

Application of Unmanned Aircraft Systems as an Instrument in Flight Inspection

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BIOGRAPHIES

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ABSTRACT

During the last years, unmanned aircraft systems have developed from mainly military operated vehicles to tools for data gathering and support in the field of photogrammetry, meteorology, civil protection, and even water safety. In parallel, UAS have developed from tools for professionals to toys for hobby pilots controlled by smartphones. For this reason, this paper is going to have a look at the applicability of UAS in flight inspection.

A complete automatic flight inspection system can weigh up to 100 kg or more and thus would need an unmanned system capable of carrying this payload, flight control and avionics systems, and propulsion installations including fuel. The operation of unmanned aircraft of this size can be complex and laborious with regard to certification, training of personnel, and regulatory limitations.

When thinking of an UAS as an additional tool for flight inspection instead of as a replacement for regular FIS installations in FI aircraft, considerably smaller unmanned systems can be used. Such a small UAS could be equipped with one sensor specific to the measurement task and a data recorder. Data could be processed and analyzed after the flight or during the UAS operation in near real-time via a data link.

This paper presents potential scenarios for the operation of UAS as an instrument in flight inspection and assesses the applicability of these. Additionally, an exemplary overview on the regulations regarding the operation of UAS is given.

INTRODUCTION

Unmanned aircraft have developed from highly specialized, military tools to a consumer product, which can be bought in many consumer electronics shops. In addition, the number of civil applications for small unmanned aircraft has significantly increased during the last years. These range from aerial photography [1], meteorological measurements [2] to applications in civil protection [3] and water safety [4]. Thus, this paper is going to investigate the applicability of unmanned aircraft in flight inspection (FI).

Before getting into detail with the topic of unmanned aircraft, a common nomenclature should be defined. Unmanned aircraft (UA) or unmanned aerial vehicles (UAV) are most of the time connected to a ground station via a data link for command and control (C2) functions. In case this control of the UA is done by a remote-pilot, who can interact with the aircraft at any time, ICAO uses the term remotely-piloted aircraft (RPA). Thus, RPA are considered a subset of UA. Both, the aircraft and the ground segment including the C2 data link, are described as an unmanned aircraft system (UAS) or remotely-piloted aircraft system (RPAS), see [5]. An overview on the different subsets of unmanned aircraft is provided in [6].

This paper concentrates on smaller UAS and their application in flight inspection. For this, an exemplary overview on the legal regulations regarding the operation of UAS is given. Since a complete overview on the international legal framework of RPAS operation would exceed the scope of this paper, the European and German situation is utilized as an example.

LEGAL FRAMEWORK

ICAO's work on the air traffic management of unmanned aircraft concentrates on the application of RPA. *"The functions and responsibilities of the remote pilot are essential to the safe and predictable operation of the aircraft as it interacts with other civil aircraft and the air traffic management (ATM) system"* ([5], chapter 2.2, p. 3). Unmanned aircraft without the near real-time control or supervision by a remote pilot are not considered, yet, since the communication with ATC is essential for the integration into civil airspace. The main task for ICAO is to integrate RPAS into the rules given by the Convention on International Civil Aviation, signed at Chicago on 7 December 1944 and its amendments [7]. Key elements for the integration of RPA into airspace mentioned in [5] are to guarantee the collision avoidance, to implement RPA specific procedures into air traffic management, and to describe adequate equipment for unmanned aircraft to ensure the compliance with existing regulations. Licensing of personnel involved in the operation of RPAS has to be considered as well for remote pilots and other members of the crew, and for air traffic controllers. Additional information is given in ICAO's concept of operations (CONOPS) regarding RPAS in IFR operations [8].

Both, the RPA related CONOPS of ICAO [8] and EUROCONTROL [9] describe a concept for RPAS in ATM. This is planned to happen in two phases. First an accommodation of RPAS into airspace *"describes the condition when RPAS can operate along with some level of adaption or support that compensates for its inability to comply with existing operational constructs"* ([8], chapter 1.4.1, p. 6). Accommodation is the current way of operating RPAS into airspace in many states. From the year 2025 onwards, RPAS operations are expected to work in the so called integration phase. This means, that Standards and Recommended Practices (SARPs) and procedures (PANS) have been harmonized in order to regularly integrate RPAS into air traffic management.

One of the latest steps undertaken by the European Aviation Safety Agency (EASA) regarding UAS has been the publication of the Opinion 01/2018 [10]. It proposes a new European Regulation for UAS operations in 'open' and 'specific' category. The main aspects of the regulation are given at EASA's website [11] as:

- *"It provides a framework to safely operate drones while allowing this industry to remain agile, to innovate and continue to grow. The risk posed to people on the ground and to other aircraft as well as privacy, security and data protection issues created by such drones are also taken into account.*
- *It defines the technical and operational requirements for the drones. Technical requirements refer for example to the remote identification of drones. Operational requirements refer among others to geo-awareness, a system that inform the remote pilot when a drone is entering a prohibited zone. The proposal also addresses the pilots' qualifications. Furthermore, drone operators will have to register themselves, except when they operate drones lighter than 250g.*
- *It breaks new grounds by combining Product legislation and Aviation legislation. Indeed, design requirements for small drones will be implemented by using the legislation relative to making products available on the market (the well-known CE marking). The standard CE mark will be accompanied by the identification of the class of the drone (from C0 to C4) and by a do's and don'ts consumer information that will be found in all drone boxes. Based on the drone class an operator will know in which area he can operate and what competence is required.*

- *It allows a high degree of flexibility for EASA Member States; they will be able to define zones in their territory where either drones operations are prohibited or restricted (for example to protect sensitive areas), or where certain requirements are alleviated. For operations posing higher risks, an operational risk assessment will define the requirements that the operator needs to comply before flying the drone.” (source: [11])*

An overview on the EASA member states’ implementation of the regulations regarding the professional use of unmanned systems is given in a conveniently accessible map at [12]. As an example, Germany’s current rules on the operation of RPAS are presented in this paper. An overview is given in Figure 1.



Figure 1: Overview on regulations for professional RPAS operation in Germany, [12]

The application of RPAS in flight inspection is considered to be of a professional operation, so that regulations for recreational use are not considered in this paper. In any case, it is necessary to have a liability insurance, which covers RPAS operations. If the maximum take-off weight (MTOM) is above 250 grams, a fireproof, permanent label with owner name and address is required to be attached to the RPA. Above 2 kg MTOM a proof of qualification for the pilot from an authorized entity is necessary. From an MTOM of 5 kg and more a special authorization by the federal state’s aeronautical authority is required. The operation of UA with an MTOM of more than 25 kg is forbidden, but in certain cases an exception granted by the aeronautical authorities might be possible. During operation of the UA it is necessary to keep a minimum distance of 1.5 km to e.g. people, populated areas, nature reserves, hospitals, or aerodromes. With permission by the aviation authority, minimum distances can be reduced or removed in certain cases. The operation of multi-copter type UA is only allowed below a flying height of 100 m. A more detailed overview on the regulations for the operation of UA in e.g. the federal state of Lower Saxony is provided at the website of its aeronautical authority [13].

APPLICABILITY IN FLIGHT INSPECTION

The applicability of unmanned aircraft in flight inspection has already been discussed in a couple of publications. An early mention of UAV for FI operation as a future outlook is given in [14]. In recent years, with an increase in the maturity of the unmanned aircraft technology - also in non-military applications - and of the legal framework, the topic of UA in FI has gained interest accordingly. During the 2016 International Flight Inspection Symposium (IFIS) papers on this topic have already been presented. FAA’s Mark E. Whittington gives a comprehensive evaluation of the suitability of UAS for flight inspection in [15]. He proposes mission modules for UAS which are suited to specific flight inspection tasks. ENAV’s Fabrizio Maracich presents the position of the International Committee for Airspace Standards and Calibration (ICASC) in [16] and introduces an evaluation matrix for the application for RPAS in flight inspection and procedure validation.

One of the main motivations for introducing RPAS into flight inspection tasks is the reduction of costs involved in the operation of manned FI aircraft. The current implementation of the legal framework make it nearly impossible and at least impracticable to operate a UAS of an appropriate size and weight in order to hold a fully equipped flight inspection system (FIS) in German airspace. It also has to be considered, that one of the functions of flight inspection and procedure validation is to check the “flyability” of procedure by human pilots and how this can be achieved with an automated and unmanned aircraft. For this reason, this paper concentrates on small RPAS with specialized sensors, which can support flight inspection missions.

An example for such a specialized small, unmanned, octocopter type UAS is presented by [17] and [18]. Its payload consist of a dedicated set of receivers and antennas for Signal-in-Space measurements. The proposed application is e.g. during the deployment phase of new ILS installations. In this way, a mid- or long-term replacement for low-altitude ILS measurements by masts

or vehicles could be found. It can be imagined, that similar RPAS with appropriate receivers and antennas could be used for measurements of GBAS VDB signals or other legacy navaids like VOR or DME.

EXAMPLE FI APPLICATION: PAPI

Most consumer RPA are equipped with a camera. Thus, the probably most straight-forward application of an unmanned aircraft in flight inspection would be one for visual measurements. For this reason, the exemplary application of RPAS in flight inspection of the precision approach path indicator (PAPI) is discussed in the following paragraphs.

For the inspection of a PAPI installation, the transitions between the red and white light constellations and the angular coverage have to be checked. The four PAPI lights at a runway appear either red or white, dependent on the angle and height of the approaching aircraft. The task is to determine, whether the elevation radiation of the lights is within given tolerances, and whether the lights are clearly visible within given azimuth limits. An accordingly equipped helicopter hovering around the nominal transition points in the approach path of the PAPI can inspect the light transition elevation angles. The same helicopter could be used for flying a partial orbit of 4 NM at 1500 ft height above threshold (HAT) in order to inspect the visibility azimuth. For this, the camera would have to look sideways in order to capture the PAPI lights.

The requirements for the PAPI flight inspection RPAS are defined by the required tolerance angle for the transition elevation and by the distance to the PAPI installation. The distance directly influences the flying height of the RPA and thus has to be considered in order to not violate existing regulations. A distance of 500 m from the PAPI lights has been identified as good compromise between position reference accuracy requirements, flying height, and requirements towards the camera sensor.

The PAPI FI UAS requires a camera, which provides a sensor with a resolution high enough to allow the identification of the PAPI colors from the necessary distance. A gimbal mount and even automatic tracking of the PAPI light would be beneficial to the flight inspection task, since the operator of the UAS then might be able to better concentrate on other tasks of the process.

When selecting a camera and monitor setup for a PAPI or any other vision based flight inspection mission, it has to be ensured, that this equipment represents the situation of a pilot using the inspected navaid. For this, the resolution, optic enhancements, and color representation have to be as close to the human pilot's eye as possible. The visibility of PAPI lights in a high resolution, zoomed-in picture does not guarantee the visibility by the pilot.

The elevation angles of the PAPI light transitions have to be accurately measured. For this a position and possibly attitude reference systems is required. The smaller the distance between the PAPI and the RPAS position is, the higher the accuracy of the position reference system has to be. An obvious choice for a position reference system is a receiver and an antenna for global navigation satellite systems (GNSS). An attitude reference system might be necessary in order to compensate for lever arms between the GNSS antenna and the camera sensor.

A distance of 500 m between PAPI installation and RPAS would require a GNSS position solution based on phase measurements. This can be achieved with a differential GNSS ground station with real time kinematic (RTK) / phase differential GNSS (PDGNSS) algorithms, see [19]. Alternatively, a precise point positioning (PPP) solution, that does not require a ground station, can be used. PPP uses correction data distributed by geosynchronous satellites and requires a subscription to a service like TerraStar-C, see [20].

A C2 data link is already required in order to complete the RPAS setup. For the flight inspection operation it would additionally be beneficial to receive the flight inspection related data like the position and the video stream of the camera on the ground. With such a data link the ground operator could easily push an event button, when the PAPI light transitions happens in the video stream and in this way get a near real time information on the status of the PAPI. In future applications it could also be thought of an automatic detection of the light transitions and thus a fully automated PAPI inspection, just supervised by the ground operator.

CONCLUSION

The exemplary concept of a PAPI flight inspection UAS and research presented in [17] and [18] shows, that small unmanned aircraft can already be a valuable contribution to flight inspection operations. Current regulations concerning MTOW limitations and operation outside the line of sight of the remote pilot make it unlikely to replace a manned FI aircraft with an unmanned system in the near future. Nevertheless, (small) UAS can be a valuable addition to regular flight inspection operations and might deliver precise spot measurements with the flexible flight trajectories of multi-copters. It might also be considered to increase the interval length between manned aircraft flight inspections and fill the gaps with appropriate measurements from RPAS. In

the end, the objective of flight inspection does not change. Nav aids have to be capable to deliver reliable signals that allow manned aircraft to navigate safely. Thus, flight inspection and procedure validation has to be oriented towards the human pilot and its use of these nav aids and procedures.

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