Research on Flight Inspection Using Unmanned Aircraft

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Abstract. Flight inspection is an important way to verify and evaluate the integrity and effectiveness of flight procedures, civil aviation communications, navigation and surveillance equipment. It is directly related to the safety of civil aviation. Traditional flight inspection is completed by adding special flight inspection equipment to high-performance aircraft. This paper mainly studies a new flight inspection method based on unmanned aerial vehicle (UAV). The feasibility, difficulties, advantages and risks of UAV flight inspection are discussed in this paper. This method may be implemented in the next five to ten years.

1. Introduction
UAVs have developed rapidly in China in recent years, at present, China has launched pilot navigation projects in an all-round way and continuously expanded the application fields of UAVs. The application of UAVs is becoming more and more widespread. In 2013, Spain began using unmanned aerial vehicles for flight inspection [1]. At present, research on this subject has begun in China. In January 2019, the flight inspection of the navigation lights was completed for the first time by the CAAC Flight Inspection Center at Daxing Airport in Beijing.

2. Flight Inspection
Flight inspection is an important way to verify and evaluate the integrity and effectiveness of flight procedures, civil aviation communications, navigation and surveillance equipment. It is directly related to the safety of civil aviation. At present, the traditional flight inspection in the global is completed by adding special flight inspection equipment to high-performance aircraft, which is operated by the flight inspection staff, and adjusted by the ground equipment maintenance personnel. The flight inspection is operated by the pilot according to the calibration procedure.

2.1 Classification of flight inspection
Flight inspection is divided into four categories: production inspection, monitoring inspection, periodic inspection, and special inspection [2].

(1) Production inspection refers to flight inspection performed to obtain all technical parameters and information of the inspection object after the inspection object is newly built, relocated or updated.

(2) Surveillance inspection refers to the non-scheduled flight inspection of the inspection object in operation after the production inspection is verified, or the civil aviation bureau or the regional administration considers that it is necessary.

(3) Periodic inspection refers to the flight inspection of the inspection object in operation according to the specified inspection period in order to determine whether the inspection object meets the technical standards and meets the requirements of continuous operation.
(4) Special inspection, special inspection needs to be organized due to the replacement of major components of the equipment or abnormal equipment signals, which may affect flight safety, or investigations due to flight accidents [2].

2.2 Flight inspection implementation

2.2.1 Flight inspection object and period. The flight inspection object includes a communication device, a navigation device, and a monitoring device. The check cycles of different devices are different, as shown in Table 1 [2].

| Equipment               | Commissioning inspection | Monitoring inspection (after production) | Periodic inspection |
|-------------------------|--------------------------|------------------------------------------|--------------------|
| ILS (Class I)           | need                     | 90 days                                  | 180 days           |
| ILS (Class II)          | need                     | 90 days                                  | 120 days           |
| ILS (Class III)         | need                     | 90 days                                  | 90 days            |
| DVOR/DME route          | need                     | 540 days                                 | 1080 days          |
| DVOR/DME terminal       | need                     | 270 days                                 | 540 days           |
| NDB                     | need                     | 270 days                                 | 540 days           |

2.2.2 Ways of flight inspection. At present, in China, the flight inspection is carried out by the Flight Inspection Centre of CAAC. It is mainly completed by using high-performance aircraft such as Citation Jet or Kings Jet to install flight inspection equipment.

3. UAV Flight Inspection

The UAV inspection system is mainly divided into two parts, the air part and the ground part. The air part group should include the UAV system, the flight inspection system installed on the UAV, the satellite positioning system, and the ground part mainly includes UAV ground control and monitoring system, flight inspection data receiving and analysis system, GPS precise positioning system station [3].

3.1 UAV system

The UAV system is mainly composed of three parts, mainly including UAV, UAV ground control station, data communication system, mission load, support and maintenance system.

3.2 Flight inspection system

The ordinary airborne flight inspection navigation evaluation system needs to collect and process the spatial signals to be evaluated and generate an evaluation report. [4] The basic inspection principle of the flight inspection system is to use the precise positioning of the inspection aircraft itself [5], and compare the collected navigation signals with the ideal signals that should be provided at the position to obtain flight inspection data and errors. After flight inspection, we should adjust the ground navigation equipment allows the spatial signal to ultimately meet operational specifications. The flight inspection signal acquisition and processing is received in real-time and accurately by the aeronautical navigation receiver to obtain analog and digital signals, and the signals are demodulated, filtered, and modulated, measured by frequency, measured by signal strength, etc. to obtain the desired calibration result.
3.3 UAV flight inspection system

3.3.1 The composition of the UAV flight inspection system. The UAV flight inspection system mainly includes two parts, air and ground. The air part mainly includes UAVs, multi-mode receivers and processing systems capable of receiving navigation signals such as GPS\ILS\VOR\DME\NDB\MB, Transmission system, the ground part mainly has UAV control station, flight check data analysis and processing system, GPS precise positioning system station, data transmission system [6].

3.3.2 Selection of flight inspection system for UAV

3.3.2.1 Selection of UAV. In order to meet the needs of flight inspection and cost, the selected type of UAV is Class IV UAV in the classification and classification of China's civil aviation “Light and
Small UAV Operation Regulations (Trial)”. The weight of the aircraft is 15kg<W≤116kg. The take-off weight is 25kg<W≤150kg.

3.3.2.2 Selection of airborne calibration equipment. The signal analyzer uses Rohde & Schwarz (R&S)’s EVSF1000, which can be connected to high-sensitivity antennas for acquisition, recording and high-precision analysis of airborne signals from VOR, ILS, MB and other navigation devices (in accordance with ICAO Doc 8071) And ICAO Appendix 10), its dimensions are 95mm × 177mm × 360 mm, 3.7kg.

Table 2 . EVSF1000 performance indicators

| ILS signal analysis | Accuracy -75 dBm to +10 dBm | VOR signal analysis | Accuracy -80 dBm to +10 dBm |
|---------------------|-----------------------------|---------------------|-----------------------------|
| Modulation depth    | ≤ 0.3 %                     | azimuth             | ±0.05º                      |
| DDM (LOC)           | ≤ 0.04%                     | 30/9960Hz AM        | ≤0.5 %                      |
| DDM (GP)            | ≤ 0.08%                     | 1020Hz Identification modulation | ≤1 %                       |

Since the DME works by transmitting a pulse signal from the on-board device, the ground device receives the signal and returns a response signal to the onboard device. The airborne equipment can calculate the distance between the aircraft and the ground station based on the speed of the radio wave based on the time difference between the transmitted signal and the received response signal. Therefore, the verification of DME requires a device to simulate the aircraft sending an interrogation signal to the DME station. The R&S SMA100A signal generator can add various analog signals and various ILS, VOR, MB, and DME. The modulating signal, the size of which is the R&S EDS300, enables the acquisition, recording and high-precision analysis of DME station signals (in accordance with ICAO Doc. 8071 and ICAO Annex 10). Its size is 342 mm × 157 mm × 266 mm, 7.3 kg.

The flight inspection UAV has a flying altitude of 0-3000 meters and a flight distance of less than 25 NM. Therefore, long-distance communication equipment is required to ensure that the control and data transmission of the drone can be successfully completed [7]. Iridium Modem 9522B is based on a highly stable Iridium network with low transmission delay time satellite links for global voice and data transmission services. Its size is 162mm × 81mm × 28mm, 420g.

For flight inspection, it is important to verify the accurate positioning of the UAV itself, especially during the ILS calibration process, where the position accuracy directly affects the flight calibration results. Therefore, it is necessary to install a position correction system on the verification drone. The BDM682 four-system eight-frequency high-precision positioning orientation board can be selected, which is 46mm×71mm×4mm.

Table 3 . BDM682 performance indicators

| Positioning method | Horizontal accuracy | Height accuracy |
|--------------------|--------------------|----------------|
| Single point positioning (RMS) | 1.5m | 2.5m |
| DGPS(RMS) | 0.4m | 0.8m |
| RTK (RMS) | 10mm+1ppm | 15mm+1ppm |

3.3.2.3 Ground station and flight inspection joint adjustment system. The ground station mainly needs to realize the status monitoring of the unmanned verification aircraft in the air, the issuance of control commands, and the analysis of the unchecked aircraft verification data. The function of the flight verification joint adjustment system is to start verification according to the unmanned verification
aircraft. The subject will be set to the corresponding state by the calibration equipment, and the equipment parameters can be adjusted according to the verification result of the ground station analysis, so that the air signal of the equipment meets the requirements of the calibration specification, and the automatic or manual flight can be realized as needed check. The specific process is shown in Figure 3.

![Flight inspection flow chart](image)

**Fig 3. Flight inspection flow chart**

4. **The Current problems and future development prospects of UAV flight inspection**

The construction of the UAV flight inspection platform is completed, and the next step is to carry out the specific implementation of flight inspection. There are two modes of operation. One is automatic autonomous flight to collect air data. This requires pre-setting the calibration subjects and flight lines of the UAV according to the flight procedure. The UAV transmits the collected data back to the ground data processing center in real time. Determine whether to adjust the ground equipment according to the air parameters.

At present, the biggest difficulty in implementing UAV flight inspection in China is that the state has not yet issued relevant regulations and technical standards to support it, and it is still in the experimental stage [8]. In addition, since there is no calibration equipment specially designed for UAV calibration, the existing calibration equipment is large in size and requires more than Class IV drones to carry. The UAVs have a long flight distance and are mostly in line of sight. And the load is large, once the loss of control may cause more serious accidents, so the anti-collision system [9], control data and calibration equipment data transmission requirements of the UAV are relatively high.

However, due to the current high cost of traditional flight inspection, ranging from $4700 to $5700 per hour, and it has a greater impact on civil aviation flights. Also, often subject to airspace restrictions, the use of UAV inspection can greatly reduce flight inspection costs [10].
5. Conclusion
It is believed that with the continuous maturity of UAV technology and the establishment of relevant legislation, and the use of UAV inspection can greatly reduce the cost of flight inspection. Therefore, it is a general trend to use UAVs for flight inspection in the future. Perhaps using this method for flight inspection will be achieved in the next few years.

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