Implementation of RPAS in Flight Inspection Activities at Brazilian Airspace Control System (SISCEAB)

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ABSTRACT

With more than 900 navaids under its responsibility to carry out flight inspections and maintain the high operational and safety standards of air navigation in the Brazilian Airspace Control System (SISCEAB), the Brazilian Department of Airspace Control (DECEA)), through the Special Flight Inspection Group (GEIV) and the Institute of Airspace Control (ICEA), has implemented studies to enable the use of Remotely Piloted Aircraft Systems (RPAS) in the conduct of flight inspections of navaids.

GEIV's mission is to assess the effectiveness of systems that support air navigation, equipment and procedures in order to ensure safe operation of all aircraft in Brazilian airspace during all phases of flight, especially in adverse weather conditions. In this context, GEIV was responsible for the implementation of the use of RPAS in the conduct of flight inspections of visual navaids at SISCEAB, in order to generate cost reductions, greater operational flexibility to maintainers and mitigate operational impacts to terminal areas.

This paper presents an analysis of the operational design and actions generated for the implementation of the RPAS in the flight inspection of visual navaids at SISCEAB, the initial results obtained in the project validation campaigns and the intentions of applying this type of equipment for flight inspection of navigation signals generated by ILS and VOR. This concept was conceived aligned with the activity and the access rules of the RPAS to Brazilian airspace.

INTRODUCTION

The use of the Remotely Piloted Aircraft System (RPAS) in the execution of flight inspection missions in SISCEAB has as its focus to reduce operational costs, as well as to provide agility in carrying out periodic inspections of navaids, mitigating impacts in terminal areas (TMA) or aerodromes that are supported by navaids which require constant flight inspections.

The RPAS consists of RPA (aircraft), RPS (remote piloting station), pilot link (also called Command and Control link or C2 link) and associated components such as launch and pickup systems, communication equipment with ATS and surveillance units, navigation equipment, flight management, autopilot, emergency and flight termination systems, among others. As an RPA is an aircraft (ICAO, 2015), its operation must obey the current rules, except for specific laws or special authorizations issued by a competent aeronautical authority.

Therefore, it cannot generate negative security and capacity impacts for SISCEAB, the operation of this technology being subject to accommodation and limited to specific areas or special conditions (BRAZIL, 2016). Operational safety is paramount. Hence, the operation of an RPAS shall be such as to minimize the risk of danger to manned aircraft and to persons and property in the ground.

FLIGHT INSPECTION AT BRAZILIAN AIRSPACE CONTROL SYSTEM (SISCEAB)

The flight inspection in Brazil is carried out by the Special Flight Inspection Group (GEIV), a unit of DECEA, whose mission is to assess the effectiveness of systems that support air navigation, equipment and procedures in order to ensure safe operation of the all aircraft in Brazilian airspace during all phases of flight, especially in adverse weather conditions. Currently, the organization regularly inspects the approximately 900 installed navaids and systems that support air traffic in Brazil. In this context, the supervision of the flight inspection activity in SISCEAB is carried out by DECEA Subdepartment of Operations (SDOP).

Over the years, the increase in the number of flights has boosted the amount of flight inspections. For instance, given the number of navigation aids and considering the interval between periodic flight inspections applied in Brazil, 54 VOR, 75 ILS, 85 PAPI/VASIS are inspected annually, without considering special and homologation inspections.

Fig. 1 - GEIV's scope of responsibility

The flight inspection aircraft, in accordance with BRAZIL (2017), must be adequate to comply with the verification of the navaids throughout its operational range and must be aerodynamically stable and capable of supplying energy to the flight inspection systems without causing any interference on the signals to be measured, providing safety and reliability to flight inspection teams.

Flight inspection systems are composed of antennas properly positioned on the aircraft and by the UNIFIS 3000 flight inspection panel capable of collecting, processing and recording in flight the data pertaining to the systems / navaids used in air navigation, approach and landing, in accordance with the tolerances provided in BRAZIL (2017), guaranteeing the reliability and the necessary security to the user.

According to ICAO (2000), the use of aircraft positioning systems (SPA) is necessary to perform the flight inspection in order to determine the accuracy of the signal emitted by the navaid. This system should be independent of the navaid inspected, with the SPA error rate five times better than that published for the signal issued by the aid. The following SPA are used by GEIV to carry out flight inspections:

- DRTT: manual monitoring of the aircraft by the SPA Operator. The THD is coupled to a digital azimuth and elevation data transmitter system, the data being transmitted automatically by a data link;

- DGPS: the DGPS station provides GPS of the Flight Inspection System (SIV) with positioning corrections that allow greater accuracy to the SIV especially for use in precision approach navaids. The DGPS (NSM-2100-GRS) used by GEIV allows a decrease to the GPS error of the SIV to about 20 centimeters.

The training of Aircraft Positioning System Operators is carried out in course GEI106, in which instructions are given on the aircraft positioning equipment used in the flight inspection (THD, DRTT and DGPS) and practical assessments are provided of the execution of the actions required by the SPA Operators for the conduct of flight inspection missions.

Flight inspection teams require highly specialized and qualified personnel to carry out their duties. The teams consist of an Operational Pilot, an Inspector Pilot, a Flight Inspection System Operator, and Aircraft Positioning System Operators. The training of the Pilot Inspector and the Flight Inspection Systems Operator is combined, and divided into three modules, in which the pilots and technicians study standardizations related to the flight inspection activity, flight inspection standards and all kinds of SISCEAB navaids functionalities. Training lasts between two and three years and involves at least 100 hours of effective flight inspection.

Furthermore, dealing with flight inspections in the middle of Brazil's busiest terminals like São Paulo and Rio de Janeiro is a growing challenge. Many measures are adopted by the stakeholders to decrease the impact of this activity. For example, specific time frames are scheduled for performing flight inspection in order to avoid the peak hours. In spite of that, the number of holdings between each approach is increasing, which results in a longer flight time and, consequently, in a cost increase for performing the inspection.

Despite the significant investment in technology and operational procedures, which provide efficiency, the flight inspection activity in Brazil still has a lot of challenges to face. Among them, it is necessary to point out the attempt to mitigate the impact of flight inspections in busy Terminal Control Areas and reduce the cost of the activity itself.

REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS) FEATURES

The RPAS involves "a remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design" (ICAO, 2015), being all the component structures of the system considered for the operation.

Fig. 2 - RPAS component structures

According to BRAZIL (2016), the RPAS have modified the deployment of maintenance services and monitoring services around the world, according to the demand for higher mobility and high-quality data. This aeronautical segment has a wide range of applications and their aircraft present varied designs and aerodynamic profiles. Accordingly, "first of all it is necessary to define the specifications of the mission package. Many options are available and operational possibilities ranges from a simple mission to a complete integration of various systems" (MARIACHIC, 2016).

According to ICAO (2015), RPAS operations could be divided into Visual Line-of-Sight (VLOS) and Beyond Visual-Line-of-Sight (BVLOS) operations. In VLOS, the remote pilot must maintain direct visual contact with the RPA at all times, unaided by any device other than corrective lens.

Otherwise, “when the remote pilot or RPA observer(s) cannot maintain direct unaided visual contact with the RPA, the operations are considered BVLOS. Minimum equipment requirements to support BVLOS operations increase significantly as the range and complexity of such operations increase, as does the cost involved in ensuring the robustness of the C2 link. The ability to detect conflicting traffic or obstacles and take appropriate action to avoid them is essential” (ICAO, 2015).

Among the various types of RPA, the table below summarizes the characteristics of each segment:

RPA Type	Operation Type	Airspeed	Range	Operational Ceiling	Payload	Logistic	Cost
Rotary Wing	VLOS/BVLOS	Low	Low	Low	Low	Low	Low
Fixed Wing	BVLOS	Medium	Medium	Medium**	Medium	High	Medium*
Multirotor	VLOS/BVLOS	Low	Low	Low	Low	Low	Low

* Depending on the type of equipment, payload and costs may be high.
** Depending on the type of equipment, operational ceiling may be high.

Table 1 - RPA Features

Regarding the use of SPA, the vast majority of RPAS use the RTK technique (Real Time Kinematics). The RTK System makes corrections to the data collected by the GPS of the aircraft in real time with precision of centimeters. That is because it uses a special ground base, which contains a precision Geodetic GPS. It records the point where it is positioned, serving as a static geographic reference for the RPA that is in motion. During the flight, the RTK sensor (on the aircraft) exchanges information with satellites and with the base to correct the geographical positioning of the RPA, taking into account the fixed point the base collected. A disadvantage of conventional RTK is the loss of data due to aircraft telemetry oscillations. During a flight with the RPA, the signal may suffer some interference and this, when it happens, compromises the data generated by the RTK during that short period of time.

Another technique used is the Post Processed Kinematic (PPK) whose system is very similar to the RTK, but does not depend on the telemetry link, ensuring that all the geographic data is stored in the aircraft's on-board computer. In this way, they can be processed after the flight. That is, we can say that this is a redundant system (backup), which guarantees the accuracy of the data even if the aircraft misses the base during a long-haul flight.

RPAS INTO BRAZILIAN AIRSPACE CONTROL

In Brazil, the RPAS operation is regulated by three regulatory agencies: ANATEL (responsible for the use of the electromagnetic spectrum and for the homologation of the C² link and the RPS), ANAC (responsible for the type approval of the equipment and the type of operation, aircraft registration and operator training) and DECEA (responsible for the analysis and authorization of access and use of airspace by RPA).

ANAC issued, in May 2017, regulation RBAC-E94 that regulates the use of civil RPAS in Brazil. Although it has no jurisdiction to regulate military equipment, the following aspects related to RBAC-E94 should be highlighted: a) The planned classes were incorporated by ICA 100-40, issued by DECEA, in order to align the concepts of operation; and b) There is no provision for specification of pre-requisites for the training of RPAS operators. With this, there are no approved training courses for RPAS operators.

In Brazil, there are several private operator training courses. In the public sphere, many organizations, such as Firefighters and the Police, have done a good job in the RPAS area and have an internal course for operator training.

Regarding ANAC regulations, RBAC-E94 divided the RPAS into 03 classes, which are:

- **CLASS 1**: Maximum Take Off Weight over 150 kg. The regulation provides for such equipment to undergo a certification process similar to that existing for manned aircraft, promoting adjustments of the certification requirements to the specific case. These drones must be registered with the Brazilian Aeronautical Registry and identified with their nationality and registration marks;
- **CLASS 2**: Maximum Take Off Weight between 25 kg and 150 kg. The regulation establishes the technical requirements that must be observed by the manufacturers and determines that the project approval will occur only once. In addition, these drones must also be registered in the Brazilian Aeronautical Registry and identified with their nationality and registration marks; and

- **CLASS 3**: Maximum Take Off Weight up to 25 kg. The standard determines that Class 3 RPAS that operate beyond the visual line-of-sight (BVLOS) or above 400 feet (120m) must be of a project authorized by ANAC and must be registered and identified with their nationality and registration marks. RPAS of this class that operate up to 400 feet above the ground line and in line-of-sight (VLOS operation) shall not need to be an authorized project, but operator and on the equipment shall be registered with ANAC through the SISANT system.

With regard to the regulation issued by DECEA, ICA 100-40 provides several criteria and guidelines for the safe and coordinated access of airspace by RPAS, being more flexible the use of RPAS with maximum takeoff weight of less than 25 kg.
For the use of RPAS at aerodromes, ICA 100-40 stipulates that "operation from aerodromes shared with manned aircraft shall only be permitted if expressly authorized by the aerodrome administrator and the local ATS provider (if any), subject to the stoppage of manned operations on the ground and in the traffic circuit," and if RPAS night operation is required, such operation shall be subject to compliance with item 4.2.4 - LIGHTS TO BE DISPLAYED BY AIRCRAFT, of ICA 100-12.

ICA 100-40 also provides that the RPA shall be equipped with a device or mechanism, or a pre-programmed flight termination system, function or procedure, automatically or manually operated, which shall take the aircraft to the ground safely, in the event of an interruption or failure of any control systems. The Flight Termination Plan shall be executed as the last resort upon failure of all contingency procedures or in the case of another potential hazard that requires the immediate discontinuation of the flight.

It is established that for operations occurring in controlled airspace, the Operator shall establish procedures to ensure that the Remote Pilot is able to notify the ATS provider responsible for the overflight area immediately of the activation of the Flight Termination Plan. Such notification shall include:
a) The last known position of the RPA;
b) Altitude and Velocity;
c) Endurance;
d) Possible Crash Site; and
(e) Other information deemed relevant.

Another important point to note is that the BVLOS operation requires the issuance of NOTAM by the Regional Authority of DECEA, as well as communication between the Operator and the ATS provider.

RPAS AND FLIGHT INSPECTION ASSUMPTIONS

Studies carried out and presented recently in IFIS 2016 - "*UAVs Flight Inspection: Should We Brace For Impact?*" (MARIACHI, 2016), analyzing the trajectories flown in the inspection of navaids, demonstrated that all operations of Flight Inspection with RPAS are characterized as BVLOS operations, with all associated technical and regulatory requirements as described in ICAO Doc 10019, and adjustments are required for manned aircraft operations with unmanned aircraft.

For PAPI flights, high quality electro-optical equipment with a precise positioning system (RTK, OMNISTAR, STARFIRE, etc.) is required. These aids are evaluated with good precision and with minimum restrictions imposed on the airspace, which is technically feasible, but many of these evaluations can be performed in association with an ILS, and a cost-benefit relationship must be performed.

The IFIS 2016's "*Evaluation of the Suitability of Unmanned Aircraft Systems for Flight Inspection*" (WHITTINGTON, 2016) reports that the use of RPAS provides a number of benefits, as it enables more frequent assessments of air navigation aids, enabling training with equipment capable of capturing signals of air navigation aids, thus reducing the workload for inspection aircraft. However, there is great regulatory difficulty for the RPAS operation.

Regarding the accuracy of the use of RPAS in the in-flight inspection, TI 8200.52 - *Flight Inspection Handbook*, used by the FAA, states that "the use of equipment other than an aircraft configured for in-flight inspection may be necessary. The reliability of such equipment shall be established prior to use for in-flight inspection." As examples of methods for verifying the accuracy of such equipment, TI8200.52 guides you to:
(a) Compare with any aid verified by maintenance or other inspection aircraft;
(b) Compare with two or more operating aids;
(c) Use VOT or similar equipment to test radiated signals.

In addition, ICAO (2010) delineates that due to the high traffic density during the day, conducting flight inspection during the day may cause delays to traffic if there is no coordination. Nevertheless, flight inspections can be conducted at night to avoid interference with normal flight operations, taking into account safety levels appropriate to the conduct of the inspection. So, if applicable, the use of automated RPAS in flight inspection of aerodromes after the last manned operation, at night, could be efficient to reduce impact in the Terminal Area (TMA).

Considering the navaids at SISCEAB and their respective flight inspection features, some considerations can be made can be made about the flight inspection systems and equipment parameters involved, as follows:

Parameters	ILS*	VOR*	Visual Navaids	GNSS	IAC/SID
Airspeed	Medium/High	High	Low	High	Medium/High
Endurance	Medium	High	Low	High	Medium
Range	Medium	High	Low	High	Medium
SPA	DGPS	GPS	DGPS	DGPS	GPS
ATM Impact	High	High	Low	High	High
Flyability	N/A*	N/A*	N/A*	Applicable	Applicable

* N/A – Not Applicable

Table 2. Navaids Flight Inspection Features at SISCEAB

<u>RPAS & FLIGHT INSPECTION AT SISCEAB</u>

As aforementioned, currently, all flight inspections are performed by manned aircraft equipped with modern Flight Inspection Systems (SIV), UNIFIS 3000. This system stands out for providing the results obtained from the evaluated parameters, independently of the Aircraft Positioning System (SPA). Inspection flights are performed in "windows" stipulated by the Air Navigation Management Center (CGNA), during less busy times at the aerodrome to be inspected. However, despite previous coordination, operational impacts still occur at inspected aerodromes, due to the high air traffic flow, especially in large terminals.

In order to reduce costs with navaids inspection, to reduce impacts on Terminal Control Areas (TMA) caused by flight inspection aircraft traffic and also to allow the independence and flexibility of Regional Authorities of DECEA (CINDACTA I, II, III, IV and SRPV-SP) in order to assess their navaids more frequently, the Special Flight Inspection Group (GEIV), together with the Airspace Control Institute (ICEA), the DECEA Operations Subdepartment (SDOP) and Technical Subdepartment (SDTE) of DECEA are conducting studies with the purpose of making feasible the use of the Remotely Piloted Aircraft Systems (RPAS) for flight inspection.

These studies are initially aimed at conducting PAPI, VASIS, ALS, runway and flasher lights, with their conditions established by DECEA, through ICA 100-40, which regulates procedures and defines responsibilities for access to airspace of Remotely Pilot Aircraft Systems (RPAS). The other aids will be approached in future conceptions, considering the degree of difficulty in the development of the sensor to be embedded.

In July 2016, a flight inspection test of visual aids with rotary-wing and fixed-wing RPAS was carried out at SBYS facilities. In this campaign, the following technical / operational needs were verified:
a) Rotary-wing aircraft performed better for visual aids inspection;
b) The flight profiles should be adapted to the RPAS, and the full implementation of the methods for manned aircraft in flight inspection is not efficient;
c) It is necessary that the equipment is automated, enabling prior programming of the flight profiles to be executed;
d) The RPA must have a vertical ascent rate that allows the recognition of the transition angles of the PAPI lights;
e) It has been found that the impact caused by the operation of the rotary wing RPA for the inspection of visual aids is minimal because of the volume of airspace used for the inspection;
f) It is necessary to stipulate an origin point, by means of precise coordinates, in the form of a waypoint that makes it possible to program the angular calculation necessary to verify the PAPI data;
g) It is necessary that, if possible, the calculation of the transition angles of the boxes is automatically done by the RPAS sensors;
h) The view from the camera on the RPA is considered degraded when compared to viewing the navaid with human vision, even using Full HD cameras.

Fig.3 – SBYS Visual Aid RPAS flight inspection test (Source: the author)

Following the tests, ICEA developed a simulation environment to implement the use of RPAS for inspection of visual navaids (PAPI) in conjunction with GEIV.

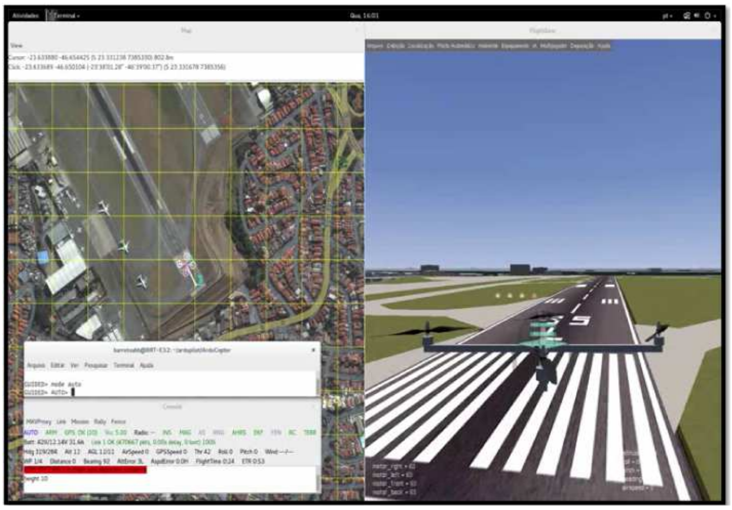

Fig. 4 – Simulated environment for RPAS flight inspection of Visual Navaid (Source: ICEA)

In June 2017, another field test was carried out at SBSJ. In these tests, the possibilities of automatic recognition of color transition in the PAPI boxes were proven, and the work received the Innovation Award in Aviation 2016/2017 from the Civil Aviation Secretariat (SAC-MT). Due to the importance of the subject, DECEA included it into the SIRIUS Program as a project to be executed by SDOP, in conjunction with ICEA, in favor of the evolution of air traffic management in Brazil.

After those tests, the RPAS Committee of DECEA and GEIV developed an RPAS Concept of Operations (CONOP) and established a workgroup in order to conduct field tests to implement RPAS in the flight inspection of Visual Navaids. In this CONOP, assumptions and constraints were analyzed.

On 24th March, the third test was carried out at SBSJ aiming at testing the operational modes, the recognition of angle of color transition by the RPAS and the capacity of the camera embedded on the RPA to differ the pink color at the transition angle and recognize the PAPI to measure the coverage of the visual navaid. One important point observed at this event was an occurrence of jamming in the C2 link frequencies, which revealed a possibility of constraint when RPAS is used at a congested electromagnetic environment with many navaids and radars, as many of the main aerodromes operate, and which could deny the remote pilot the possibility to intervene in RPA automated flight, if necessary.

ASSUMPTIONS & OPERATIONAL LIMITATIONS

According to the results arising from the test campaigns with RPAS applied to flight inspection activity, the following assumptions (ASP) and limitations (LIM) were considered in the development of the CONOP for the use of RPAS in flight inspection missions:

CODE	ASSUMPTIONS
ASP.01	Initially, due to the complexity involved in the flight inspection of ILS and VOR, it is preferable to focus on flight inspections of visual aids. The implementation of RPAS in flight inspections of ILS and VOR will be outlined in an appropriate time.
ASP.02	In order to comply with the regulation, it is preferable that the RPAS to be used has a maximum take-off weight of up to 25 kg.
ASP.03	Considering the flight inspection of visual aids, the single rotor/multi-rotor RPA are the most appropriate.
ASP.04	It will be sought the possibility of the RPA automatically identifying transition angles of the light's color in PAPI and VASIS systems, as well as their variants.
ASP.05	The accomplishment of flight inspection using RPAS at night is feasible, provided that RPA has identification lights, as defined in item 4.2.4 of ICA 100-12.
ASP.06	The flight inspection of air navigation aids in aerodromes shared with manned aviation requires the issue of a NOTAM.
ASP.07	The RPAS must have position-fixing system with accuracy equal to or greater than the used by GEIV in flight inspections (less than 20 cm).
ASP.08	The RPA flight profiles used for the inspection of air navaids should be adapted to meet the full operational scope required to validate the flight inspection with RPAS.
ASP.09	At first, the sharing of optical sensors (visual navaids inspection) and electronic sensors (ILS and VOR inspection) will be planned in timely manner given the complexity involved.
ASP.10	Considering the required expertise, the commitment of the professionals of GEIV in the implementation of the flight inspection with RPAS is of paramount importance, especially for team building that will act in data acquisition of inspection.
ASP.11	Partnerships will be sought with companies or institutions, manufacturers and operators of RPAS, in order to obtain equipment and know-how in the operation of this type of vehicle.
ASP.12	Management and communication with the ATS unit of an aerodrome to be inspected are crucial.
ASP.13	Data acquired by the RPAS applied to flight inspections shall be tested for validation of reliability, integrity and accuracy.
ASP.14	The RPAS should have the ability to record the data obtained during the inspection for further analysis, as well as generate a report with this data.
ASP.15	The RPA should be able to automatically perform the navigation from the point of departure and to carry out the acquisition of necessary data to the flight inspection; in addition, the operator must be allowed to act whenever required.
ASP.16	The use of RPAS in flight inspections is more efficient for periodic inspections.
ASP.17	The logistics for the operation of the RPAS should be as simple as possible to ensure a significant reduction in costs.
ASP.18	Generally, the fixed wing RPA has more endurance than the single rotor/multi-rotor RPA. So, for the ILS/VOR studies, maybe, the fixed wing RPAS could be more efficient.

Table 3. Initial Assumptions for RPAS Flight Inspection.

CODE	LIMITATIONS
LIM. 01	At the moment, simultaneous inspection of visual and electronic aids is not possible due to the focus chosen for the project.
LIM. 02	Nowadays, simultaneous operation of RPAS and manned aircraft in shared aerodromes is not possible.
LIM. 03	In accordance with the applicable legislation, a NOTAM must be available to airspace users at least 7 days before the mentioned operation.
LIM. 04	Flight Inspections aiming at the navaid approval are designed to obtain complete information as to system performance and to establish parameters that will support the other inspections of the aid, as well as to ensure there are methods that demand greater engagement of the flight inspection crew.
LIM. 05	Considering the airspace access rules, the operation of RPAS does not allow a prompt response in case there is need for celerity in the inspection.
LIM. 06	The logistics required to operate fixed wing RPA is more complicated in comparison with single rotor/multi-rotor RPA.
LIM. 07	Generally, the single rotor/multi-rotor RPA payload capacity is lower than the fixed wing RPA.
LIM. 08	The autonomy of a single rotor / multi-rotor RPA is approximately 30 minutes.
LIM. 09	Possibility of jamming in the C2 frequencies when used in congested electromagnetic environments.

Table 4. RPAS Flight Inspection Initial Limitations.

Fig. 5 – RPA used in third test of Visual Navaid RPAS flight inspection. (Source: GEIV)

SUGGESTED OPERATIONAL MODES IN FLIGHT INSPECTIONS WITH RPAS OF VISUAL NAVAID

Considering the premises and the limitations of RPAS implementation to accomplish visual navaids flight inspection missions, possible methods of visual aids flight inspection with RPAS were outlined , following the parameters to be evaluated, as established in MANINV 2017.

In accordance with the aforementioned, the following methods were considered:

Operation, Intensity and Brightness of Lights

RPAS must be able to evaluate if all lamps are operating uniformly, with intensity and brightness appropriate to each commanded position, considering the commissioned volume of coverage. The aids installed at SISCEAB normally have a five-position hand control (brightness 1, 2, 3, 4 e 5).

Transition Angle and Normal Glide Path Angle

RPAS should be able to perform automatic navigation in order to evaluate the box angles according to the transition between red and white lights. The capability to identify the transition colors, transition width and the record of the angle at which the transition took place should be computational, issuing an automatic report of angles and colors captured.

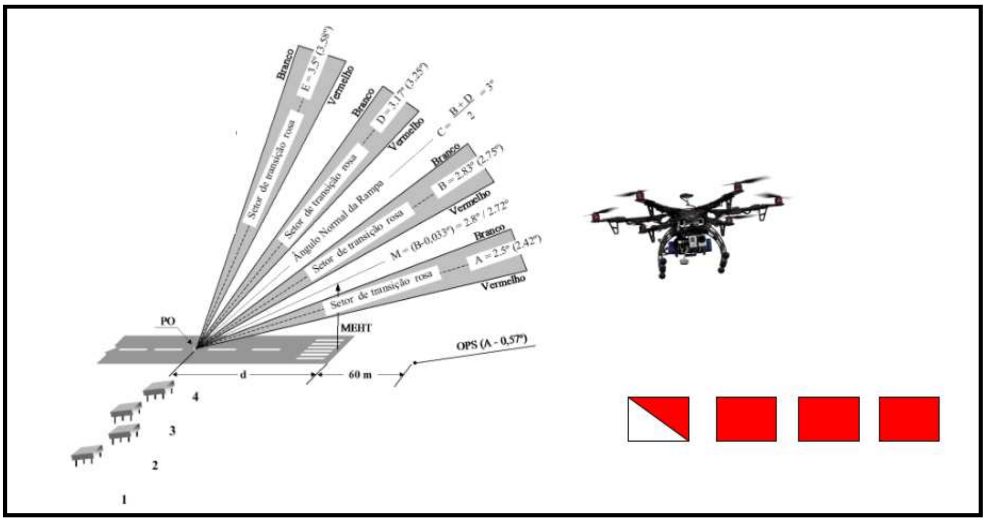

Fig. 6 – RPAS Transition Angle Inspection Concept.

Coincidence with Precision Electronic Glide Path

Due to the high complexity involved in integrating ILS signal reception sensors, the evaluation of this parameter can be performed in spot checks with an aircraft approaching the aerodrome or in Surveillance Flight Inspections with manned aircraft of GEIV.

Coverage

a) Usable Distance

RPAS should be able to evaluate the system in the navaid coverage volume (± 4NM), without specific lenses that achieve gain; in other words, RPAS cannot compensate the luminosity as a form of masking of usable distance of the navaid.

b) Angular

RPAS must be capable of performing automatic evaluation of the angular coverage by identifying the light beam produced by the system boxes through an azimuth angle of at least 10° on either side of the extended runway centerline, using appropriate positioning system.

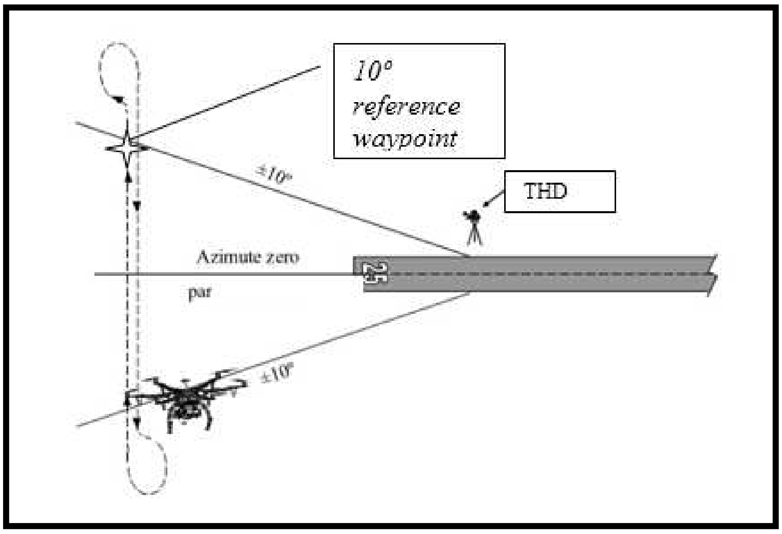

Fig. 7 – RPAS Angular Coverage in the Visual Navaid Flight Inspection Concept.

Contrast and Glide Path Definition of System

The view delivered by RPAS should be able to provide a glide path which is easily identifiable and readily distinguishable from other visual navaid and aeronautical lights within the runway threshold and touchdown zone area.

Obstacle Clearance

RPAS must be able to provide clearance above all obstacles by means of topographic survey, through a 3D mapping of the approved volume of coverage. It should also identify the highest elevation and verify if the obstacle does not interfere with safety, even when flying in the lowest sector (all boxes red).

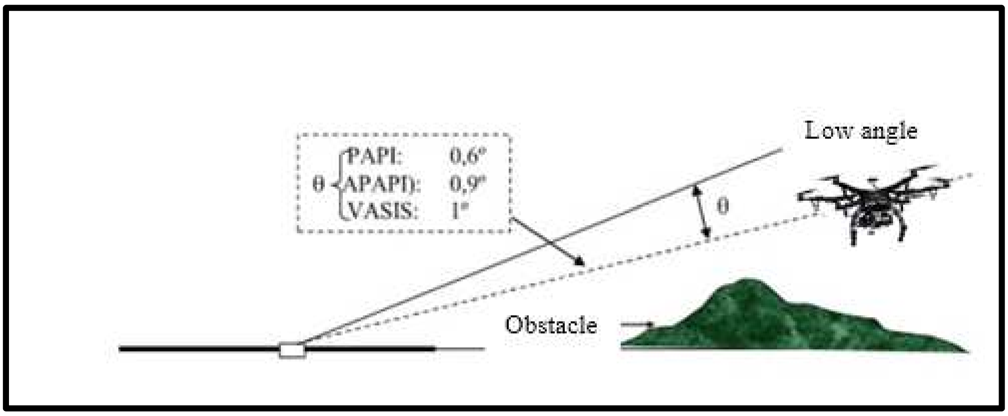

Fig. 8 - RPAS Obstacle Clearance in the Visual Navaid Flight Inspection Concept.

Operation, Intensity and Brightness of Lights of the Approach Lighting System (ALS)

RPA should be able to fly over the ALS, according to the commissioned angle of ILS, PAPI or VASIS in order to evaluate if all lamps are operating uniformly, with intensity and brightness appropriate to each commanded position, considering the commissioned volume of coverage. The aids installed at SISCEAB normally have a five-position hand control (brightness 1, 2, 3, 4 and 5).

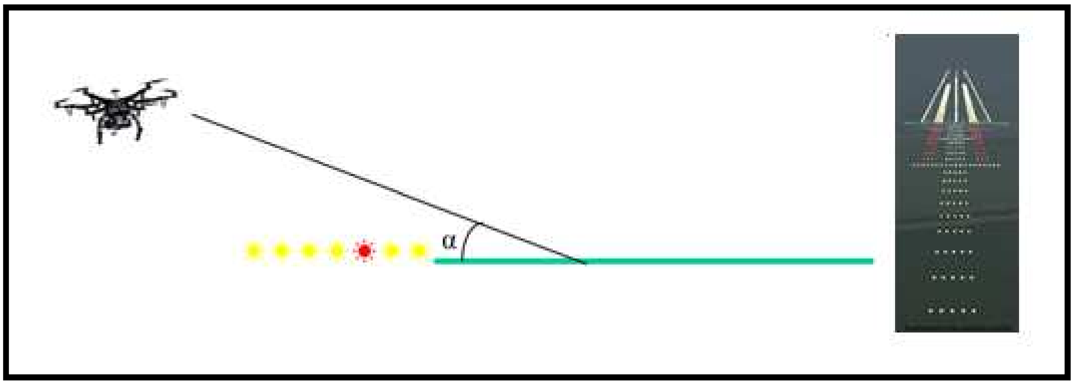

Fig. 9 - RPAS Operation, Intensity and Brightness of Lights of the ALS Flight Inspection Concept.

Lamp Alignment

RPA should be able to fly over the ALS, according to the commissioned angle of ILS, PAPI or VASIS, providing conditions, to identify if the lights or light bars are operative and aligned.

Radio Controlled Lights

RPAS should be able, or provide conditions, to perform the evaluation of the radio-controlled lights using an appropriate equipment.

Sequence Flashing Lights

RPAS should be able, or provide conditions, of evaluate the uniformity of the sequence and verify lights or light bars inoperative or misaligned.

Runway Lights

RPAS should be able to be positioned on a 3º glide path angle for proper evaluation, flying over the complete runway extension. During this approach, the view delivered by the RPA must be able to provide the evaluation of the lamp operation (brightness and intensity) of runway lights.

OPERATIONAL/TECHNICAL INITIAL REQUIREMENTS

After three field tests and some simulations, the RPAS Committee of DECEA, ICEA and GEIV conceived a few operational and technical initial requirements, which will be tested in other field tests in order to acquire the needed parameters to validate the use of RPAS in Visual Navaids Flight Inspection.

Some of these Operational and Technical requirements (REQ) are:

CODE	OPERATIONAL/TECHNICAL REQUIREMENTS
REQ.01	RPAS maximum take-off weight must be up to 25 kg, in order to facilitate compliance with the Brazilian national rules.
REQ.02	RPAS must have BVLOS operation capability.
REQ.03	RPAS should be able to cover the full range of distances necessary to perform data acquisition required for visual aids inspection, moving away from the operator in a controlled manner to at least 4 NM (± 7.2 km).
REQ.04	RPAS must have position-fixing system with accuracy equal to or greater than the used by GEIV (NSM-2100-GRS). Therefore, the GPS error of the RPA should be less than 20 cm.
REQ.05	RPAS should have enough autonomy to assure accomplishment of the full range of actions necessary to visual navaids inspection (approximately 02 hours), continuously or with battery change. Battery replacement, if necessary, should be performed in a prompt and easy way by the RPAS operator, in order to avoid discontinuity in a visual aid flight inspection mission.
REQ.06	RPAS should be able to operate automatically, by setting preprogrammed flight parameters.
REQ.07	RPAS must have vertical speed compatible with the embedded sensors capability of identifying the color changes and angles related to visual aids.
REQ.08	RPAS should have capability of daytime and nighttime operations.
REQ.09	The RPA must have identification lights to accomplish flight inspection at night, as defined in item 4.2.4 of ICA 100-12.
REQ.10	The RPAS should have the capability to record the views and data obtained during the inspection for further analysis by GEIV.
REQ.11	The extraction of the data obtained and recorded by RPAS should be easy to perform by the operator.
REQ.12	The RPA should be aerodynamically stable and maintain the error rate of the positioning system under action of wind intensity up to 20 kt.
REQ.13	RPAS must have flight termination systems (RTH, AutoLanding,...) and Geofence programmable by the operator.
REQ.14	RPAS must have equipment to provide voice communication between the operator and the ATS unit.(handheld VHF AM, ...).
REQ.15	The RPA must have embedded optical or electro-optical sensors capable of identifying the colors and transitions of the PAPI/VASIS lights, as well as identifying obstacles that could interfere in RPA flight path during daytime and nighttime operation.
REQ.16	The RPA must have optical or electro-optical sensors capable of automatically determining the angles (according to the light color of PAPI/VASIS) in relation with a point of departure that could be set for the operator, in order to allow the evaluation of the Transition Angles, Normal Glide Path Angle and Glide Path Width.
REQ.17	The RPAS should be able to issue a report containing PAPI/VASIS observed angles, distances and colors in time to allow the operator to perform the adjustments to the visual aid whenever necessary.
REQ.18	The RPA must have optical or electro-optical sensors capable of enabling visualization and filming of visual aid lights, at least in high resolution, allowing the operator to evaluate operation, intensity and brightness of the lights.
REQ.19	The RPAS must have telemetry with at least horizontal and vertical speed data, angles relative to the point of interest, GPS error rate, relative height above ground, distance of the point of interest, heading and autonomy.

REQ.20	RPAS should have a remote control that allows the operator to intervene promptly in automated flight in case of emergency, in particular allowing the immediate landing of the RPA.
REQ.21	RPAS should enable transportation and operation of a maximum of two persons.
REQ.22	RPAS should have alarm systems to the operator regarding positioning (maintenance of acceptable GPS error rate), battery autonomy, telemetry/remote control status and information of any damage that could compromise the integrity of the RPA or the accomplishment of the mission.
REQ.23	RPAS should have an adequate data update rate regarding the processing of data and images obtained in real time from the operator.
REQ.24	The RPA should have precise altimetry information with aeronautical calibration.
REQ.25	The RPA should be able to program photos and take them at a speed that satisfies the evaluation of the angles provided for the aid.
REQ.26	The RPA should allow specific programming of the angles of interest and photo rate for each visual aid.
REQ.27	The RPA should have automatic stabilization system and allow steering the camera to the area of interest.
REQ.28	The RPAS shall obtain values, related to flight inspection parameters, similar to the values found when using inspection methods with the manned aircraft.
REQ.29	RPAS should have a robust telemetry/remote control system capable of maintaining signal integrity and mitigating the possibility of unintentional or unlawful interference.

Table 5. Operational and Technical Initial Requirements for RPAS Flight Inspection .

FINAL CONSIDERATIONS

The desired scenario is that the RPAS will be able to perform flight inspection of PAPI, VASIS, ALS, Runway Lights and Sequence Flashing Lights, according to the tolerances established in MANINV, without affecting the Brazilian air traffic at SISCEAB.

The fulfillment of all the requirements is crucial, considering that they are conceived as minimum requirements for the establishment of feasible equipment for the flight inspection and evaluation of visual navaids.

Based on the Concept of Operations, a prototype will be assembled to cover all the demands outlined herein and whatever is pointed out as necessary during the testing period.

In addition, all the knowledge acquired in flight inspection tests with RPAS at this project will be paramount to provide the base to develop the ILS and VOR flight inspection with RPAS, which is the actual milestone sought.

FUTURE WORK

Based on the Concept of Operations, the workgroup intends to carry out another two tests, aiming to fulfill all the operational requirements conceived.

Reaching the project aims, which are basically reach costs reduction in visual navaids flight inspection, when compared with manned aircraft, and the mitigation of the impact of flight inspection in terminal areas.

Additionally, at the end of the visual navaids project, the Project about Flight Inspection of ILS with RPAS will initiate, which will be a daring event to RPAS Committee of DECEA and GEIV.

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