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Inspection of Components with the Support of the Drones

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Abstract - *There is quite frequent requirement to provide load-bearing structures in order to safely access components installed at height. This implies, even for the initial and preliminary analysis activities, the construction of scaffolding or the use of special equipment such as lifting platforms. Therefore, considerations regarding technical times and costs to be incurred are objective and necessary. Nowadays, the technological development of the RPAS (Remotely Piloted Aircraft Systems) allows the effective bypass of the above-mentioned difficulties, allowing the carrying out of various checks useful to formulate a possible following campaign of punctual and localized checks. The small size and the sophisticated handling systems gives the possibility of locating with precision in the space at different heights, even in areas characterized by access difficulties. The on-site activities must be conducted by devices and personnel in possession of appropriate authorizations and certifications.*

The objective of this article is to propose basic guidelines for carrying out surveys with the support of RPAS. In particular, the technical considerations to be considered for the choice and characteristics of the device and its accessories as well as the necessary actions such as the preparation of the flight plan, risk assessment and communication to the competent groups.

Key Words: Drone, Remotely Piloted Aircraft Systems, Inspection, NDT (Non Destructive Testing), Corrosion.

1. INTRODUCTION

The drone, also called unmanned aerial vehicle (UAV), can be equipped with different devices specific to the type of survey to be performed. We are witnessing the advent of a new era of robots - drones - that can autonomously fly in natural and man-made environments. Autonomous flight in confined spaces presents great scientific and technical [1].

Initially, the uses were only in the military sphere. It is only recently that the civilian application is being explored en masse [2]. Certainly, although its use is very widespread in the military field, it is in the civil field where its applications, with a broad range of use, presents the greatest challenges, although the actual legal framework reduces its possibilities due to a very restricted use of these devices [3]. Some industry and policy actors are concerned about public opposition to civil drones, in particular because of their association with military drones [4].

In fact, in addition to the camera with sensors in the visible and infrared band also electronic noses, gas detectors, spectrometric chambers, laser scanners can be installed. Depending on the aforementioned devices, it is possible to perform surveys relating to, for example: structural subsidence, corrosion, cracks, gas or liquid leaks, energy analysis, fishery protection, forest fire detection, natural disaster monitoring, contamination measurement, road traffic surveillance, power and pipeline inspection [5].

2. REQUIREMENTS FOR SUPPLIED DEVICES

To perform inspections, on the aircraft, are mounted special digital devices that acquire and transmit information. Usually, ultrasonic sensors, color, thermal or infrared cameras or laser range finders are used to acquire information about the surrounding environment [6]. These devices must be characterized by reduced dimensions and weights.

On-board sensor types:

- proprioceptor: IMU (gyroscope, accelerometer), compass, altimeter, GPS module, payload measurement;
- interoceptive: camera (CMOS, infrared), gamma sensors (radar, sonar, lidar);
- exteroceptive: internal / external thermometer, gimbaled camera.

In the visible field inspections, high-resolution cameras are used, i.e. 4k (3840 × 2160 pixels). We highlight below some of the characteristic possibilities:

- 20-megapixel wide-angle camera mounted on 3-axis brushless gimbal;
- 1080p / 60 fps video.

Interesting results can be acquired with the multi-spectral sensor that is able to record the amount of reflected energy of objects of the Earth's surface in the different wavelengths of the electromagnetic spectrum (generally visible and infrared). The multi-spectral sensor then returns a multi-spectral image that allows, through the analysis of the spectral response in the different bands acquired, to extract territorial information and produce accurate thematic maps with the use of classifiers. Possible technical features of the multi-spectral sensor:

- 4-CCD multi-spectral camera and single optic;

- 2048x2048 pixel 12bit CCD;
- Spectral sensitivity range of CCDs: 350 - 950 nm;
- 12 selectable and interchangeable interference filters (3 x CCD);
- Apochromatic F35 / 2.8 objective.

For infrared surveys, it is necessary to distinguish between non-radiometric and radiometric cameras. The former only detects the thermal energy (associated with the infrared component) present on a surface of a certain object, without entering into physical contact with the same (non-invasive inspections) consequently providing essentially a thermal image that shows the differences in temperature on the object or area that we analyze, without measuring the temperature accurately. The latter, on the other hand, also allow the detection of the temperature for a single point on the image [7].

According to the needs, it is possible to choose different models having the following performance characteristics:

Table -1: - Technical features of IR cameras.

Video resolution	320 × 240	÷	640 × 480
Thermal sensitivity (NETD)	40 mK	÷	100 mK
Accuracy rating	4%	÷	2%
Pixel Pitch	17 μm	÷	25 μm
Optic	6 mm	÷	19 mm
Frame rate	9 Hz	÷	60 Hz
Digital Zoom	2X	÷	10X
Spectral field	7.5 μm	÷	13.5 μm

2.1 Resolution test chart

To judge an image the following parameters are fundamental:

- Resolution: the ability of an optical device to clearly define a particular size or feature. Most commonly a grating is used to measure the resolution in line pairs per mm.
- Distortion: the alteration of the optical image caused by imperfections or faults in the optical components. A percentage measurement is normally used.
- Contrast: the measurement of the ability of an optical device to clearly separate the light and dark areas of an image. Normally expressed in terms of percentage.

Resolution test targets are typically used to measure the resolution of an imaging system. They consist of reference line patterns with well-defined thicknesses and spacings and are designed to be placed in the same plane as the object being imaged. By identifying the largest set of non-distinguishable lines, one determines the resolving power of a given system. The camera is said to "resolve" a chart element, if the horizontal and the vertical bars can still be recognized as three distinct bars und don't blur into one another. In practice, the spatial resolution of an imaging system is measured by simply inspecting the system's image of the slide. The largest element observed without distinct image contrast indicates the approximate resolution limit. This element's label is noted by the observer (each group, and each element within a group, is labeled with a single digit). This pair of digits indicates a given element's row and column location in the series table, which in turn defines the spatial frequency of each element, and thus the available resolution of the system [8]. The resolution test charts can also be used in cases where drones are used [9].

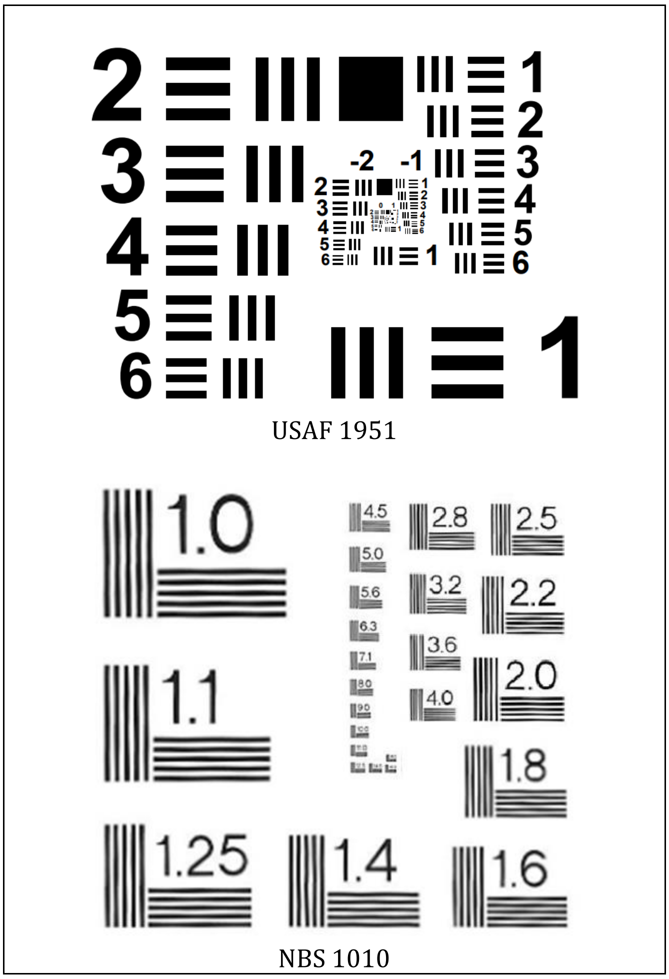

Fig -1: Examples of resolution test chart

3. APPLICATIONS AND OPPORTUNITIES

The use of RPAS for investigations has taken significant levels, extending the application to both the industrial and agricultural world. For example, the fields of application can be:

- Inspections of equipment and / or pipes
- Flare inspections
- Direct contact with the component under consideration is not required
- Acquisition with thermal imaging cameras and laser scanners
- Control of solar panels efficiency
- Pillars and structural walls inspections
- Monitoring landfills and orography of water courses
- Mapping and surveillance of coasts and piers
- Control of crops in agriculture
- Orthophoto for cartography, georeferencing, 3D modeling
- Remote sensing with multi-spectral camera
- Acquisition of images and videos in high definition [7]

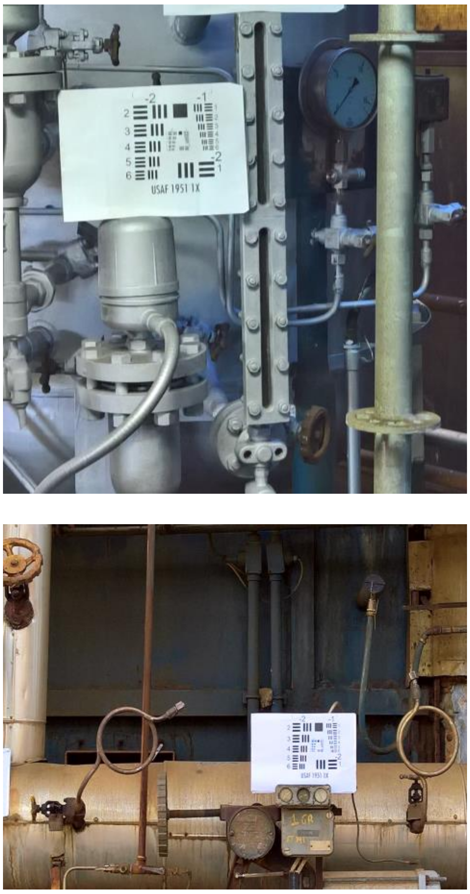

Fig. -2: Example of digital visual inspection of a mechanic components

For example, the experience of inspections on power lines is significant and at an advanced level. The main objective of the project is to provide a low cost solution for aerial power line inspection based on unmanned vehicles which have to be able to perform long range flights in relatively short time [10]. Also interesting is the experience in refineries structures where of the drones are equipped with electro-magnetic hold mount elements to stick the ultrasonic sensor probe on the surface of the metallic structure and to measure thickness of wall [11]. Innovative systems for the inspection are the patent of the inventor J. M. Cavote in which the drone moves in closed spaces and can land on horizontal or vertical surfaces [12] and the patent of the inventor B. Richman et al. where it is possible to obtain information on potential damages on the roof of a building [13].

The following are the strengths and weaknesses related to the use of the RPAS for monitoring and inspection activities. Advantages:

- Small aircraft
- Easy transportability
- Reduction of time and costs
- Possibility to easily inspect components that present difficulties in direct access
- Fast, flexible and repeatable operations
- Good data resolution
- No infrastructure necessary for operations
- Inspection with running systems

Disadvantages:

- Mediocre results in case of wind presence
- Weight limitation and load size (e.g. camera, etc.)
- Reduced power engines
- Reduced battery life
- Over-temperature of the motor

For this last case it is possible, through a special system with sensors connected to the engine, to land the drone safely when the engine temperature exceeds the pre-set threshold [14].

4. CLASSES AND CATEGORIES OF RPA

For the purposes of obtaining the pilot certificate, the RPA are divided into Classes and Categories according to the Operating Mass at Takeoff (MOD) or the total weight of the RPA including any type of accessory at the time of use (gimbal, camera, terminator, etc. ..).
A pilot may have recognized multiple classes and categories.

Table -2: - Types of classes with which the Unmanned aircraft system (UAV) are divided

class	range
Very Light (VL)	0,3kg <MOD≤ 4kg
Light (L)	4kg <MOD≤ 25kg
Heavy (H)	MOD> 25 kg

Below a mass threshold of 250 g it is reasonable to classify drones as "harmless" [15]. The technique has achieved important and innovative developments by making small and mini drones [16] inspired by insects [17]. The potential for inspection in these cases becomes considerable.

5. PROCEDURES FOR NON-CRITICAL OPERATIONS

The inspection and monitoring activities with the assistance of the RPAS, must be carefully evaluated and designed to verify the environmental compatibility (component morphology, orography, adjacent structures, presence of people, etc.) to the flight operations. In general, it is desirable that the operations are defined in such a way to be classified as "non-critical". In this case, the procedures provide: before starting operations, the operator must submit to National Aviation Authority of its country the declaration attesting the compliance with the applicable sections of the Regulation "Remotely piloted aircraft" and indicate the conditions and limits applicable to the flight operations envisaged, including, where appropriate, the need to operate in segregated airspace. The operator is responsible for assessing the risk associated with the operations and for the continuation of the conditions that make the operation non-critical.

The inspection investigations, if classified as non-critical operations, must be conducted in a volume of space of 150 meters in height and 500 meters in radius and among the following conditions:

- At a horizontal distance of adequate security (and never less than 150 m) from congested areas;
- At a distance of at least 50 m from people and things that are not under the direct control of the operator;
- In daylight conditions.
- Under conditions of BVLOS;
- Outside the Aerodrome Traffic Zone (ATZ) and from the areas below the take-off and landing trajectories;
- In the areas below the take-off and landing trajectories beyond the limits of the ATZ and up to 15 km, the height limit for the operations of the RPAS is set at 30m AGL (Above Ground Level);
- At a distance of more than 5 km from the airport (Aerodrome Reference Point or published geographical coordinates), where an ATZ is not established to protect flight operations;

6. AIRCRAFT AND PILOTS REQUIREMENTS

The RPAS are subdivided into two main types:

- Fixed wing, planning wing drones that allows measurements in very large surfaces, in relation to a higher speed of navigation and a lower batteries consumption;
- Rotary wing, multi-rotor drones that can obtain the maximum detail in medium / small size areas, to allow close scans.

The rotors can be variable from 3 to 8. The materials used are very resistant and light in order to guarantee reduced weights.

The pilot of the RPA, or recognized operator for specialized operations, for operations in VLOS conditions must be in possession of an appropriate certificate. For the achievement will have to overcome in succession

- A medical examination for the psycho-physical requirements;
- A theoretical exam related to knowledge of aeronautical law, meteorology, air traffic and the use of the RPAS;
- A practical exam consisting in a mission of at least 10 minutes, whose flight maneuvers must be carried out without the aid of GPS.

The RPA Pilot Certificate is valid for 5 years. At the end of this period the pilot must go to an authorized center, attend a theoretical refresher course (refreshment) and support a proficiency check with an RPA examiner. For the BLOS operations, or for the RPASs of 25 kg or more, a pilot license is required, issued in application of the procedures in use for the issue of the other licenses for the flight personnel.

7. FUTURE EVOLUTIONS OF THE REGULATIONS

The use of drones or Unmanned Aerial Vehicles (UAVs), with their ability to collect data, are re-shaping the way we think about our physical environment. The drones have been legitimized by regulations and licenses from National agencies, for are used for surveying, inspecting, and imaging [18].

Many, and remarkable, are the news that await us with the new European regulation, valid for all EASA (European Aviation Safety Agency) countries that will come into force in the first half of 2019. There will be news on the role of flying schools, distinction between model aircraft and RPAS, geofencing and mandatory registration will be provided. With reference to the current differences between model aircraft and RPAS, a single type called Unmanned Aircraft (UA) will be provided. Although with the possibility of derogations for recreational flights. The new specifications for courses and certifications that will be related to the scenario are particularly significant. Today there are three operational scenarios:

- Recreational and sports flying;
- Specialized non-critical operations;
- Specialized critical operations.

With the obligation to have obtained a license in a flight school for the last two categories. With the new European regulation EASA, the framework is always divided into three categories, but this time they depend on the distance between drone and people: different rules and drones to fly close to people, far or above people. Depending on the scenario, to pilot the drone it is sufficient to simply have knowledge of the manufacturer's instructions or it may be necessary to have attended a final exam course or to have taken a theoretical course in a training center. In the following table a summary is shown of the various possible combinations.

News for the mandatory registration of pilots and drones and transponders are planned. Such registration may relate only to the pilot (in the case drones uses up to 900 grams of mass or impact with an energy of less than 80 joules), or pilot and drone, even with mandatory untransponder if you are flying in areas that require it. In this case, the transponder must send the recording data of the drone, its pilot, the class to which the drone belongs, the altitude and the flight coordinates in addition to the geofencing status. Only small drones up to 250 grams of mass are exempted, only if they are not provided with cameras with more than 5 megapixels on board for reasons related to privacy protection. There are also 5 increasing classes of aircraft from C0 to C4. The C0 is the smallest class, up to 250 grams of weight, which must comply with the European regulations on toys or in any case do not exceed 24 volts, have protected propellers and do not fly beyond 50 meters. C1 is the class of drones up to 900 grams in weight. The flight must be limited to 120 meters (today in Italy the limit is 150 m for the RPAS and 70 m for aircraft models) and the maximum speed cannot exceed 18 meters per second (65 km/h), the maximum voltage is 24 volts. C2 is the class of drones up to 4 kg. The maximum voltage is always 24 volts. Also for them the quota must be limited to 120 meters and contrary to the C1 must have a geofencing system to prevent the flight in the forbidden areas and the flight terminator. C3 are drones up to 25 kg; the characteristics are the same as for C2, except for the voltage rising to 48 volts. C4 finally are drones that do not meet the previous requirements with weight less than 25 kg [7].

8. CONCLUSIONS

In the inspection filed, visual inspection is certainly one of the most convenient and important methods of investigation because it provides a quick overview of the surface conditions of the structure in a very short time. In the case of concrete structures, for example, it is believed that about 80% of the relevant information can be provided by visual inspections with about 20% of the total inspection costs. The visual survey is therefore the first and unavoidable phase of an evaluation process and must be carried out in a rigorous manner, following a logical and schematic procedure. This activity allows, for example, the identification and location of cracks of structural and/or accessory elements, deformations, cracks or surface corrosion. This is a set of elements useful for the assessment of degradation or of the progressive change of an initial state of the material due to time and in response to environmental aggressiveness.

Today the use of RPAS, equipped with accessories for recording digital images in the field of visual and infrared, allows close access to the various areas of the structure to be examined without the need to prepare and use special fixed structures and/or furniture with consequent savings in time and costs. Interesting is the use of the drone as an inspection tool for safety managers within the construction site [19].
A further innovative application concerns the visual examination of bridges. Inspections of visual conditions remain critical to assess the current state of deterioration of a bridge and assign repair or maintenance tasks to ensure continuity of maintenance of the structure. As a tool for inspecting bridge conditions, unmanned aircraft (UAVs) or drones offer considerable potential, allowing visual assessment of a bridge without the need for inspectors to cross the bridge or to use inspection units under the bridge. With current inspection processes that put a strain on existing bridge maintenance resources, the technology can significantly reduce overall inspection costs and disruptions caused to the traveling public. In addition, the use of automated aerial image capture allows engineers to better understand a situation through the 3D spatial context offered by UAV systems [20]. The use of drones to perform visual checks on bridges, and in general civil engineering works, allows inspection to be carried out at a lower cost compared to traditional methods [21]. Even in the case of checks on photovoltaic panels, excellent results are obtained with acceptable costs [22].

The technological level currently available on the market, both for aircraft and for rooms, allows accurate and reliable preliminary analysis.

REFERENCES

[1] D. Floreano, R.J. Wood, "Science, technology and the future of small autonomous drones", Nature, vol. 521, pp. 460–466, ISSN 1476-4687 (online), doi.org/10.1038/nature14542.
[2] S.J. Fox, "The Rise of the Drones: Framework and Governance-Why Risk It", Journal of Air Law and Commerce, vol. 82, 2017.
[3] J.S. Esteve, C. B. Domènech, "Rights and science in the drone era actual challenges in the civil use of drone technology", Rights and Science, ISSN-e 2531-1352, 2017, pp. 117-133.
[4] P. Boucher, "'You Wouldn't have Your Granny Using Them': Drawing Boundaries Between Acceptable and Unacceptable Applications of Civil Drones", Science and Engineering Ethics, October 2016, vol. 22, issue 5, pp. 1391–1418.
[5] ICAO Circular no. 328, Unmanned Aircraft Systems (UAS), ISBN 978-92-9231-751-5.
[6] K. Máthé, L. Buşoniu, "Vision and Control for UAVs: A Survey of General Methods and of Inexpensive Platforms for Infrastructure Inspection", Sensors, 2015, vol. 15, iusse 7, pp. 14887-14916, doi.org/10.3390/s150714887.

[7] F. Giacobbe, A. Sili, F. Milazzo, "Analisi su componenti in quota. Valutazioni, opportunità e caratteristiche dei droni", Proceedings of National Conference on Non-Destructive Testing, Diagnostic, Monitoring, 25/27 October 2017, Pero (MI), Italy.
[8] MIL-STD-150A, "Military standard: photographic lenses", 1959
[9] O. Mian, J. Lutes, G. Lipa, J.J. Hutton, E. Gavelle, S. Borghini , "Direct georeferencing on small unmanned aerial platforms for improved reliability and accuracy of mapping without the need for ground control points", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XL-1/W4, 2015
[10] G.J. Adabo, "Long Range Unmanned Aircraft System for Power Line Inspection of Brazilian Electrical System", Journal of Energy and Power Engineering, vol. 8, number 2, February 2014, pp. 394-398.
[11] R.A. Mattar, R. Kalai, "Development of a Wall-Sticking Drone for Non-Destructive Ultrasonic and Corrosion Testing", Drones, 2018, vol. 2, iusse 1, doi.org/10.3390/drones2010008.
[12] J.M. Cavote, "Drone for inspection of enclosed space and method thereof", patent No.: US 8,874,283 B1.
[13] B. Richman, B.J. Michini, A.J. Poole, "Unmanned aerial vehicle rooftop inspection system", patent No.: US 10,061,470 B2.
[14] L. Huimin, L. Yujie, M. Shenglin, W. Dong, K. Hyoungseop, S. Seiichi, "Motor Anomaly Detection for Unmanned Aerial Vehicles Using Reinforcement Learning", IEEE Internet of Things Journal, vol. 5, issue: 4.
[15] A la Cour-Harbo, "Mass threshold for 'harmless' drones", International Journal of Micro Air Vehicles, 2017, journals.sagepub.com, doi.org/10.1177/1756829317691991.
[16] M. Hassanalian, A. Abdelkefi, "Classifications, applications, and design challenges of drones: A review", Progress in Aerospace Sciences, vol. 91, May 2017, pp. 99-131, doi.org/10.1016/j.paerosci.2017.04.003.
[17] K.Y. Ma, P. Chirarattananon, S.B. Fuller, R.J. Wood, "Controlled Flight of a Biologically Inspired, Insect-Scale Robot", Science, May 2013, vol. 340, issue 6132, pp. 603-607, doi: 10.1126/science.1231806.
[18] B. Rao, A.G. Gopi, R. Maione, "The societal impact of commercial drones", Technology in Society, vol. 45, May 2016, pp. 83-90, doi.org/10.1016/j.techsoc.2016.02.009
[19] R.J. Irizarry, M. Gheisari, B.N. Walker "Usability assessment of drone technology as safety inspection tools", Journal of Information Technology in Construction, ISSN 1874-4753, ITcon vol. 17, 2012.
[20] B. Chan, H. Guan, J. Jo, M. Blumenstein, "Towards UAV-based bridge inspection systems: a review and an application perspective", Structural Monitoring and Maintenance, vol. 2, issue 3, pp. 283-300, 2288-6605 (pISSN), 2288-6613 (eISSN), doi.org/10.12989/smm.2015.2.3.283, 2015.
[21] J. Seo, L. Duque, J. Wacker, "Drone-enabled bridge inspection methodology and application", Automation in Construction, vol. 94, October 2018, pp. 112-126, doi.org/10.1016/j.autcon.2018.06.006.
[22] S.G. Saavedra, L.H. Callejo, O.D. Perez, "Technological review of the instrumentation used in aerial thermographic inspection of photovoltaic plants", Renewable and Sustainable Energy Reviews, vol. 93, October 2018, pp. 566-579, doi.org/10.1016/j.rser.2018.05.027.

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