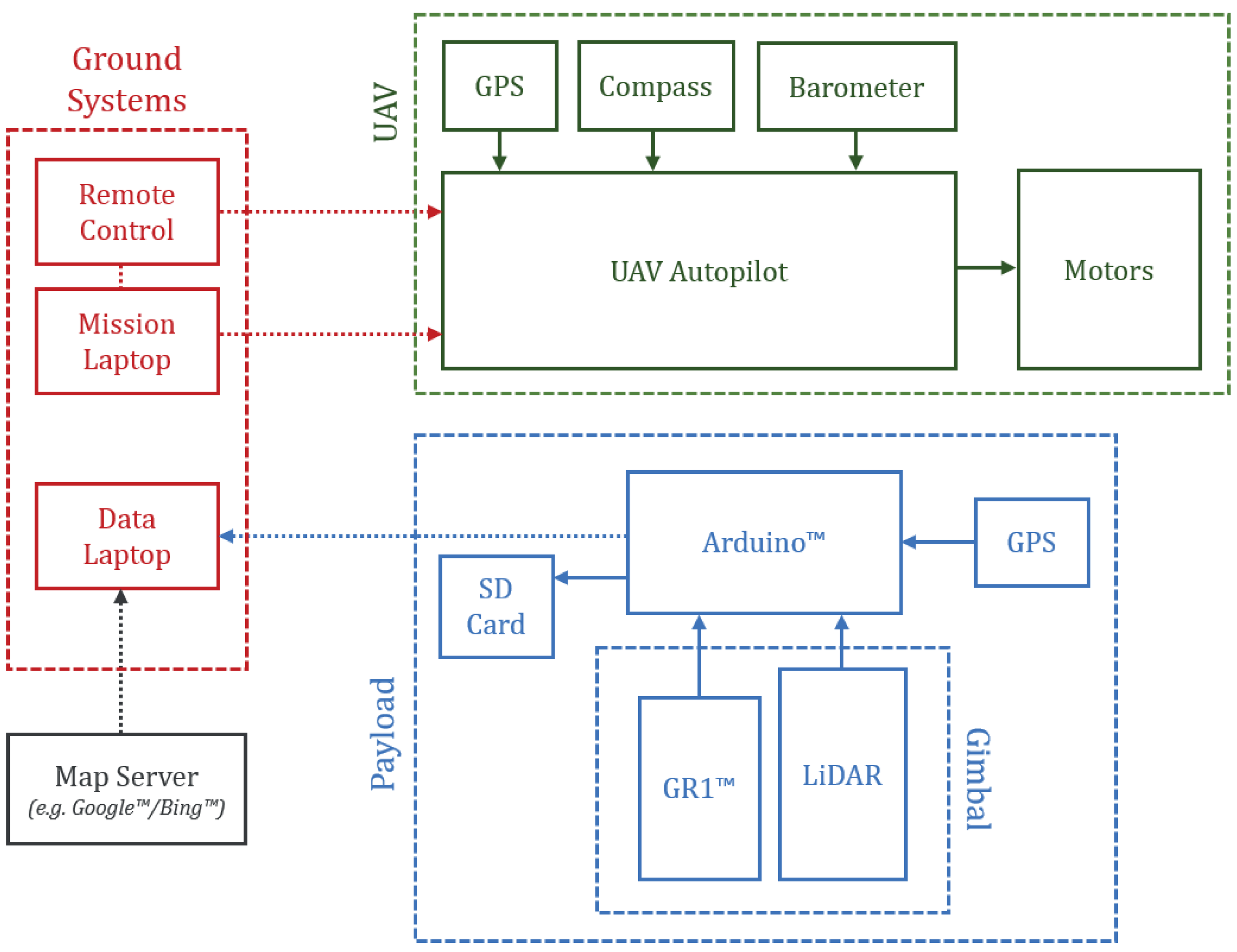

Fig. 2. (above) Schematic of the low-altitude unmanned aerial vehicle (UAV), comprised of the flight platform, the associated ground control systems and the attached lightweight detection payload.

The System

Utilising an X8 configuration, for improved in-flight stability and redundancy; the UAV is capable of performing autonomous radiation mapping flights of 25 minutes duration on its lithium-polymer batteries – at velocities of up to 40 mph. Using pre-programmed GPS waypoints, the system can operate out of the operators visual range as well as that of standard radio controls.

The associated detection payload was mounted to the underside of the UAV. It consisted of a lightweight gamma-ray spectrometer and single-point rangefinder unit (for height normalisation) – both mounted on a gyro-stabilised gimbal to ensure they remained normal to the ground surface. Coupled to a high-accuracy GPS unit, readings are stored locally on the device as well as being transmitted wirelessly via an encrypted datalink whereby the progress of the survey could be monitored in near real-time. The system has been employed on both the Sellafield Ltd. Site, the region surrounding the FDNPP as well as numerous radiological test sites within the UK.

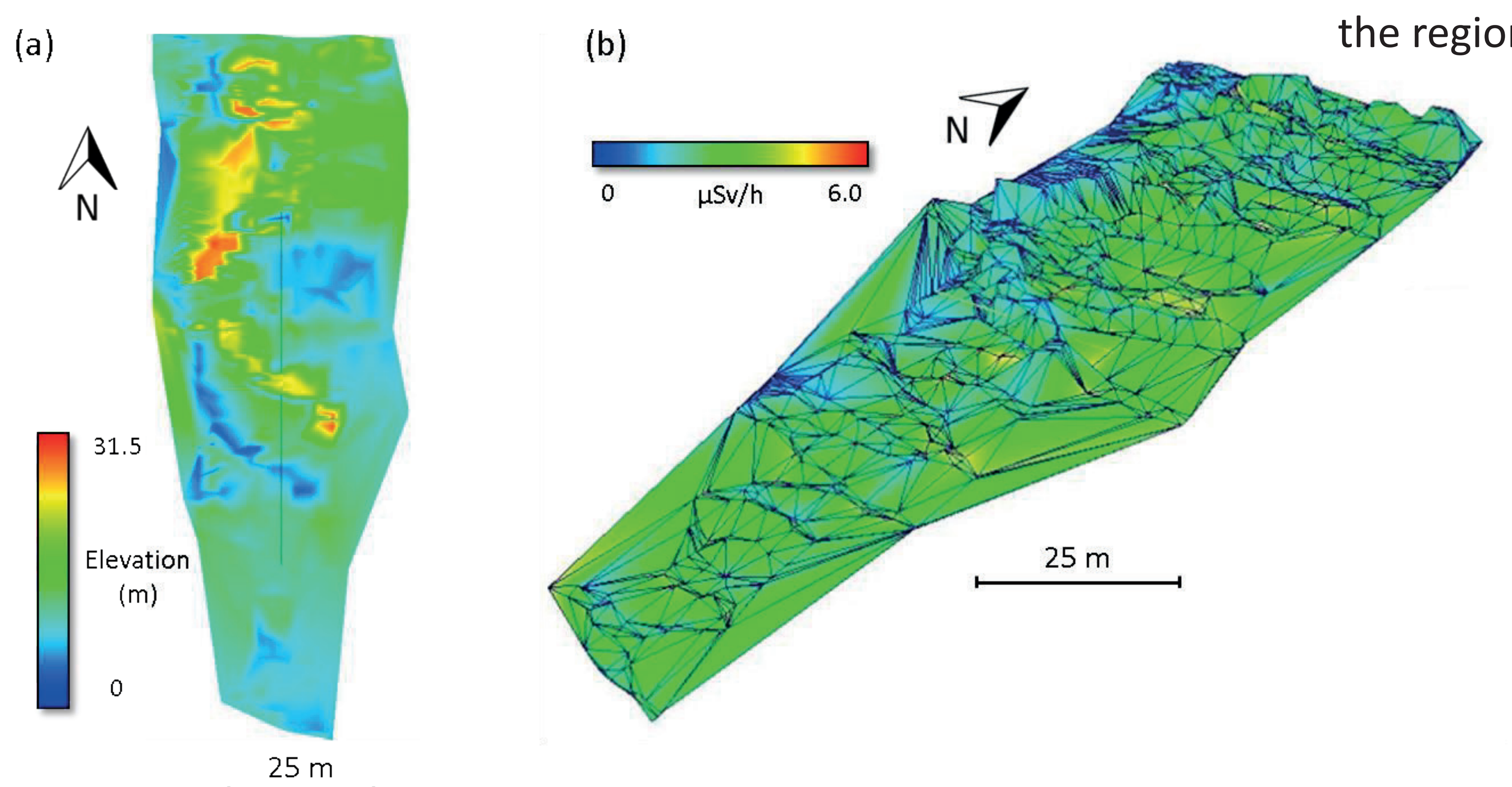

Fig. 3. 3-dimensional radiation survey generated by the unmanned platform. (a) detailed topographic map of a tiered site within Fukushima Prefecture and (b) a triangular irregular network (TIN) overlain with the contamination measurements obtained.

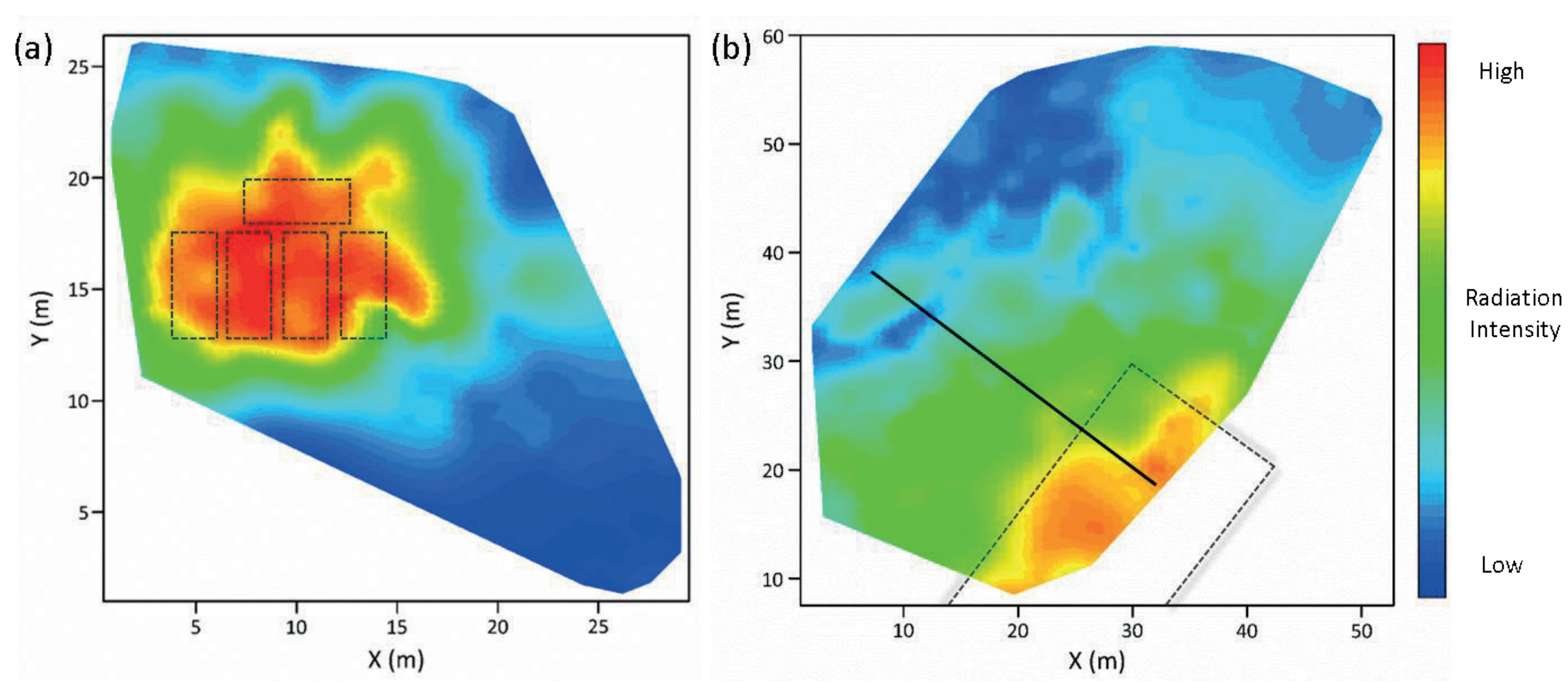

Fig. 4. Radiation anomaly maps produced from two areas of the Sellafield Ltd. site, (a) an iso-freight storage yard [the locations of the 5 containers is illustrated] and (b) the corner of a fission-product waste storage facility [the outline perimeter of the structure is marked].

Conclusions & Future Work

The use of such a rapid and high spatial resolution mapping system developed at the University of Bristol, presented in this work, has applications not only following the release of contaminant material after events such as at the Fukushima Daiichi Nuclear Plant or within routine site monitoring - but for defence or in the aftermath of malicious dispersal events. As a platform, the UAV has the potential for deployment with a range of other sensor types for wider detection and monitoring applications.

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