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A UK Civil Aviation Authority (CAA)-approved operations manual for safe deployment of lightweight drones in research

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ABSTRACT
The academic literature of late is rich with examples of lightweight drones being used to capture data to support scientific research. Drone science is a blossoming field, but alongside a long-standing public concern about drone safety, the research community and our collaborators are increasingly calling for a ‘code of best practice’ for researchers who fly drones (no matter how small). Researchers who have long enjoyed the freedom of operating separately from ‘hobbyist’ and ‘commercial’ operators are now finding that their institutions and collaborators are demanding evidence of operational competence. In the UK, such competence can be formally accredited by obtaining a UK Civil Aviation Authority (CAA) ‘permission for aerial work’ (PfAW). Part of this process requires that the operators produce an ‘operations manual’ (OM) – a lengthy document explaining protocols for safe drone deployment, alongside maintenance and flight records. This article provides the frontispiece to an OM produced as part of a successful PfAW accreditation process. We share our OM, which is available as supplemental material to this article, in the spirit of research as a collaborative endeavour, with the aim that it will assist others facing the same stringent checks as ourselves, whilst also serving as a guide to safe flying that can be adapted and adopted by others.

1. Introduction
Lightweight drones, now widely used in environmental science research, are variously referred to as unmanned or unpiloted aerial vehicles (UAVs) or systems (UASs) or remotely piloted aircraft systems (RPAS). In this article, we refer to such aircraft systems as RPAS and drones interchangeably, but in all cases we restrict definition to lightweight platforms, in our case with a take-off-mass not exceeding 7 kg.

There are a plethora of scientific projects now utilizing lightweight drones as data collection platforms, servicing a diverse range of civilian, scientific, and remote-sensing applications. Recent examples of such drone use in ecology include surveys of: marine...
fauna (Hodgson, Kelly, and Peel 2013), vegetation structure (Cunliffe, Brazier, and Anderson 2016; Dandois, Olano, and Ellis 2015), biodiversity (Getzin, Wiegand, and Schöning, 2012), and wildfires (Merino et al. 2012). In geoscience research, drone-based data collection is increasing, largely because drones can capture data for ‘structure-from-motion’ photogrammetry (Westoby et al. 2012), which is useful for erosion studies (D’Oleire-Oltmanns et al. 2012; Kaiser et al. 2014), and for quantifying glacial dynamics (Ryan et al. 2014), to provide just a few examples. Indeed, this article is published in a special issue of the *International Journal of Remote Sensing* devoted to the use of drones in scientific research and environmental monitoring (volume 38, pages 2737–2744).

DeBell et al. (2015) chart the rise of the drone in environmental science publications, showing an exponential rise in the number of papers published on this topic in the past decade. This trend of increasing usage is likely to continue, as the capabilities and applications of these systems continue to develop and the cost of hardware decreases (Anderson and Gaston 2013; Sandbrook 2015). The expansion in drone use has led to a growing number of works that highlight the need for a safe operational protocol for drone deployment. Some papers have already sought to determine the effects of drone disturbance on wildlife (e.g. Pomeroy, O’Connor, and Davies 2015; McEvoy, Hall, and McDonald 2016) but most recently, work by Hodgson and Koh (2016) states that, ‘there is a need for a code of best practice in the use of UAVs to mitigate or alleviate risks’ to third parties. In the context of biological research, this relates primarily to disturbances to wildlife, but such consideration should be given also to safe operations and minimizing disturbance in a wide variety of settings. Sandbrook (2015), writing about drone use in conservation suggests that, ‘little attention has been given to their possible social impacts’ whilst Hodgson and Koh (2016) define the need for work that improves the suitability of drones ‘as a low impact ecological survey tool’.

Drones look set to play a continued key role in underpinning scientific survey methodologies. With a large international research community now using drones for good purpose the time is ripe for that same community to demonstrate the spectrum of opportunities that this technology can deliver, so as to counter the popular view that drones are simply an operational and social nuisance and/or threat, (including a military or terrorist). We also argue that a rigorous and carefully designed protocol for drone deployment within the sciences is useful if researchers are to be able to demonstrate competency, safety, and reproducibility of drone operations. A simple step towards this (for all drone operators including scientists) is to follow agreed procedures such as may be set out in an operations manual (OM) for all flights. Doing so enhances awareness amongst the community of optimal operational procedures, and builds trust amongst colleagues and collaborators that operations are conducted within safe limits and to exacting standards.

As UK-based researchers utilizing lightweight (sub-7 kg take off mass) drones, we have enjoyed a period of relative freedom where we were able operate under a separate banner from ‘hobbyist’ and ‘commercial’ aerial operators. However, in the past 2 years, we have noticed an increasing number of our collaborators requesting paperwork that provides evidence of our competency to fly, and the airworthiness of our drones. For some research projects, it has become impossible for us to secure permission to fly without providing evidence of accreditation from the UK Civil Aviation Authority (CAA),
despite the sites concerned being uncongested and low risk. Examples have included remote upland moorland sites and areas of lowland rough grassland, hundreds of metres from roads and buildings (and thus uncongested according to the UK CAA’s definition), but where the landowner(s) expressed a concern about the use of drones for environmental survey. In response, our research group (comprising the authors) has completed a full accreditation being issued with a ‘permission for aerial work’ (PfAW) being granted by the UK CAA, for a period of 12 months. Once this accreditation was granted, we found it easier to negotiate with cautious landowners who were then more willing to grant permission for us to fly over their properties. Note that academic drone operators should not normally require PfAW to fly within uncongested areas in the UK (see Section 2), but they do require the landowner’s permission to fly.

The purpose of this intentionally short manuscript is to provide an introduction to the OM that we produced as part of that accreditation process, and which was formally approved by the UK CAA in August 2016. This OM is deposited as supplemental information (SI) related to this article (as both .pdf and .docx formats). In what follows in the article, we provide a basic background to airspace regulations, scientific research and permission to fly drones, and the UK procedure for obtaining PfAW, so that readers of this article can understand the framework within which the shared OM sits.

2. Airspace regulations

Civilian airspace in many countries of the world is regulated by National Aviation Authorities (NAAs), for instance the CAA in the United Kingdom. A directory of NAAs can be found at the World Aviation Reporting Authorities website (http://www.airlineupdate.com/content_subscription/authorities/country_index.htm). Use of civilian airspace must be authorized by the relevant NAA for all air users, including unpiloted aircraft, and airspace regulatory frameworks are evolving rapidly to cope with the expansion of civilian drone technologies (CAA 2014a, 2014b, 2015a; FAA 2015a, 2010, 2015b, 2013, 2012) as well as in response to calls for innovation in the drone industry. For example, we refer to recent (July 2016) changes to UK airspace regulations to allow Amazon to test beyond-line-of-sight flight and detect-and-avoid capabilities for delivery drones in Cambridgeshire. Presently, authorizations for the use of airspace by lightweight drones commonly cover both recreational and/or commercial operations (CAA 2015b; FAA 2015c).

In the UK, recreational authorizations permit the operations of lightweight drones (termed by the UK CAA as ‘RPAS’) in uncongested airspace, subject to several limitations such as remaining within visual line-of-sight (VLOS) of the operator and not exceeding an altitude of greater than 400 ft (122 m) above ground level. A CAA PfAW is required for operations which are ‘commercial’ (defined by the CAA as ‘performed for valuable consideration’), or which are undertaken in ‘congested airspace’ (defined by the CAA as ‘any area which, in relation to a city, town or settlement, is substantially used for residential, industrial, commercial, or recreational purposes’) (CAA 2014b). Furthermore, private landowners are increasingly requiring RPAS operators, including researchers to hold a CAA PfAW in order to conduct operations over their property. Two examples are the National Trust (who own 350 heritage properties and 247,000 ha of land in the UK) (National Trust 2015) and the Royal Botanical Gardens, Kew, London, UK.
3. Flying drones for research and CAA permission

In the UK, whilst some researchers have obtained CAA permission (CAA 2015a, 2015c) for RPAS operations (e.g. Pomeroy, O’Connor, and Davies 2015; Woodget et al. 2015, 2016), others have operated their RPAS under the existing authorizations granted to hobbyist users (CAA 2013) which permit researchers to carry out flights in uncongested areas so long as permission from relevant landowners is first obtained (DeBell et al. 2015; e.g. Puttock et al. 2015, 2017; Carbonneau and Dietrich 2016; Anderson et al. 2016). Increasingly, academic researchers utilizing RPAS may deem it necessary to obtain permission from the CAA, codifying their operational competence, in order to (i) comply with institutional insurance requirements (Lloyd’s. 2015), (ii) demonstrate professional standards to collaborators, (iii) operate in congested airspace, and (iv) undertake consultancy work for monetary reward. We argue, that in instances where a researcher may not be undertaking aerial work for commercial gain, or operating in airspace where special licenses are mandatory, having a working document such as an OM will both allow for consistent and safe operation of drones and reassure collaborators and institutions that drone operations are being conducted in a professional manner. This could apply across different organizational scales, from individuals to a research group or an entire research institute. Alongside having a working document, understanding the process by which PfAW is granted can demonstrate the best practice that Hodgson and Koh (2016) advocate as the precautionary principle to manage operational risks.

4. Procedure for obtaining PfAW in the UK

Obtaining a CAA PfAW requires evidence that the RPAS will be operated in a safe manner by the organization concerned (Figure 1). This evidence normally requires that:

1. The pilot(s) have appropriate theoretical knowledge of air law, flight planning and operational procedures.
2. The organization submit an OM, a comprehensive technical document describing all aspects of RPAS operation including aircraft maintenance and incident reporting procedures.
3. The pilot(s) can demonstrate a good level of practical flight competency, including adherence to the procedures described in the OM.

These three components may be examined by a CAA-authorized entity, and evidence of satisfactory performance during these various assessments may be submitted to the CAA for consideration in support of a PfAW application. Broadly speaking, although the process varies from one country to another, there are great similarities across many NAAs, including the USA, Canada, Australia, and various EU member states, so the OM shared here has relevance and utility beyond UK borders.

5. The OM

Writing and developing the OM is a time-consuming process. The document structure is stringently defined according to criteria on style, organization and content (CAA
To produce our OM took several weeks of work and consultations with a CAA-approved assessment centre in the UK. The whole process leading to formal CAA PfAW certification took over one year to complete (Figure 2), with the majority of time occupied with OM editing whilst waiting for a suitable weather window for the practical flight test.

Figure 1. A schematic representation of where the operations manual fits into the typical accreditation process for ‘aerial work’ according to the UK Civil Aviation Authority (CAA). Please note that we show two routes for its use. The left-hand part of the flow chart shows the process for CAA accreditation of aerial work, which permits remotely piloted aircraft system (RPAS) use for commercial operation. However, as we argue in the article and as shown in the right-hand part of the flow chart, any researcher could use (following adaptation for their specific aircraft and procedures) our operations manual within their flight protocols, to demonstrate to collaborators a competency and safe protocol for drone flights outside of those operations requiring special permission from the CAA for ‘aerial work’.
In sharing this OM, we hope that other researchers using drones for their research can benefit from emulating the style and content of the document. It is important to note that we are not arguing that the procedures described in our OM are the only way to safely deploy drones for research; rather, it is shared as an example for reference to others in developing their own operational procedures specific to their operational requirements either in the UK or in other countries. This document can also serve as an example of good practice for researchers working in countries with less stringent/developed airspace regulations. Any parts of the shared OM (see supplementary information) may be used by other researchers, provided this assistance is accredited in any outputs arising from works supported.

6. Conclusion

Our OM is shared in the spirit of research as a collaborative endeavour with the aim of assisting other researchers in all areas of environmental or social science, who are using drones as part of their academic practice to follow a safe and CAA-approved protocol for flying. The OM can be downloaded and copied by any researcher wanting to achieve the same levels of accreditation as us. In such cases, researchers would need to substitute the names of their pilots and aircraft and to cross-check and modify (as required) the details of the operational flying procedure to reflect their own practice. In sharing this document, we hope that other researchers can save considerable time by having an approved CAA OM to use as a guide. The document may also provide a useful framework for those applying for accreditation with other national aviation authorities, or for those who are seeking robust operational procedures to follow when flying drones for research.
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