Utilization of UAV for Flight Inspection in JAPAN

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BIOGRAPHY

Mitsuhiro Maruhashi graduated from Aeronautical Safety College in 2013. His major was Aeronautical Electronics. After graduation from the college, he was ATS engineer for operation and maintenance of Aeronautical Radio facility, from 2013 to 2016. Since 2016, he has been working at Flight Inspection Center as a Flight Inspector.

ABSTRACT

Unmanned Aerial Vehicles (UAVs), which emerged in the early 2000s, are used in a wide variety of fields, including cargo transport, life-saving supplies delivery, wildlife monitoring, disaster management support, and infrastructure inspection, thanks to their autonomous and automated capabilities and flexibility to choose the implementation scale according to the application. In this situation, discussions and considerations have started to regard the technical and operational aspects of using UAVs for flight inspections, and stakeholders will be paying close attention to their feasibility and effectiveness.

In Japan, the government has called the utilization of UAVs an "industrial revolution in the sky," and public and private sectors are working together to develop the necessary technology, rules and manuals with international cooperation. The final goal is to fully utilize small UAVs by flying beyond visual line of sight in urban areas by the end of the 2020s.

With this background, Japan Civil Aviation Bureau (JCAB) has started to consider the introduction of the utilization of UAVs for flight inspection from 2021, with the aim of realizing evaluation operations from 2024.

INTRODUCTION

Considering the superiority of UAVs which is so called ‘Drones’, JCAB has been tackling to utilize drones to inspect a part of Precision Approach Path Indicator (PAPI). In order to introduce this new inspection method, it is necessary to develop an evaluation method for validity and effectiveness compared to the current inspection by flight inspection aircraft, as well as rules and methods of operation. In addition, the project must resolve various challenges, such as coordination with airport operators and other stakeholders related to drone use, and ensuring social needs such as safety and noise reduction measures.

This paper shares the outline of background, objectives, usefulness, challenges, and plans leading to the utilization of drones for this project, including current flight inspection challenges, and also introduces the progress of this project and its future prospects. And then, it proposes to invite to share your practice and lesson learned with regarding those concerns and challenges to relevant stakeholders involve flight inspection who are considering and/or implementing the utilization of UAVs.

CHALLENGES OF FLIGHT INSPECTION FOR SOCIAL RESPOSIBILITIES

Currently in Japan, the soundness of radio signals and lights provided by Air Navigation Facilities are checked by fixed-wing flight inspection aircraft. In principle, the flight time zone is during VMC (Visual Meteorological Conditions), which allows for visual safety checks during the inspection flight, and this flight is usually conducted from 6:00 am to 5:00 pm during the daytime when VMC is available in summer. For this thing, in the case of conducting an ILS Monitor inspection during this time would require the issuance of a NOTAM stating that the ILS is unavailable during airport operating hours, and may result in degraded service levels due to the facility being unavailable. Besides, at congested airports such as Tokyo International Airport and Kansai International Airport, Flight inspection operations are limited to the hours from sunrise to early morning before rush hour, when air traffic is relatively light in order to reduce the impact on airlines. In other words, the time available for flight inspections is limited. In addition, in the case of flying at low altitudes over dense residential areas such as urban centers, noise concerns must be taken into consideration. Such low-altitude flights also consume more fuel than flights in normal operations, resulting in higher CO2 emissions.

Furthermore, recently, not only existing (conventional) Air Navigation Facilities such as ILS and VOR, but also advanced and various satellite navigation systems such as LPV have being introduced, and flight time for flight inspections is increasing. On the other hand, resources such as flight inspection aircraft and personnel are limited, so these issues must be addressed.

ADVANTAGES OF USING UAVS

Under these situations, utilizing UAV for flight inspection have attracted international attention and have being actively discussed at IFIS. Several states have already introduced UAV for flight inspections, and have reported that they have contributed to improving the efficiency of inspection items. Considering this background, JCAB has decided to consider the introduction of flight inspections using UAV as one of the counter measures to solve the aforementioned challenges. One of the big advantages of using UAV for flight inspection operation is able to be conducted during runway closure hours (nighttime) that means is less impact of airport operations during the daytime. In addition, the noise impact on nearby residents can be minimized because the inspections can be conducted in the vicinity of Air Navigation Facilities. CO2 emissions also can be greatly reduced since UAV flies electrically.

INPREMENTATION PLAN

As a short-term goal for the utilization of UAV in Japan, JCAB planned to start preliminary preparations in FY2021 and conduct a portion of PAPI flight inspections using Drone in FY2024. Specifically, as follows,

- Cost-effectiveness analysis, coordination among relevant section, and other implementation studies in FY2021
- Investigation of the performance of Drone and preparation of procurement specifications in FY2022
- Preparation related procedures and manuals, training (Including licensing), and procurement Drone (For PAPI inspection)in FY2023.
- Actual introduction tests using Drone and official operation in FY2024.

Figure 1 is a chart of implementation plan for this project by JCAB.

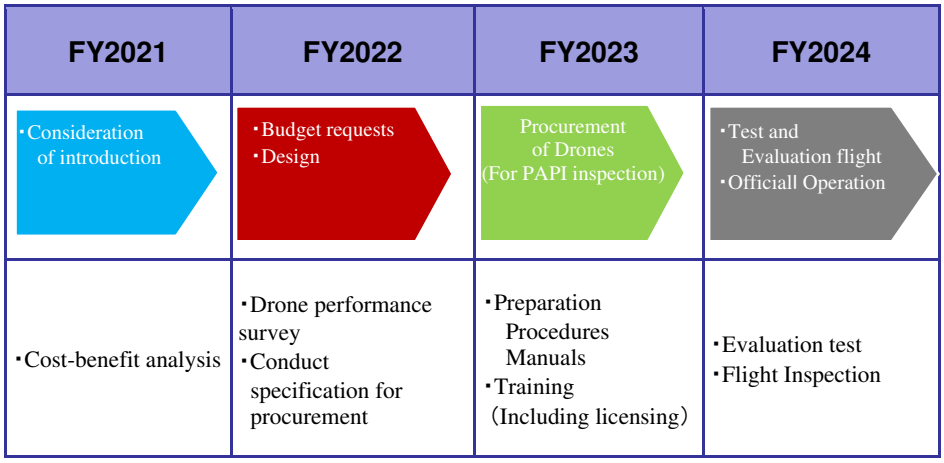

Figure 1. Implementation plan utilizing Drone for flight inspection by JCAB.

The first airport where flight inspections using Drone will be conducted will be Tokyo International Airport, the busiest airport in Japan, where the introduction of PAPI flight inspections is expected to be highly effective. By conducting visual approach angle inspections with Drone, it is expected that the number of low approaches conducted by flight inspection aircraft will be reduced from three to one per a facility.

SPECIFICATIONS OF DRONE

Focusing on PAPI visual approach angle inspections, JCAB examined the performance requirements for an unmanned aerial vehicle suitable for this purpose and decided to procure a drone with the following specifications in fiscal year 2023. Figure 2 is an image of drone for PAPI flight inspection.

- Type: Multicopter type
- Maximum takeoff weight: less than 25 kg
- Maximum wind speed resistance: 10m/s or more
- Operating environment temperature : Must satisfy 0～+ 40 ℃ (Without Batteries)
- The drone shall fly along a specified route automatically with its nose always pointing to a pre-set point.
- The drone will be equipped with a gimbal-mounted camera, peripherals, PAPI inspection software and a tethering device for safety.
- The drone shall be capable of descent maintaining the specified angle.
- The drone has a battery capacity of more than 15 minutes to fly, and the battery can be replaced while it is powered on.

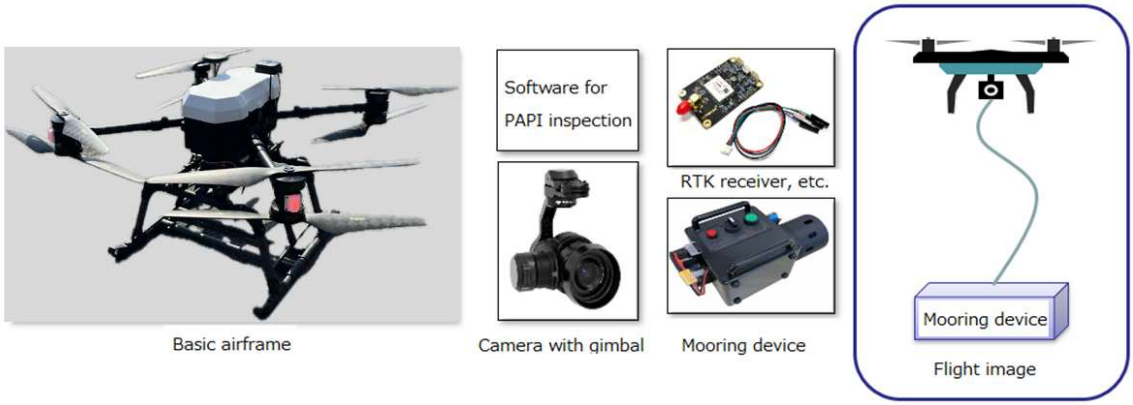

Figure 2. Image of drone for PAPI flight inspection

In addition, the following functions shall be available for the inspection of the visual angle approach of PAPI.

- In the analysis, the positioning error shall be within 61 cm horizontally and 8.3 cm vertically.
- The drone has a capable to output data (PAPI vertical angle, flight altitude, flight distance, PAPI horizontal angle, etc.) in real time.
- The drone has a capable to measure the angle from the PAPI at the event button timing at the PAPI red-white change point.

FLIGHT PERMISSION

Generally, in order to obtain a flight permit for an UAV, it is necessary to submit a flight permit application and a flight plan to the relevant authorities in charge. In Japan, these procedures are conducted by the Drone/UAS Information Platform System (DIPS). Applicants for the use of UAV submit information online via DIPS, including aircraft/pilot information, flight location and method, etc., and a screening officer verifies this information and issues a flight permit. Figure 3 shows an image of how DIPS is used.

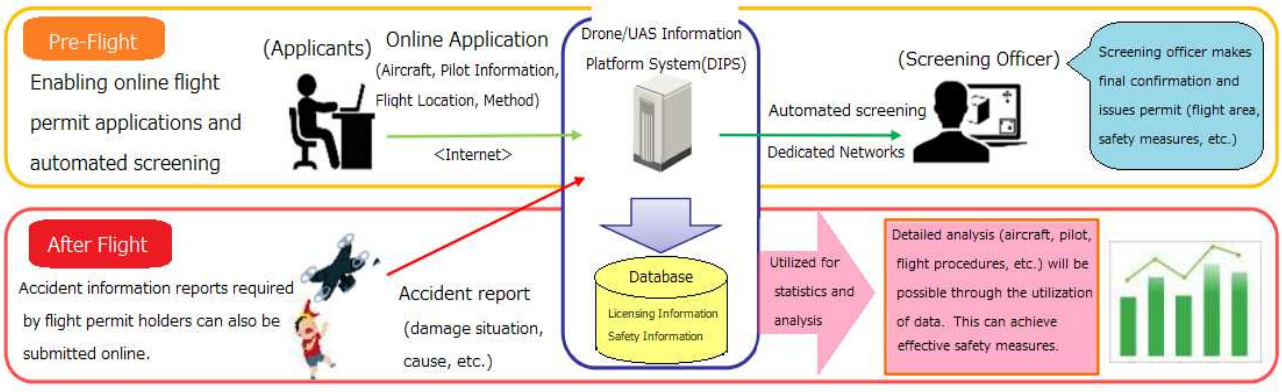

Figure 3: Procedures for flights in the Drone/UAS Information Platform System (DIPS)

TEAM FOR PAPI FLIGHT INSPECTION BY DRONE

In order to ensure safety, typical team for inspections using drone will consist of a drone pilot, a person in charge of flight inspections, and a monitor.

EVALUATION

Angle inspections of each light instrument of the PAPI are conducted at a distance of at least 250 m from the PAPI (300 m to 400 m away is recommended), with the drone pilot ascending and descending vertically, and the flight inspector checking images captured by a camera equipped on the drone by a terminal (laptop) on the ground. ABCD the average value is obtained by measuring the "angle of change from red to white and from white to red" for each of a total of four lights. Since the terminal on the ground has a function to replay the video images, differences in both real-time and replay analysis will also be checked. The flight pattern is shown in Figure 4.

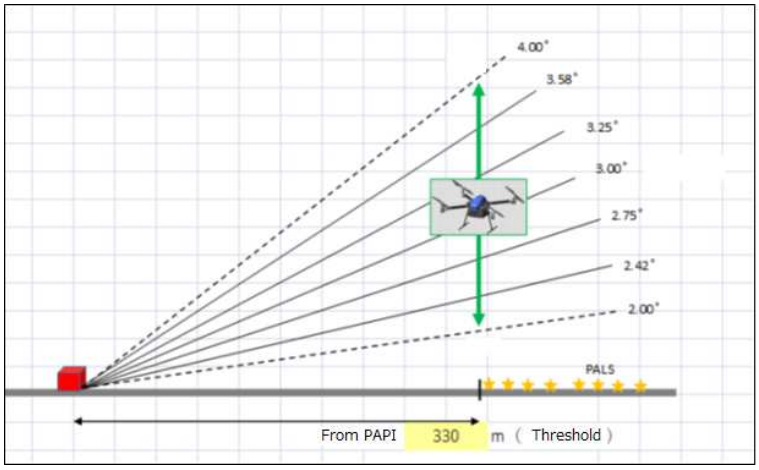

Figure 4. Flight pattern for PAPI flight inspection

PAPI (18/36) at CHUBU CENTRAIR International Airport, which is adjacent to the Flight Inspection Center, will be the target facility for evaluation. The evaluation period will be four months, and visual and error evaluations are scheduled to be conducted from June 2024 using the following judgment methods from the standpoint of availability. The evaluation will consist of a visual evaluation to check the visual angle of approach using the onboard camera of the drone for flight inspection, an error evaluation (stand-alone) to check the variation of errors in the visual evaluation, and a comparative evaluation to check the difference in measurement of the drone and the flight inspection aircraft. Details are shown below.

- Visual Evaluation (Feasibility study for identification of visual approach angle using onboard camera for flight inspection)

  (1) Number of evaluators

  Since this is a subjective evaluation, three evaluators will check the visibility under similar conditions from the viewpoint of equalizing the evaluation results.

  (2) Evaluation position

  The camera image visibility will be checked at different evaluation positions to evaluate the adequacy of visual performance required for visual angle of approach inspections. The two evaluation locations are approximately 250 m and 400 m from the PAPI. If the evaluation position is closer to the PAPI, the brightness of the lights is stronger and color discrimination is more difficult, but the flight altitude of the drone can be lower. On the other

hand, if the evaluation location is far from the PAPI, color discrimination is easier, but the flight altitude of the drone is higher, which results in greater fluctuation due to wind effects, and the flight is also expected to consume more battery power.

(3) Evaluation criteria

Two things are to be confirmed: the appearance of color change for each of the four ABCD lights must be similar, and the color change (red and white) must be clearly distinguishable. The combination of evaluation position and evaluator is shown in Figure 5. Figure 6 shows an image of the evaluation.

Condition No.	Evaluation position (example)	evaluator
A1	About 250m from PAPI	A
A2	About 250m from PAPI	B
A3	About 250m from PAPI	C
A4	About 400m from PAPI	A
A5	About 400m from PAPI	B
A6	About 400m from PAPI	C

Figure 5. Table of combinations of evaluation positions and evaluators

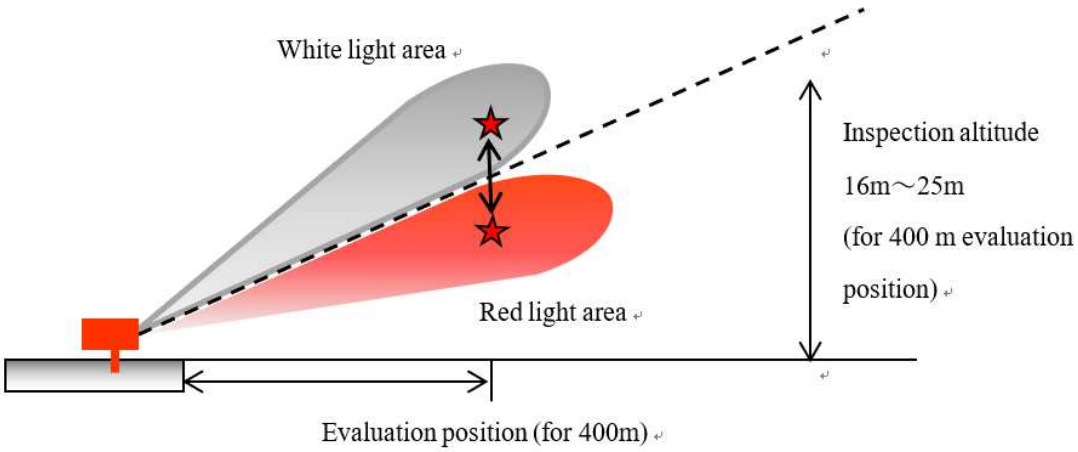

Figure 6. Evaluation image

- Error evaluation (standalone)

After confirming that the performance of each of the four ABCD lights is the same by visual evaluation, only the B light is used as the sample for evaluation. As in the visual evaluation, “the color of the lights changes from red to white and from white to red” is measured twice as one set, and the average angle is calculated from the measured values. Since the number of samples is small and the mean is estimated, the evaluation method uses interval estimation with 95% confidence using T-distribution to confirm that the range of estimated values (μ) that can be taken by the drone meets the evaluation criteria. The evaluation criteria are that the acquired sample is

within ±0.05° of the center value at the 95% confidence interval. An image of the 95% confidence interval by t-distribution is shown in Figure 7.

Formula for interval estimation with 95% (2σ) confidence using t-distribution

μ: Population mean (Unmanned aircraft estimate)、$\bar{X}$: Sample mean、
s: Sample standard deviation、n: Number of samples
t: Statistic (A value determined by the reliability and number of samples in the t-distribution. Refer to the list)

$$\bar{X} - t\frac{s}{\sqrt{n}} \leq \mu \leq \bar{X} + t\frac{s}{\sqrt{n}}$$

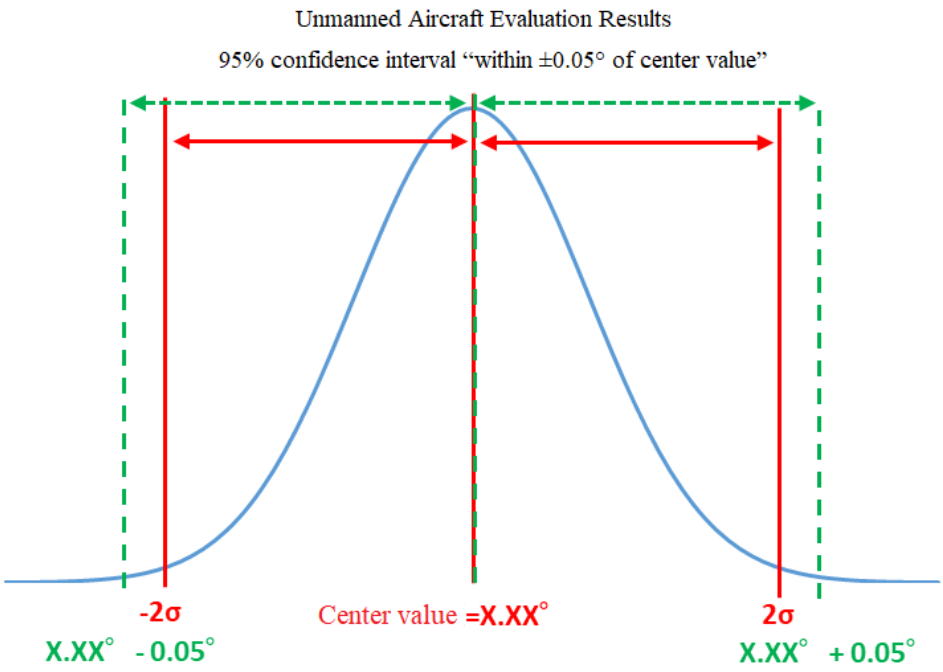

Figure 7: Image of 95% confidence interval based on t-distribution

- Comparative Evaluation (Comparison with flight inspection aircraft)

As in the case of a stand-alone evaluation, a 95% confidence interval estimation using a t-distribution is performed based on the difference between the inspection results obtained by the drone under evaluation and the flight inspection aircraft, and it is confirmed that the range of error estimates that can be obtained by the drone does not differ from the inspection results obtained by the flight inspection aircraft. The evaluation criterion is that the difference between the acquired sample and the inspection result of the inspection aircraft is within 0.00°±0.05° within the 95% confidence interval.

OTHER CHALLENGES IN IMPLEMENTING FLIGHT INSPECTIONS ON DRONE

In case of introducing a drone, in addition to obtaining the performance required for the mission, consideration must also be given to the use of frequencies, inspection times, and weather conditions. It is also necessary to prepare for accidents (insurance and accident handling procedures) due to operational errors or malfunctions of drone.

（1）Frequency usage and coordination

The 5.7Ghz frequency band is used for data transmission of video images acquired by cameras mounted on UAV to flight inspection terminals on the ground. This 5.7Ghz band is the frequency newly distributed to UAS (UAV Systems) in ITU-R in 2012. In Japan, it has been available for long-distance transmission of high-quality images since 2016. The license for the use of this frequency is valid for five years, so if it is to be used continuously, an application for relicensing must be made every five years.

In order to use such frequencies, it is necessary to share frequency resources and coordinate frequency use among drone operators to ensure the necessary communications. In addition, since the same and adjacent frequency bands are used for other purposes, it is necessary to operate with consideration for these radio stations. In Japan, these adjustments can be made by joining an organization that coordinates the use of the frequencies by drone operators.

（2）The time zone of flight inspection by drone (conducted during runway closure hours (nighttime))

In Japan, the airspace around airports and other facilities is an airspace that may affect the safety of aircraft navigation. Therefore, prior permission from the airport administrator must be obtained when flying a drone in this airspace. Also, when conducting inspections at night during runway closure hours, due to the lack of visibility, it is necessary to pay close attention to the circumstance in case of transporting a drone to aiming points /sites and during flight inspections.

（3）Weather

Drone operations are greatly affected by weather conditions such as rain and wind. In general, multi-copter drone is difficult to fly in rain, snow, or wind speeds of 5 m/s or higher due to propeller and structural limitations. Temperatures must also be taken into consideration. Therefore, it is necessary to plan the inspection schedule well in advance, considering the possibility of postponing or changing the inspection schedule due to weather conditions.

（4）Responsibility in the event of an accident

In case of an accident or serious incident involving UAV in Japan, the person who operates the UAV must immediately stop the flight operation, shall provide first aid to the injured, and promptly report the details of the incident to the regulatory authorities using DIPS.

VISION OF THE FUTURE

As a future vision for the use of UAV for flight inspections in Japan, JCAB plan to introduce flight inspections for ILS in the future. And we will continue to assess the feasibility and cost-effectiveness of this introduction. In addition, from the perspective of increasing the sophistication and efficiency of flight inspections, we will continue to actively explore the use of new technologies, particularly with regard to the implementation of flight inspections using RPAS (Remotely Piloted Aircraft Systems), and we will continue to focus on the improvement of technology and development of research in the future.

CONCLUSIONS

By utilizing drone for flight inspections for PAPI in FY2024, inspections at airports with busy traffic can be conducted during nighttime hours outside of airport operating hours, JCAB will contribute to reducing the impact on airlines and other operators, reducing CO2 emissions, and reducing noise.

JCAB shares the above activities and invites you to discuss the following topics regarding the use of UAV for flight inspection:

- Invite issues in countries/organizations that have already introduced
- Invitation to advise on challenges in our country's implementation
- Invite advice on evaluation criteria and methods