

Introducing Drones to the Team: Ensuring Safe and Correct Use through Proper Documentation, Training, and Monitoring

Introduction

Over the last twenty years there has been a significant expansion in the use of drones, or unmanned aerial vehicles (UAVs), in academic and developer-funded archaeology (Adamopoulos and Rinaudo 2020; Fiz *et al* 2022). While arguable still at a nascent and experimental stage, drone technology has numerous archaeological applications (Campana 2017). Nevertheless, despite their evident value, they have the potential to pose significant legal, safety, and operational risks. It is integral that comprehensive safety protocols are implemented; serious drone accidents, although rare, do occur (*ibid.*). As such, the project manager must implement a robust process to ensure that the equipment is used correctly and safely.

Initial Research: The Drone, The Team, and The Legislative Framework

As a responsible project manager, it is vital to conduct thorough research on the specific drone that is required before it is introduced to the team. There are a multitude of factors to consider: Is the drone operationally suitable for its intended task? What are the operational and safety limitations of the drone? Is the drone reliable and what are the potential risks? For example, the project manager would need to consider how the specific drone would be affected by strong winds and non-ideal weather conditions; few drones have any significant capacity to automatically respond to such risks (*ibid.*). Likewise, as will be expanded on below, the weight of the drone has significant legal and training implications. For the purposes of this report, the drone to be introduced to the team is a DJI Mini 3 Pro (Fig.1). The DJI Mini 3 Pro weighs less than 250g and its utility has recently been demonstrated in relation to photogrammetric surveys of excavations and of historic buildings (Rodriguez-Navarro 2022; Banfi *et al* 2023).



Fig.1: The DJI Mini 3 Pro

Beyond research into the specific drone required, it would be necessary for the project manager to gauge the interest of particular employees in receiving training on the new equipment. It is well-established that many organisations face concerns and sometimes resistance to the introduction of new equipment, particularly in the case of new digital and robotic technologies such as drones (Trenerry *et al* 2021; Lawluy *et al* 2022). This, in theory, should not be an issue in the introduction of drones if the benefits and applications are sufficiently conveyed to the team by the project manager

in preliminary discussions; when individuals within an organisation perceive that technological equipment will be beneficial to their work and improve their performance, and is easy to become proficient in and use, the likelihood of effective and enthusiastic adoption increases (Burton-Jones and Hubona 2006; Wang *et al* 2014). Since drones are a 'specialised' piece of equipment, only a limited number of team members would need to be trained to use them, making their introduction less complicated. It is probable that several employees would be interested in gaining competence in drone use – perhaps those who are already trained as archaeological illustrators, historic building surveyors, or those regularly involved in surveying excavation sites.

While the introduction of any piece of new equipment can be a complex process, with a multitude of factors to consider, these issues are considerably compounded by the complex and oftentimes chaotic state of drone regulation in the UK (McLachlan *et al* 2022). Indeed, the core *CAP 722: Unmanned Aircraft System Operations in UK Airspace Guidance* document by the Civil Aviation Authority (2022) has been significantly revised and updated eleven times since its publication in 2002. The responsible project manager would need to be well-informed and up-to-date on the continuously changing regulations

The hypothesised choice of drone noted above is significant in light of UK drone regulation. Pilots of drones weighing less than 250g, as A1 Subcategory drones within the 'open category', do not require the wide array of specific legally mandated training (e.g. A2 CofC Training or General VLOS Certificate) and can legally operate within 'congested' areas and fly over people. In summary, specifically in relation to the drone outlined above and the operational category that the typical archaeological application would require, the minimum responsibilities of drone users include:

- The requirement for all commercial drone flights to have valid insurance cover;
- The requirement for the drone to be registered with the CAA and for the registration to be renewed every year;
- The requirement of a Flyer ID, which identifies the pilot and demonstrates that they have completed the CAA online-based theory test;
- The requirement of an Operator ID, which is to affixed to each drone to identify the operator (whether it be an individual or a company) that is responsible for the aircraft;
- The requirement for 'visual line of sight' (VLOS) operation at all times for pilot-alone operations;
- The requirement of an observer that maintains VLOS if the pilot is using 'first person view';
- The requirement to ensure a maximum flight altitude below 120m (400ft);
- The requirement for the pilot to be at a distance of separation from vessels, vehicles, and structures so as not to cause endangerment;
- The requirement for all drone accidents or serious incidents to be reported to the Air Accidents Investigation Branch (AAIB); and
- The requirement to check for pertinent flying restrictions and hazards, which include:
 - o 'Flight Restriction Zones' (FRZ), which include airports and spaceports.
 - o Restricted Airspace, which include military facilities, prisons, and governmental buildings.
 - o Events, emergency incidents, Sites of Special Scientific Interest (SSSI) or Special Protection Areas (SPAs), and tall structures.
 - o Specific local and regional bylaws. Cadw, for example, prohibit operations over its guardianship sites unless they are contractors commissioned for a specific purpose, meet the criteria set by the CAA, and have written permission from Cadw (RCAHMMW 2019).

Operational Manual and Documentation

Drone operators are responsible for developing procedures in line with regulations that can be adapted to the specific types of operation and of potential risks, and they are responsible for ensuring compliance with these protocols. In order to ensure that the above regulations are adhered to, and the drone is correctly and safely utilised, the project manager would need to create and implement an *Operational Manual* that covers all of the procedures to be followed by all personal who are involved in drone operations (e.g., Wardell Armstrong 2022). While commercial operators solely using A1 Subcategory drones are not always legally required to have an operations manual that is approved by the CAA before conducting any flight, with the drone manufacturers guide sometimes being considered sufficient (Civil Aviation Authority 2022: 113), such a document should regardless be implemented by a responsible project manager to ensure safe and proper use. Operation manuals are the core documents for drone use – which cover documentation, training, and monitoring – and typically details on the following:

- Drone specifications and capabilities;
- Insurance documentation details;
- Pilot qualifications and training;
- Pre-flight procedures – including feasibility checks, site assessments and pre-notification, equipment checks, weather checks, and risk assessments;
- On-site procedures – including site operational survey, crew briefings, cordon procedures, weather checks, equipment checks, and pre-flight safety checks;
- In-flight procedures – including take-off, in-flight, landing and shutdown procedures;
- Emergency procedures – including procedures for the range of in-flight failures and accidents;
- Safety Management Systems – including safety policy, safety assurance, employee safety commitments, mandatory occurrence reporting procedures, and safety training systems.
- Template documents required for operationality and safety, including:
 - o Pre-Deployment Risk Assessment and Method Statement (RAMS)
 - o Pre-Deployment On-Site Assessment.
 - o Pre-Flight Procedure Checklist.
 - o Flight Procedure Checklist.
 - o Post-Flight Procedure Checklist.
 - o Emergency Procedure Implementation Checklist.
 - o Incident Management Checklist.
 - o Aircraft-Specific Maintenance Checklist
 - o Flight Logbook Form.
 - o Emergency Incident Report Form.
 - o Maintenance Logbook Form

Commercial operation of drones necessitates the utilisation of various types of interlinked documentation, the details of which are enshrined in the core *Operations Manual*. While it would be entirely reasonable for the project manager to use a system of detached word documents and excel spreadsheets, there are online platforms that centralise and integrate these documents – such as DroneLogbook (2023) or AirData (2023) – that would be an effective, time-saving, and cheap (c.£84 per annum) tool. The integrated online system, the details of which would be incorporated into the *Operations Manual*, would be accessible to the entire drone operation team and includes all the compliance and operation logs (Fig. 2-4). In addition to providing details and logs, DroneLogbook enables the responsible project manager and specified operators to receive notifications whenever their operations deviate from authorised procedures. This includes alerts for incomplete checklists,

flights that deviate from permitted project parameters, violations of compliance items, and upcoming expirations of documentation and maintenance events. These features allow the project manager to focus on practical operations and other profitable tasks, while significantly reducing the time required to maintain regulatory and operational compliance.

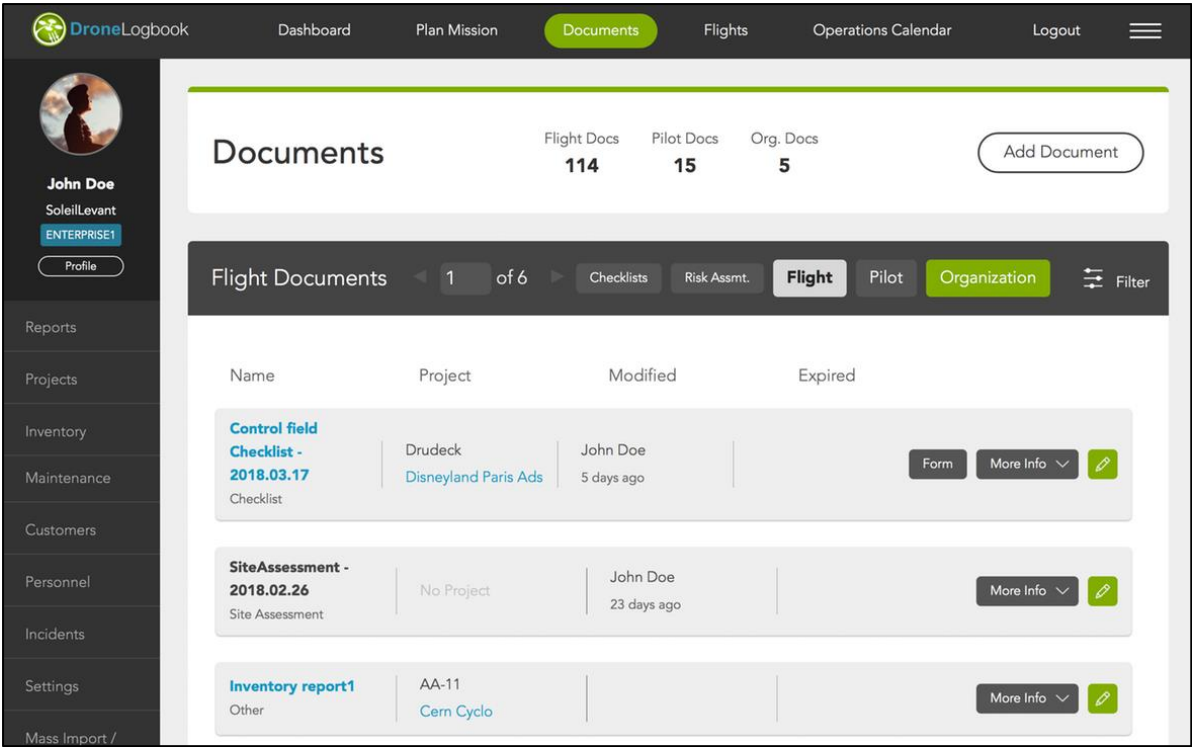


Fig.2: A screenshot of the centralised document record (DroneLogbook 2023).

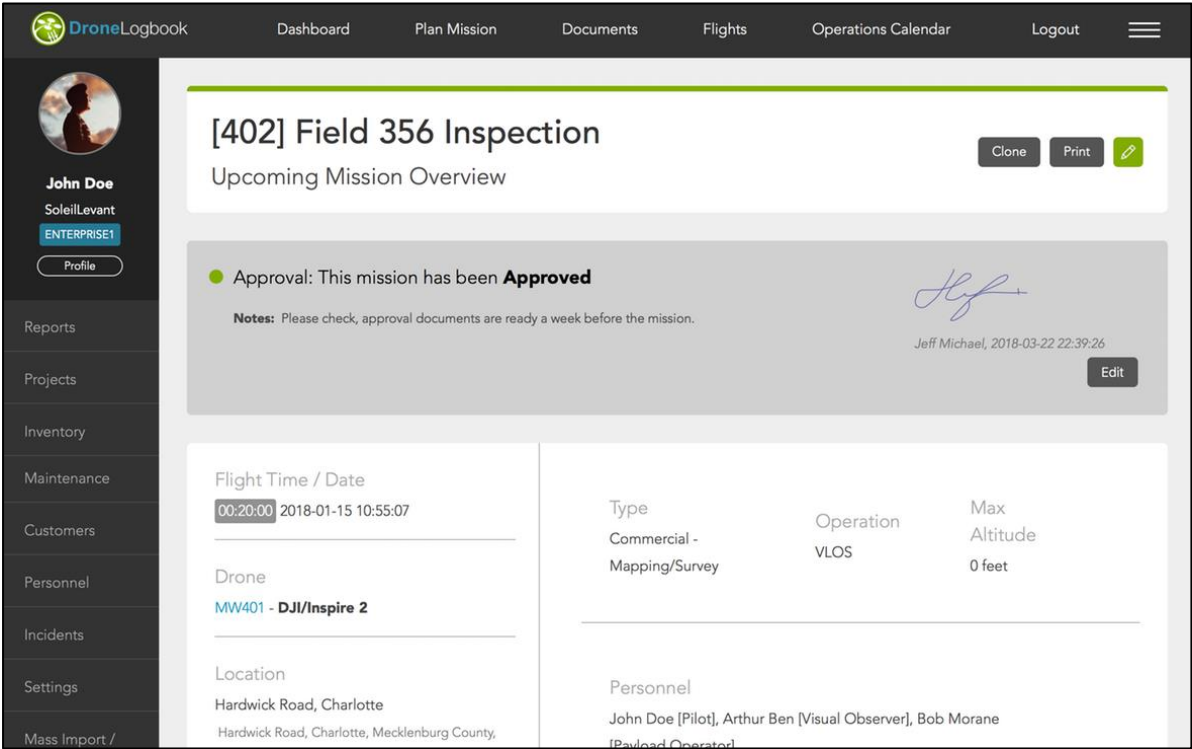


Fig.3: A screenshot of the Pre-Deployment On-Site Assessment (DroneLogbook 2023).

DroneLogbook | Dashboard | Plan Mission | Documents | Flights | Operations Calendar

Weather / 2019-02-01
Incident Overview

Review Status: Under Review
Drone: LUM-QAV400 Robert Schlupp

Description: Strong side wind behind tree line. Turbulence and low battery level make to drone to fail on its left side.

Aircraft Damage: Propeller CW1

Other Damage: Only some leaves in the surrounding trees...

Incursions (people, aircraft...): Only some trees and birds...

Related to Flight: Flight 2016-08-04 18:30:26 - Commercial ads

Project: Burgundy Ad

Location: Chicago stadium

Personnel Involved: Arthur Ben, John Wayne

Attachments: Pictures (3), Documents (1), Tracking Notes (9)
Add Picture

Fig.4: A screenshot of the incident report form (DroneLogbook 2023).

Training: Safety and Operationality

Training is an integral factor to consider when introducing any piece of equipment as an archaeological project manager. Indeed, as stated in guidance by the CAA (2022), the competency of the operator is a major factor in ensuring that drone operations are ‘tolerably safe’. While considerable training would also be needed to produce some of the outputs and deliverables from the data collected by the drone, on processing software like DJI Terra and TerraSolid, this is beyond the scope of this discussion. In order to properly execute and maintain qualifications and standards, a specific training plan and log would be produced and implemented. A somewhat crude and incomplete example of such a training log database, which details some of the training programmes to be mandated by the project manager, is provided below (Table 1). The individual training plans, a myriad of templates of which are available, would comprise a strategy to achieve competency and ensure ongoing proficiency through scheduled programmes of legally required training, practical and operational training, safety training, and professional development training.

DATE OF TRAINING	NAME	COURSE	TAKEN	PASS/FAIL	REFRESHER BEFORE
19.04.2023	Liam Podbury	Flyer ID Test	Yes	Pass	19.04.2028
19.04.2023	Chris Burgess	Flyer ID Test	Yes	Pass	19.04.2028
19.04.2023	Victoria Johnson	Flyer ID Test	Yes	Pass	19.04.2028
19.04.2023	Emma Warner	Flyer ID Test	Yes	Pass	19.04.2028
05.05.2023	Liam Podbury	Practical Flight Course	No	-	-
05.05.2023	Chris Burgess	Practical Flight Course	No	-	-
05.05.2023	Victoria Johnson	Practical Flight Course	No	-	-
05.05.2023	Emma Warner	Practical Flight Course	No	-	-

Table 1: Example of the type of training log that could be utilised.

In order that commercial drone operations are conducted in line with regulations, as outlined above, it would be necessary for all pilots to have a Flyer ID and for the individual responsible for the aircraft to have an Operator ID. For the purposes of this scenario, the project manager intends for four team members to operate the drones, one of whom would lead the drone team. All four pilots would be required to pass the CAA's official online theory test in order to gain a Flyer ID, and the organisation would register for an Operator ID with the drone team leader being the 'accountable manager'. Flyer ID registrations expire after five years, while Operator ID's require re-registration every year. As such, as part of the abovementioned training plan and log, a system of monitoring would be implemented to ensure that these registrations do not expire – such an expiration could result in programming difficulties and non-compliance with safety regulations.

As an A1 Subcategory drone, those piloting the DJI Mini 3 Pro do not legally require the A2 CofC Training or General VLOS Certificate that is required for heavier drones that pose a greater safety risk. Regardless, substantial practical flight training for all pilots would be necessary for the drone operations to be safely and correctly executed. There are numerous external programmes, run by CAA authorised organisations, which offer training courses for groups that have no previous drone piloting experience (e.g. UAVHub 2023). These in-person courses are designed to teach trainees the necessary practical skills to ensure that they can fly safely. Significantly, part of the training course entails operators to become conversant with the DJI Mini 3 Pro user manual. It may eventually be deemed beneficial to provide A2 CofC Training to members of the team, depending on the commercial and operational success of the drone operations, with the aim of ensuring that the drone team possesses the necessary competencies and are 'future-ready'; A2 CofC Training is required to operate the heavier drones that are oftentimes used to conduct extensive archaeological LiDAR, thermal and near infrared (NIR), geophysical, and landscape surveys (Campana 2017; Adamopoulos and Rinaudo 2020; Hill *et al* 2020; Gavazzi *et al* 2021; Casana *et al* 2021).

In addition to training the pilots to fly the drone safely and proficiently, it is essential to equip them with the necessary skills to conduct operations that yield precise and usable data. There are numerous external programmes, run by CAA authorised organisations, which offer drone surveying training courses (e.g. Heliguy 2023). The drone pilots would be required to complete these training programmes. Drone surveying courses typically cover pre-flight preparations, slight design, data capturing, data processing, and data deliverables for operations related to photogrammetry, mapping, and LiDAR. The courses are not specifically tailored to archaeologists, but this is certainly not a limitation as the skills are transferable. Training for drone surveying courses is typically conducted over five days – comprising theoretical, scenario-based, and practical training – and are delivered in the field and in the classroom.

Safety should be a top priority during training. While the aforementioned courses and qualifications are designed to promote safe practice, in order to ensure the necessary safety protocols are followed it is integral that all drone team members are conversant with the core *Operation Manual* and all of the documentation hosted on the DroneLogbook platform (e.g. RAMS forms, procedural checklists, and emergency incident logbook form). An internal training course, perhaps over a single day, should be held by the drone team leader to go through the specifics outlined within the *Operation Manual* and the DroneLogbook platform in order to address any uncertainties and familiarise the team members with the procedures they must follow. *Operation Manuals* are 'living documents'; as such, the document would need to be re-issued to each member of the team, well in advance of any scheduled flight, if any modifications to safety and operational procedures have been enacted.

Following the abovementioned training programmes, but before introducing drone usage into commercial archaeological projects, team members would be given the opportunity to practice using

the equipment in a controlled environment; for example, if deemed safe, the drone pilot for whom historic building surveys would be their focus may be tasked with conducting a photogrammetry survey of the company offices, while the more excavation focussed pilot may produce an aerial orthographic survey of the company car park. In addition to helping build confidence, it allows the drone team leader and project manager to ensure that the equipment is being used correctly and safely before being employed in a for-profit project.

To ensure the effectiveness of the outlined external and internal training programmes, it is necessary to evaluate their impact. In order to evaluate their effectiveness, short surveys should be compiled for each training programme; similar surveys, which could inform those implemented by the project manager, have been utilised in relation to a drone training course focussed on mapping surveys for researchers in the coastal and marine sciences (Yang *et al* 2020). In-field performance observations following the training may also be useful in monitoring training impact and effectiveness. Training feedback and the anecdotal observations will allow the responsible project manager to refine their training approach, and identify any gaps in capabilities that need to be addressed.

Once the initial practice-run is conducted in a controlled environment, and any troubleshoot issues are addressed via further training or changes to operational procedures, it would be time for the drone to be introduced to a developer-funded project. As opposed to undertaking a photogrammetric survey of a substantial urban excavation in an area with numerous bystanders or a complex and sizable survey of an expansive nineteenth century industrial complex, it would be prudent to first use the new drone equipment for a comparatively 'straightforward' operation. This may mean a small rural open-area excavation or a historic building survey of a rural farmstead away from bystanders or potentially impeding structures. Of course, first introducing the drone equipment to an 'idealised' developer-funded operation may not be commercially viable given the ranging requirements of different archaeological projects and budgetary constraints; nevertheless, if possible, such a 'straightforward' operation may allow the drone team members to gain the confidence needed to tackle more complex operations.

Training is not a one-time event – operational effectiveness and safety training should be a continuous and evolving process. The individual training programmes will include scheduled refresher courses, CPD courses and webinars, and the allocation of time to read technical publications and attend conferences run by drone specialists such as the ARPAS-UK Annual Conference (ASPAS-UK 2023). By continuously supporting and providing training, the project manager can facilitate that drone team members to reinforce their skills and keep abreast of any developments in the sector.

Monitoring: Equipment and Performance

Although the DJI Mini 3 Pro is not within the 'certified' category of drones that are required by the CAA to undergo a continuous monitoring process that ensures airworthiness, it is vital that the operability, and therefore safety, of the drone fleet is continuously monitored and ensured. In addition to ensuring that each pilot fully inspects the drone prior to each flight, a responsible project manager should approach the maintenance of the equipment proactively and systematically. It is necessary to replace certain components like propellers and batteries based on the manufacturer's guidelines, or when signs of wear or failure are detected. Indeed, in line with maintenance recommendations specified for DJI quadcopters, a comprehensive maintenance would be scheduled and performed after every 200 flights or 50 flight hours. The maintenance and repairs would need to be carried out by a trained and competent technician; while it may eventually be deemed necessary to conduct such procedures in-house following maintenance training of the team, this does not appear to be financially prudent as there are numerous external contractors that offer such services at a

reasonable cost (e.g. DroneBuilders 2023). The project manager should keep detailed records of all maintenance activities, including who performed the maintenance, what was done, and when. The fleet management system by DroneLogbook described above also includes a tracking system that sends notifications for maintenance actions and logs inspections (Fig. 5); this helps the responsible project manager to ensure that safety is not compromised and that projects are not delayed by unanticipated and untimely maintenance events.

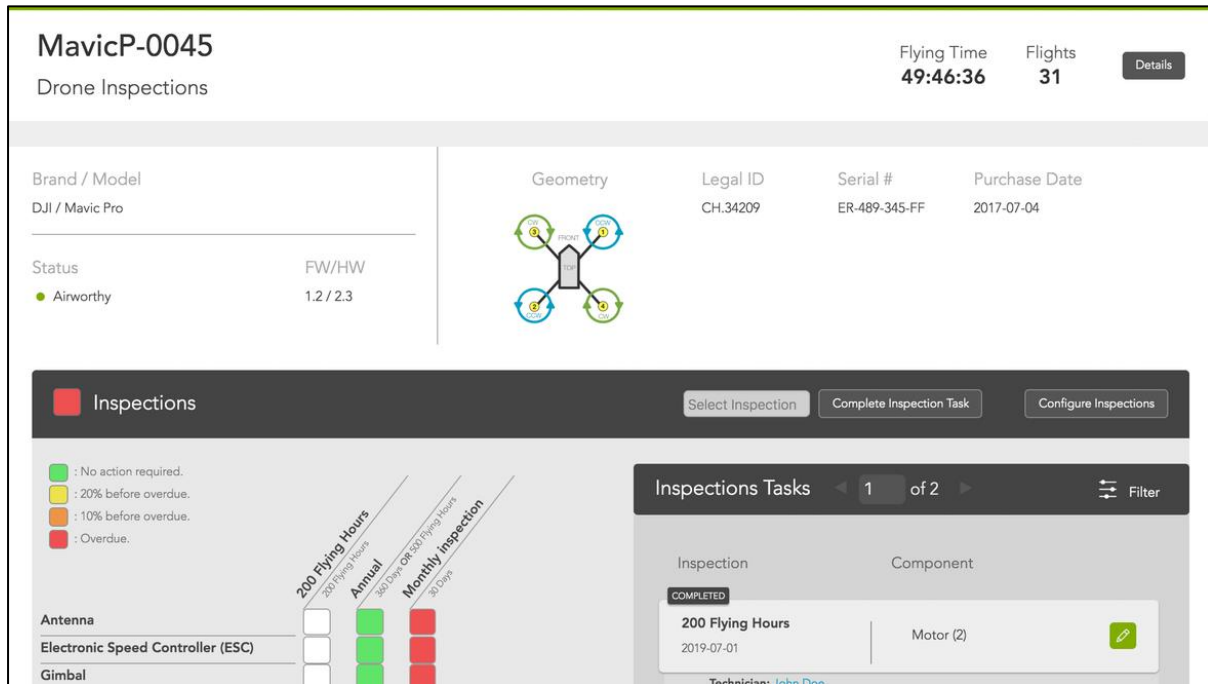


Fig.5: The integrated drone inspection and maintenance system by DroneLogbook (2023)

In addition to monitoring the accuracy of the sensors during the maintenance schedule, it is vital that the project manager ensures that flights are consistently safe and that the output of drone flights are precise and of satisfactory quality. This could involve regular check-ins by the project manager or the drone team leader to monitor and assess performance indicators and metrics, which may include: the review of the flight metrics stored on DroneLogbook (e.g. Fig. 6) to ensure adherence to the safety protocol outlined in the *Operations Manual* and regulatory requirements; and the assessment of the design and operation of flights and implications on accuracy, completeness, and resolution of the output data. Indeed, accuracy assessments of drone-derived photogrammetric models of Roman amphitheatres have demonstrated the necessity of carefully design flight plans and the need for precise georeferencing (Barba *et al* 2019). Following monitoring, constructive and specific feedback could be given to the operators so that they can refine their techniques, troubleshoot any problems they may be having, and to optimise flight plans and designs so that accurate and optimal output data is produced.

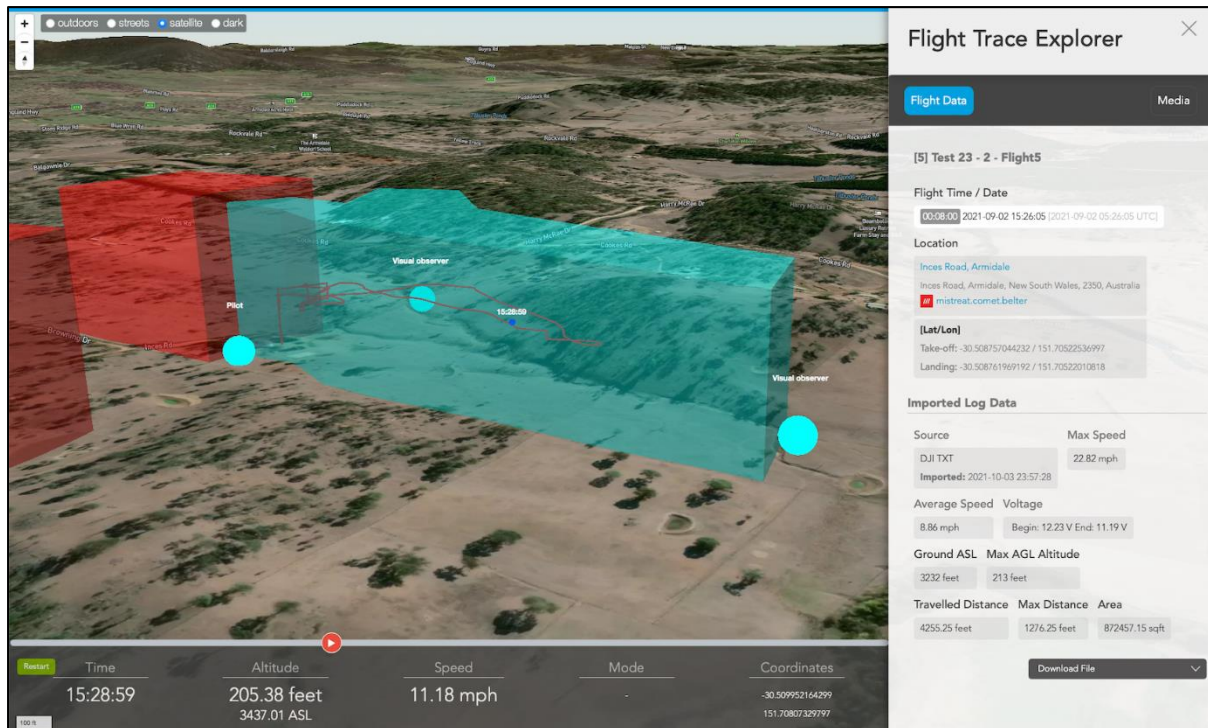


Fig.6: The flight tracker tool on DroneLogbook (2023), which can be used to monitor performance.

Conclusions

There are a myriad of factors that a responsible project manager must consider in order to ensure that drones are correctly and safely used in commercial archaeological projects; serious drone accidents, although rare, do occur (Campana 2017). As such, the project manager should implement a comprehensive and robust procedure that is exhaustively documented and enshrined in the *Operations Manual* – ideally, implemented through an integrated and specifically designed drone flight management platform like DroneLogbook – to maintain regulatory compliance, to minimise risk to operators and the public, and to produce accurate and satisfactory data output. For the project manager to ensure correct use during and following the introduction of the drones, all practitioners would be required to take part in a comprehensive programme of practical, safety, and operational training; drones equipment would be subject to regular maintenance; and the safety of flight operations and quality of data output would be regularly monitored and continuously improved.

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