Unmanned aerial vehicles ("drones") as tools for small scale radiometric surveys

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BfS-UAV View project
Unmanned aerial vehicles (“drones”) as tools for small scale radiometric surveys

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ABSTRACT
An UAV has been developed by the Federal Office for Radiation Protection (BfS) and tested in the Chernobyl exclusion zone in September 2016. A commercially available hexacopter has been equipped with a 1.5 cm³ CZT gamma spectrometric detector (µSPEC), GPS, data processing unit (Raspberry PI with Linux) and Wi-Fi for data transmission to the ground base. Optionally a camera can be carried. The system records gamma dose rate every 2 seconds and gamma spectra every 10 minutes.

The total cost of the system is significantly below 10k€ which includes the detector (6k€), data acquisition system (0.2k€) and the UAV (1.2k€). The system is very mobile, easy to set up and to operate in the field. Results are plausible and easy to interpret, spatial resolution of the gamma dose rate on the ground is surprisingly high.

Measurement results from the Chernobyl exclusion zone show that the sensitivity of the detector allows radiation survey in areas where the dose rate level is above 0.3 µSv/h. Limitation of the small system are the relatively short operation range of a few 100 m and the lack of an altimeter to assure constant flight altitude above ground. Among the results of the exercise were that a high gamma dose rate gradient in the field can be well identified and the observation that the measured gamma dose rate depends relatively little on the flight altitude between 3 and about 15 meters above ground, for a large scale contamination field.

As a conclusion, the use of UAVs for radiometric surveys is a promising and viable complement to traditional air-borne reconnaissance for small areas, and an alternative to ground-based surveys in case of high radiation levels or difficult access.

Keywords: Unmanned aerial vehicles (UAV), radiation survey, low cost UAV system, Chernobyl, measurement.
1. INTRODUCTION

A small scale UAV to measure radioactivity in the field with a maximum weight below 3 kilograms has been developed by the German Federal Office for Radiation Protection (BfS) under the premise of a cheap and robust system to measure radioactivity in high contaminated areas. Construction was straightforward, with total cost of the system significantly below 10k€, which includes the detector (6k€), data acquisition system (0.2k€) and the UAV (1.2k€). Using another detector, e.g. the Radeye, the price of the complete system is significantly below 5k€. The system is very mobile, easy to set up and to operate in the field. The UAV has the advantage over ground based measurements like by cars or by foot that it is deployable also in rugged terrain and in highly contaminated or otherwise difficult to access areas. The small scale UAV has a range of about 250 meters in each direction. Thus an area of about 0.25 km² can be scanned under optimal conditions with the UAV in a short time. Using an automatic flight control system in a well visible area e.g. without high trees, the range can be doubled. The UAV is an optimal supplement for ground based measurement as well as for aerogamma tasks.

2. MATERIALS AND METHODS

The BfS uses the UAV with a detector for radioactive surveys and source detection. It is composed of the following parts:

UAV: DJI Flamewheel F550 hexacopter with a maximum flight time of 15 minutes with one pack of batteries. For radio control the Spektrum DX6 has been chosen. For the automatic flight modus, a DJI ground station is in use.

Detector: Ritec µSPEC, CZT quasi-hemispherical detector with a crystal size of 1500mm³. A possible alternative to this one is the GR1 Kromek detector also equipped with a CZT e.g. used by MacFarlane et al. (2014) or a Radeye detector with a NaI crystal used e.g. by the Police in Berlin, Germany.

Data logger: Raspberry Pi 2 Model B, CPU: 900MHz quad-core ARM Cortex-A7 CPU, 1GB RAM, WiFi USB-stick, additionally uninterrupted power supply, optionally LTE stick. Power supply comes from the UAV rechargeable batteries.

GPS: A Blox NEO-7M GPS mouse for GPS/QZSS, GLONASS position determination has been chosen because of light weight and small size.

Data communication: A standard smart-phone establishes a WiFi network for the Raspberry Pi, a tablet and a laptop. WiFi range is about 100 meters, the system immediately reconnects the network in case of interruptions. A tablet can be used to see actual live status of measurements, data connection to BfS database and to the back-office is established via the smart phone using ftp. Alternatively, a LTE stick can be
installed, then the UAV establishes the local WiFi. The data transfer is configurable, standard transfer rate is once per minute. The data is stored additionally on Raspberry Pi in a MySQL database for offline data evaluation.

**Software:** Software that combines measurement from detector and from GPS, checks the incoming data, checks status of the system, handles user interfaces (status LED, beeper, web-interface) and initiates data transfer, is written in C and has been developed by BfS in-house. Beside the Ritec µSPEC CZT detector, three other detectors (Radeye, Automess probe and BfS GDR-probes GS05-GS08) are supported. The software is also in use in the BfS backpack systems and in handheld bags for mobile ground and car based measurements. The web-interface shows online data in a map view, a time series as well as in form of a table including actual status. The BfS Cockpit (Luff et al. 2014) is installed additionally as an interface to see and export historical data from the internal database on a map background for offline data validation in the field.

**Energy supply:** To be able to use the UAV system over several hours, a one kilowatt gasoline generator is in use. Several charging stations for the main rechargeable batteries allow a permanent operation.

### 3. RESULTS AND DISCUSSION

The UAV with the detector has been used and tested in the Chernobyl exclusion zone in September 2016. During the measurement campaign, the hexacopter was equipped either with a 1.5 cm³ CZT gamma spectrometric detector (µSPEC) or optionally with an action camera. A three minutes film has been compiled from the three camera flights (Luff et al. 2016) in the exclusion zone. During measurement flights the system records the gamma dose rate every 2 seconds and saves a complete gamma spectrum every 10 minutes.

The gamma dose rate measurements in the heavily contaminated area of the “Red Forest”, about 4.5 kilometers west of the reactor, showed gamma dose rate values of maximal 40 µSv/h. This area has been used to compare the data from the UAV with ones acquired by a calibrated automess probe, both in an altitude of one meter above the ground. This comparison demonstrated that the UAV measurements are plausible, especially for higher (> 0.3 µSv/h) dose rates. Moreover it showed that the measured gamma dose rate depends relatively little on the altitude between 3 and about 15 meters over a large scale contamination field. The spatial resolution of the gamma dose rate is surprisingly high. The detector could even detect the lower gamma dose rate values above the asphalt street in the measurement region during the flights (see Figure 1). Such variable gamma
dose rate patterns could also be detected by Martin et al. (2016) in the Fukushima area with their UAV.

**Figure 1:** Gamma dose rate in the area “Red Forest” as raw data over natural ground and interpolated. The asphalt street is clearly visible in both pictures due to the lower gamma dose rate values above the asphalt.

The 10 minutes gamma spectrum of this flight, shown in Figure 2 displays a significant Caesium-137 peak at channel 810. It also demonstrates the limited resolution of the chosen detector. Anyway a first raw nuclide determination is possible with the dataset.

**Figure 2:** Gamma spectrum from the μSPEC detector at the site “Red Forest”
The other investigated areas show significantly lower gamma dose rates. At the site Kopachi, about 5 kilometers south of the reactor, the measurements yield gamma dose rate values between 0.5 and 1.5 µSv/h. Also here, a high spartial variability in the gamma dose rate could be found. At the third site, Buryakovka, about 12.5 kilometers west of the reactor, the UAV was used for a rough inspection of the site. During the exercise, a groundborne survey was performed by BfS staff screening the area on foot carrying hand-held or backbag dose rate monitors. The area around Buryakovka is characterized by a strong gamma dose rate gradient. For identification of the geometry of that gradient, a star shaped pattern has been chosen for the flights. The gradient showed gamma dose rate values between 2.8 and 6.5 µSv/h over a distance of about 250 meters. The results of this first examination where taken into account for planning in detail where the ground based measurements should later be performed.

4. CONCLUSION

As a conclusion, use of UAV’s for radiometric surveys and source search is a promising and viable complement to traditional air-borne reconnaissance for small areas, and an alternative to ground-based surveys in case of high radiation levels or difficult access. Especially the low acquisition and the low deployment costs demonstrate the advantage against aerogamma measurements in small areas. Due to their low price, it is possible to deploy several UAV’s at the same time. This will
reduce the overall measurement time and in case of technical problems, would the continuation of the mission with the spare UAV’s. The easy technique of a modern UAV can even be handled by staff or scientists who do not use it on a daily basis.
REFERENCES

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