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CIÊNCIAS EXATAS E DA TERRA:

Teoria e prática 2

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APRESENTAÇÃO

A coleção “Ciências exatas e da terra: Teoria e prática 2” traz em sua coletânea a reunião de cinco artigos científicos de pesquisadores de algumas universidades brasileiras e também de instituições estrangeiras do México e do Uruguai. Os textos discutem sobre temas nas áreas de educação, engenharias e tecnologias.

O objetivo é publicizar os trabalhos desenvolvidos pelos pesquisadores destas instituições de ensino, respeitando as diferentes investigações e criando espaços de diálogo, visto que os autores buscaram responder questões importantes dentro de suas áreas de atuação

Desejo que as leituras dos trabalhos que compõem essa obra, possam ser proveitosas e que agucem a curiosidade para incitarem novas pesquisas nos arredores dos diferentes cenários de investigação visto que os temas discutidos nesse volume reforçam a importância do conhecimento científico nos diversos campos educativos.

Boa leitura!

Aniele Domingas Pimentel Silva

SUMÁRIO

REMOTELY PILOTED AIRCRAFT SYSTEM: PHYSICAL COMPONENTS, EMBEDDED SYSTEMS AND THE ACTUAL REGULATIONS IN BRAZIL

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ABSTRACT: Remotely piloted aircrafts have become increasingly common, both in business and hobby operations. This paper presents the hardware and software components, required and optional, that compose this type of aircraft and, with this analysis, elucidate issues that, a priori, are held in the commercial environment by the manufacturers of this technology and are not, in large majority, disseminated in the academic environment. This paper also presents the current Brazilian legislation on remotely piloted aircraft in Brazilian civil airspace. As a methodology, a bibliographic survey was made based on the current legislation published by the respective departments and regulatory agencies. This paper aims to contribute to scientific and technological innovation regarding the Remotely Piloted Aircraft Systems, approaching its operation due to its components and regulations, and can serve as a reference on the subject.

KEYWORDS: RPAS, Drones, Embedded System, Unmanned Aerial Vehicles, Brazilian Legislation.

1 I INTRODUCTION

Remotely Piloted Aircraft Systems, popularly known as drones or UAV (Unmanned Aerial Vehicles), are the new players in world aviation. Operators, industry and several international organizations are studying to understand, define and, finally, promote their integration in the context of airspace (MAGELLA, 2016). According to Anderson (2017), the data provided by drones are used in various sectors such as, for example, agriculture (mapping plants), the energy sector (monitoring solar panels and wind turbines), insurance (roof scanning), infrastructure (for inspection), communications, among many other sectors.

According to data published by ANAC[1] (National Civil Aviation Agency), until January 2020, Brazil had 76865 drones, correctly named according to Brazilian regulations as RPAS (Remotely Piloted Aircraft System), registered in the Unmanned Aircraft System (SISANT[2]). In Brazil, the estimate for the drone market in 2019 was to turn over R$ 500 million, including revenue generated by the entire production chain in the sector, formed by the development, manufacture, import and sale of equipment, embedded technology and software, in addition to service provision (GRANEMANN, 2019). Table 1 shows the growth in the number of pilots (individual and corporate) and drones (professional and recreational use) registered by SISANT in the last 5 years in Brazil.

	Dec 2017	Dec 2018	Dec 2019	Dec 2020	Dec 2021
Number of individual persons	26205	45907	60711	59389	65765
Number of legal entities	1657	2875	4406	5153	6198
TOTAL	27862	48782	65117	64542	71963
Professional use drones	11167	21130	29875	31270	38197
Recreational drones	18920	38361	49796	47986	51833
TOTAL	30087	59491	79671	79256	90030

Table 1: Growth in the number of pilots and drones registered in the last 5 years in Brazil [1]

The expressive number of aircraft, registered and in a regular situation to carry out flight operations in the national territory, as well as the number of foreign and national manufacturers, evidence the popularity and significance that this technology currently has in the world and Brazilian research and commercial scenario.

In addition to the availability of drones already produced by hundreds of manufacturers, the market is still fertile for those who wish to venture to build their own equipment. For the development of new drone technologies it is essential to have full knowledge of the basic components that make up this type of aircraft and those components that add functionality to it. These components, whether hardware or software, directly impact the performance of the flight operation and its purpose.

In addition to the construction of the drone itself, manufacturers and operators must consider the related legislation in force. According to Boanova (2014), Brazil was just starting of using these aircraft, which resulted in the absence of a complete regulation on drones. Previously not having one, now remotely piloted aircraft have their own national legislation.

1 https://www.gov.br/anac/pt-br/assuntos/drones/quantidade-de-cadastros
2 https://sistemas.anac.gov.br/sisant

Starting from the construction of an aircraft, which is a process that needs a very well elaborated project, being in accordance with the functional requirements, such as flight autonomy and operability, a good understanding of the current legislation is essential for the development of products and services innovators employing drones. These vehicles need to be in compliance with the regulations to be able to carry out their operations legally.

The construction of a remotely piloted aircraft goes far beyond the simple union of certain components in a scheme that makes sense and provides the ability to control and fly the object. This is a process that requires a project, which is in accordance with functional requirements, such as operability and flight autonomy, which, in turn, depends on an extensive series of analyzes of all components that will be loaded on the aircraft, and the requirements established by laws, rules and regulations. Therefore, the lack of material that provides a scientific basis for the construction of unmanned aircraft and that at the same time is also in line with current regulations is a major obstacle to the creation of new aircraft projects.

To address this lack of centralized documentation, this paper presents the physical components involved in the process of building a drone, as well as the necessary embedded system. This paper also presents a review of the laws in order to seek a better understanding of them and to identify the points that are relevant to the drivers of these vehicles, to the manufacturers and also to all the people that may be related to the use of them in civil airspace. A previous work, which addresses part of this paper, was published in (GLINSKI, 2017).

The methodology used in this work was a bibliographic survey, assessment of the theme of remotely piloted aircraft, and a survey, systematization and interpretation of data.

This paper is organized as follows: Section 2 presents the physical components (required and optional), as well as the embedded system (software); Section 3 presents the current legislation related to drones in Brazil, considering ANAC, DECEA and ANATEL regulations; Finally, Section 4 presents the conclusions and future work.

2 I PHYSICAL COMPONENTS AND EMBEDDED SYSTEMS

The Remotely Piloted Aircraft System (RPAS) is a set formed by the aircraft, called RPA (Remotely Piloted Aircraft), and by the remote piloting station, the equipment used by the pilot to control the aircraft remotely, called RPS (Remotely Piloted System). The RPAS is the set of RPA and RPS.

Unmanned aerial vehicles can be classified into multi-rotors and fixed wing. The multi-rotor models are the most well-known, highlighting their movable wings (propellers). These models have more limited speed, range and strength. However, they are easier to control, allowing flights in smaller areas and facilitating photos and filming.

Fixed-wing drones are more like planes. They usually have a delta wing, which supports the flight, and a propeller-type engine that propels the aircraft forward. This type of drone is more e efficient and reaches higher speeds, being used to cover larger areas. Table 2 shows some differences between the two types of drones.

Type	Advantages	Disadvantages	Typical use
Multi-rotor	easier to pilot allows for confined area flights static flight vertical takeoff and landing lowest cost	shorter flight autonomy lower load capacity lower flight resistance limited speed	shorter-time flights aerial fotos filming entertainment
Fixed-wing	greater flight autonomy greater speed larger coverage area greater load capacity greater flight resistance	greater operational complexity greater cost lower accuracy of data obtained	aerial photos aerial mapping remote sensing long distance inspection

Table 2: Differences between multi-rotor and fixed wing drones (CAMARA, 2019)

Chapman (2016) classifies drones in four types: multi-rotor, fixed-wing, single rotor and hybrid VTOL, and presents some differences between them.

Both the aircraft itself (RPA) and the remote piloting station (RPS) are built as a serie of hardware and software components (embedded system). However, for each manufacturer and their respective models, these components suffer variations, but in general we can fit them in two main categories: those essential to provide flight capacity for the aircraft and; those that provide extra resources that can be used in the flight operation, but are not mandatory (ARDUCOPTER, 2020).

In the following subsections we present the mandatory and optional physical components, as well as the embedded system. In this work we focus on the multi-rotor drone as it is more widely used and known.

2.1 Required components

In this section we present the required hardware components to provide flight capability for an aircraft. The items described below are not broken down into quantitative and individual issues, since quantity, weight, power, dimensions, etc. are not specific and will differ for each aircraft model and intended purpose:

- Structure: It is the body of the drone itself, it can also be called frame. The basic structure of the aircraft body, according to Demolinari (2016), is formed by a central region where the arms are attached and where the sensors, the flight controller and the batteries are attached. Motors are attached to the ends of the arms. Fig. 1 illustrates a DJI FlameWheel F450, for instance, along with motors and propellers;

Figure 1 DJI FlameWheel F450 (Source: https://cdn.aerialpixels.com/wp-content/uploads/2014/06/0_0.jpg)

- Electronic Speed Controller (ESC): Each RPA engine needs an ESC, as it is responsible for making the communication bridge between the controller board and the engines. The signal sent by the aircraft's ground pilot is received by the radio receiver, transmitted to the controller board that processes the commands and sends them to the ESCs, where they control the rotation speed of each engine, thus allowing the aircraft's control capacity. "In order to control the rotation of a three-phase motor, a power circuit containing inverters, sensors and a circuit that is capable of controlling the drives is required" (DEMOLINARI, 2016). An example of ESC is the DJI 420S (Fig. 2), compatible with the DJI Naza-M Lite controller board (mentioned later) and with the FlameWheel frame mentioned above;

Figure 2 DJI ESC 420S

- Motor (propulsion system): To support an aircraft in the air during flights, motors must have a high rotational capacity. Between the two main types of electric motors, there are brushed and brushless motors. For Demolinari (2016), brushless motors are the most widely used because they have great efficiency and durability. Depending on the number of motors that an aircraft has, we can classify them into tricopter (three motors), quadricopter (four motors), hexacopter (six motors) or octacopter (eight motors), regardless of the shape and layout of the motors in the aircraft structure. An example of a motor is the DJI 2312E (Fig. 3), recommended for multirotor copters, weighing between 1 and 2.5 kg (2.2-5.5 pounds);

Figure 3 Motor DJI 2312E

- Propellers: A propeller is an object that rotates perpendicularly around its own axis and provides propulsion and sustainability when coupled to a motor. The propellers of an unmanned aircraft are the components that work under the most severe conditions. “Under the propellers they act: The torque of the motors and the aerodynamic drag force of the air propulsion” (JOHNSON, 1980). An example of a propeller is the Z-Blade 9450[3], which has high thrust, low noise and excellent dynamic balance;

- Battery: It is the source of energy, it feeds all the components embedded in the aircraft. The batteries have a wide variety in terms of their load capacity, dimensions (height and width), weight, number of cells and storage technology, and for each frame model or operational need, these variables must be taken into account. The battery is one of the mandatory items that most impact financially on the value of an aircraft. An example of a battery is the Turnigy Multistar 5200 mAh 4S[4], which has 4 cells, a minimum charge capacity of 5200 milliamps per hour and a voltage of 14.8 volts, weighing a total of 475g;
- Battery charger: Considering the cost of a battery, it is essential to reuse it after use. Therefore, it is necessary to use a specific charger for these batteries;
- Main Controller: The main controller is one of the key components of building an aircraft, it is its brain. This equipment has the function of processing the input signals and generating appropriate outputs, thus allowing the control of the aircraft during its flight operations by the operator on the ground. An example of a main controller is the DJI Naza-M Lite[5], recommended for aircraft with 4 to 6 motors, can be used for both professional and hobby purposes, and is composed of one 3-axis accelerometer, one 3-axis gyroscope and a barometer;
- Remote Controller: The remote control station, called RPS, is the equipment used by the pilot on the ground to control the aircraft. There are several models of control radios, each one having its specifications, these specifications varying from the number of functions that can be pre-programmed to the accuracy of the controls;
- Radio Receiver: It is the link between the RPA (aircraft) and the RPS (remote control station). An example of a radio control set and its receiver is Radio Link's AT series[6], which allow some flight configurations, for example, the selection of the type of aircraft used, which channels and their respective functions they will have, buttons for change flight mode, etc.

2.2 Optional components and equipment

This section presents some components and equipment that can be considered as optional. Any other technology equipment may fall into this category, as they only provide resources for the aircraft, but are not required to provide flight capability:

- Camera: Also called an optical sensor, a camera can be attached to the aircraft, thus allowing to record photos and videos;
- Gimbal: The gimbal is an equipment used in conjunction with the camera and

3 http://dl.djicdn.com/downloads/e305/en/E305_User_Manual_v1.00_en.pdf
4 http://www.turnigy.com
5 https://www.dji.com/naza-m-lite
6 http://radiolink.com.cn/doce/product-categorie-48.html

attached to the aircraft, and aims to mechanically stabilize the camera to obtain, with higher quality, images and videos during flight operations. Fig. 4 illustrates a DJI Zenmuse X7, for instance, a compact Super 35 camera with an integrated gimbal;

Figure 4 DJI Zenmuse X7 (Source: https://www.dji.com/au/zenmuse-x7?site=brandsite&from= landing_ page)

- Ultrasonic sensor: Sensor that detects the presence of bodies and their distance in the event of a dangerous approach by a building, person or even another aircraft. When equipped and properly configured with an ultrasonic sensor, the aircraft can avoid a collision;
- First Person View (FPV): FPV is a device that allows you to fly with the drone in a way that conveys the feeling of flying an aircraft from inside. It is used together with an optical sensor. For an example, Fig. 5 illustrates the Dominator HD02, a FPV with a 46-degree field of view;

Figure 5 Dominator HD02 FPV (Source: https://www.fatshark.com/product-page/hdo2)

- Screen display: Equipment used in conjunction with an optical sensor, facilitates the visualization of what is being captured in image or video by the remote operator;
- Battery monitor: It allows the ground operator to monitor the battery charge level of the aircraft. It emits a light and audible signal indicating that, when the battery situation is at the end of its charge, the operator can take appropriate actions to avoid an accident;
- Telemetry: It allows data from the aircraft to be transmitted to the ground controller. This information, sent from the aircraft in real time, such as altitude, battery charge, speed, etc., can assist in the operation.

2.3 Embedded systems

There is a wide variety of main controller found on the market. For each model and manufacturer there is a set of specific instructions (firmware) as well as for each type of aircraft and flight mode there is its respective version and system configuration.

Embedded systems have differences in terms of use licenses. Open source models, maintained by free software communities, allow the end user to make changes to the controller algorithm so that it better meets their needs and desired requirements. An example of an open source controller is ArduPilot (ARDUPILOT, 2020). Other controllers have proprietary licenses and do not allow the end user to make changes to their code. An example of a proprietary license controller is the DJI Naza-M Lite[7].

Some of these models, not only restricted to the software, but the controller as a whole, have only the functions necessary to perform the flight operations, among them are the mapping of the radio control channels to determine the direction and altitude of the flight. As a result, these cards have a simpler embedded system and a lower monetary value, since they have fewer functions than more sophisticated models.

Other controllers, the most sophisticated, have the ability to process data from embedded or external sensors, such as GPS (Global Positioning System), barometer, gyroscope and telemetry. Due to these additional features of the board, embedded or external, connected and configured to it, and its software, the control and stability of the aircraft during the flight is much simpler and does not require full experience and operational capacity by the remote operator.

In addition to the ArduPilot and DJI Naza-M Lite systems, other systems can be named. Table 3 presents a more complete listing.

7 https://www.dji.com/br/naza-m-lite

Name	Developer	Indicated usage
Ardupilot	Ardupilot	Professional/Hobby
DJI Naza Assistant	DJI	Professional/Hobby
iNAV	iNAVFlight	Professional/Hobby
LibrePilot	LibrePilot	Professional/Hobby
PX4 Flight Stack	Pixhawk	Professional/Hobby
Paparazzi	Paparazzi UAV	Professional/Hobby
BetaFlight	BetaFlight	Racing
dRonin	dRonin	Racing
CleanFlight	CleanFlight	Racing
KISS	KISS Racing	Racing
RaceFlight	FlightOne	Racing

Table 3: Available embedded systems (Source: author)

3 | LEGISLATION

The use of unmanned aircraft in the most diverse applications, in the most varied sectors of the economy, and even in public services, has been growing more and more. Based on that, it soon became clear the need to create legislation that regulates the flight of these vehicles. The first regulations to be applied to unmanned aerial vehicles were the same related to aeromodelling, non-commercial operations and hobby, as seen in Advisory Circular 91-57, Model Aircraft Operating Standards 1981[8], legislation of the United States of America. In Brazil, Ordinance Nº 207 / STE of 1999[9] is responsible for establishing the rules for the operation of model airplanes in the country.

The creation of specific regulations, mainly related to commercial applications, came to be discussed later. Currently, each country that is interested in the development and use of unmanned aircraft is working to implement its own regulations based on the standards set by ICAO (International Civil Aviation Organization).

ICAO is an agency belonging to the United Nations, that aims to create standards and practices that serve as a basis for international civil aviation. These standards and practices are known as SARPs (Standard and Recommended Practices).

ICAO in its Doc 9750-AN / 963 Fifth Edition - 2016, Global Air Navigation Plan (ICAO, 2016), also known as GANP, deals with the use of unmanned aerial vehicles, specifically the use of RPAS (Remote Piloted Aircraft System) and the integration of these vehicles for operation in open air space.

8 https://www.faa.gov/documentLibrary/media/Advisory_Circular/91-57.pdf
9 https://www.anac.gov.br/assuntos/legislacao/legislacao-1/portarias/portarias-1999/portaria-no-207-ste-de-07-04-1999

Pathirana (2019) presents a study of the legislation that regulates UAVs in several countries, including Australia, Canada, the United States and the European Union, and compares these regulations. The author points that main differences in regulations among those countries are due to the different administrative standards, the level of technology and resources available to the regulatory authority, and also due to police concerns.

In Brazil, the National Civil Aviation Agency (ANAC[10]), created in 2005 (BRAZIL, 2005), agency responsible for regulating and supervising activities related to civil aviation, the Airspace Control Department (DECEA[11]), responsible for controlling the Brazilian airspace, and the National Telecommunications Agency (ANATEL), are the main organizations currently involved in the creation of legislation that regulates the use and operations of these aircraft in Brazil.

In the case of remotely piloted aircraft, there is no concern about the risk of people on board, as there is no pilot inside the aircraft and there are also no passengers, so drones are not governed by passenger transport regulations. However, we must consider the risk to people on the ground below the drone's trajectory and also the risk of collision with another aircraft in flight (manned or not) (MAGELLA, 2016).

Due to the fact that a drone is a type of aircraft, it is subject to DECEA regulations, since it is the responsibility of DECEA to manage and control air space, as stated in Ordinance Nº 913 / GC3, 21 September 2009 (BRAZIL, 2009). ANAC is responsible for issuing the Airworthiness Certificate (C.A.), Registration Certificate (C.M.) and registering aircraft, as defined by Article 8, XXXI, Law Nº 11182, September 27, 2005.

According to the Brazilian Aeronautics Code, section II, article 114 (BRAZIL, 1986), no aircraft will be authorized for flight without prior issuance of the Airworthiness Certificate, which will only be valid during the stipulate period, observing the mandatory conditions mentioned therein.

Regarding the Command and Control Link and other links that can be used in the operation, ANATEL certification of the frequencies used is required.

One of the points that should be paid more attention to is the nomenclature of unmanned aerial vehicles. Each legislation, both from ANAC and DECEA, follows the international standard established by ICAO (2015) where a standard nomenclature is adopted to refer to drones:

- RPA: A RPA (Remotely Piloted Aircraft) is an aircraft that does not fly completely autonomously, where there is human interference. Among these vehicles we can mention helicopters, quadcopters, octocopters, fixed wing, etc;
- RPS: Remotely Piloted Station is the remote pilot's workstation, components that can be loaded on the vehicle, such as sensors, equipment used for launching and/or recovering the aircraft and other components used in the operation;

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10 https://www.anac.gov.br
11 https://www.decea.mil.br/

- RPAS: Remotely Piloted Aircraft System refers to the aircraft (RPA) plus the remote pilot station (RPS).

It is still established by these laws the difference between a model airplane and what we consider to be a RPA, where a model airplane is an unmanned aircraft remotely piloted for the purpose of recreation and the RPA used for non-recreational purposes.

3.1 DECEA

According to the Instruction ICA 100/40 – Unmanned Aircraft and Access to Brazilian Airspace (DECEA, 2020), a document that deals with the use and access of unmanned aircraft and access to Brazilian airspace, since 15 November 2015, one of the main basic premises is that a remotely piloted aircraft is an aircraft and, therefore, to fly in the airspace under the responsibility of Brazil, it must follow the mandatory rules by the national aviation authorities.

The purpose of DECEA legislation is to “regulate the procedures and responsibilities necessary for safe access to the Brazilian Air Space by Remote Piloted Aircraft Systems (RPAS)”. In 2017, legislation was updated to bring ICA 100/40 into compliance with the rules established by ICAO (2015).

DECEA is also responsible for issuing the certificate of access to Brazilian airspace, a document necessary for flight operations with an unmanned aerial vehicle.

In ICA 100/40 we find questions related to the definition of terms related to flight operations with unmanned aircraft and abbreviations that are used, such as RPA, RPS and RPAS, all with the aim of creating a standard nomenclature with international conformity. Issues such as operational safety, emergency situations, infractions, legal issues and responsibilities of the RPAS operator are dealt with.

In addition to the web portal[11], which gathers necessary information on the Brazilian regulation for unmanned aerial vehicles, DECEA also has a system called SARPAS (System for Requesting Access to Airspace by RPAS), in which requests are made for access to Brazilian airspace with RPAS[12].

The instruction ICA 100/40 is applied to operations that are not exclusively for recreational purposes. Other DECEA instructions apply to other types of flight:

- AIC N 17/18: Aircraft remotely piloted for recreational use (called “aeromodelos” in Brazil) (DECEA, 2018a);
- AIC N 23/18: Aircraft remotely piloted for use on behalf of agencies linked to the federal, state or municipal governments. This instruction regulates the use of aircraft used by the Fire Department, Military Police, Civil Police, and Municipal Guard (DECEA, 2018b);
- AIC N 24/18: Remotely piloted aircraft for exclusive use in operations of the

12 https://servicos.decea.mil.br/sarpas/

public security, Civil Defense and inspection of Federal Revenue agencies (DECEA, 2018c);

- ICA 100-13[13]: Air traffic rules for military operational circulation. This instruction regulates the use of aircraft used by the Armed Forces.

With regard to aircraft registration, airworthiness certification and other related legal issues, the instruction ICA 100/40 is clear in establishing that these issues are the responsibility of ANAC and ANATEL regulatory agencies.

3.2 ANAC

On May, 2017, RBAC-E nº 94 - General Requirements for Civil Unmanned Aircraft of the ANAC came into force. RBAC-E nº 94 (BRAZIL, 2021) is the main legislation in Brazil regarding the execution of flight operations with RPAS.

An important point in the legislation is the classification of RPAS and RPA. This classification is per-formed according to the maximum take-off weight (MTOW) of the aircraft. Aircraft are classified into 3 classes, namely:

- Class 1: RPA with MTOW greater than 150 kg;
- Class 2: RPA with MTOW greater than 25 kg and less than or equal to 150 kg;
- Class 3: RPA with MTOW less than or equal to 25 kg.

As defined in the legislation, no unmanned aircraft may perform flight operations without a valid certificate of airworthiness and registration, as presented in Article 20 of the Brazilian Aeronautical Code (BRAZIL, 1986). The only exception to the certificate is for Class 3 RPAs that are intended only for VLOS (Visual Line Of Sight) operations up to 400 feet (121.92 meters). These aircraft need no certificate of airworthiness.

ANAC defines the following types of airworthiness certificates for an RPA:

- Experimental Flight Authorization Certificate [14];
- Special Flight Authorization [15];
- Special Airworthiness Certificate for RPA [16];
- Airworthiness Certificate - restricted category;
- Airworthiness Certificate - standard category.

ANAC maintains the Unmanned Aircraft System (SISANT[1]). Registration in this system is mandatory for unmanned aircraft for recreational or non-recreational use, with a maximum take-off weight between 250g and 25kg and that will not fly beyond the visual line of sight (BVLOS) or above 400 feet (120 meters) above the ground level. In addition to the

13 This document is only available by means of the CITIZEN CARE SERVICE at https://servicos.decea.mil.br/sac/index.cfm?a=publicacoes
14 CAVE - Certificado de Autorização de Voo Experimental, in portuguese
15 AEV - Autorização Especial de Voo, in portuguese
16 CAER - Certificado de Aeronavegabilidade Especial para RPA, in portuguese

aircraft, the flight operator is also registered (minimum age of 18 years).

The regulations of both ANAC and DECEA categorize flight operations in two main forms, namely IFR (Instrument Flight Rules) and VFR (Visual Flight Rules). Among these two main forms, flight operations can be subdivided into:

- VLOS (Visual Line of Sight): Operation in which the aircraft operator maintains direct visual contact with the aircraft without the need for equipment to assist its observation;
- EVLOS (Extended Visual Line of Sight): Operations where the assistance of third parties is required to perform the flight. This third party is called an "RPA Observer", someone designated, properly trained and qualified to assist the remote pilot in the safe and proper driving of the aircraft;
- BVLOS (Beyond Visual Line of Sight): Operations that, even with the assistance of the RPA Operator, it is not possible to have the aircraft's visual range from the aircraft operator;
- RLOS (Radio Line of Sight): Refers to operations in which the remote control station connects directly through the communication link with the aircraft;
- BRLOS (Beyond Radio Line of Sight): Refers to operations in which the remote control station does not connect directly with the remotely piloted aircraft. In this situation, the communication link is made with the help of other equipment, such as signal repeater antennas, other aircraft, satellites, etc.

ANAC also has some Supplementary Instructions (IS) related to remotely piloted aircraft. These instructions (https://www.anac.gov.br/assuntos/legislacao/legislacao-1/iac-e-is/is) are listed below:

- IS E94.503-001A: Issuance of Experimental Flight Authorization Certificate for Remotely Piloted Aircraft;
- IS E94-001B: Remotely Piloted Aircraft System Design Authorization - General Procedures;
- IS E94-002A: Remotely Piloted Aircraft System Design Authorization - RPAS - Technical Requirements;
- IS E94-003A: Procedures for preparing and using operational risk assessment for unmanned aircraft operators.

3.3 ANATEL

It is necessary to approve the equipment used in an RPAS with ANATEL due to the use of components, such as radio frequency transmitters. The need for this homologation extends not only to RPAS, but also to model aircraft. It is possible to apply for this approval through ANATEL's Certification and Homologation Management System[17]. During the

17 https://sistemas.anatel.gov.br/sis/LoginInternet.asp?codSistema=173

approval process, the transmission of equipment is verified, for example, the control link between the RPA and the RPS. It is also important to emphasize the need to pay a fee for approval.

It is essential for a regular flight operation that the vehicle has ANATEL approval with the ANAC Airworthiness Certificate for RPA.

Some ANATEL resolutions related to radio communication are listed below:

- Resolution Nº 715: Regulations for Conformity Assessment and Homologation of Telecommunications Products (ANATEL, 2019);
- Resolution Nº 608: Regulation on Restricted Radiation Radio communication Equipment (ANATEL, 2017);
- Resolution Nº 635: Regulation on Authorization for Temporary Use of Radio Frequencies (ANATEL, 2014).

4 | CONCLUSIONS AND FUTURE WORK

The market potential of unmanned aerial vehicles is recognized, and as it is an emerging industry, there is still a lot of innovation expected in the most varied sectors of the economy, where it has enormous growth potential in view of the diversity of products and services that can be offered to consumers.

Several aircraft models, with different specifications, can be purchased today and used in a given application, however, when aiming and promoting the development of this technology and innovation in this and other sectors due to the application of these aircraft, we first need to know the components that make up this system.

Regulation is also of fundamental importance, mainly because it establishes issues such as rules for operational safety, for people and assets, certification of pilots and aircraft and other responsibilities necessary for the good coexistence of technology with the society that owns and surrounds it. The lack of regulation to regulate drone operations in the country prevented the industry from applying new solutions because they may have some obstacle related to legal issues.

This paper covered the basic concepts and equipment related to the construction of a remotely piloted aircraft and its remote control system. This is a process that needs an adequate design and must comply with the desired functional requirements, such as flight autonomy and operational capacity, requiring an understanding of the mandatory components and those that can add functionality. This paper also presented a review of the legislation relevant to the RPAS in Brazil (ANAC, DECEA and ANATEL) in order to seek a better understanding of them.

For future work, it is recommended to study the impact that these components have on an aircraft during the performance of its flight operations, how it is possible to optimize the use of these hardware and software resources, and the development of an RPAS that meets a particular need in a branch of the economy in which research with drones is being carried out, the development of more efficient aircraft when comparing and integrating the onboard equipment, as well as the constant attention in relation to the requirements for the accomplishment of flights foreseen by ANAC and DECEA.

There is still much innovation expected in this sector and also in its application in other sectors of the economy, where it has great emerging potential due to the diversity of products and services that can be offered.

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