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A Current Vision

DRONES: GENERAL ASPECTS AND SOCIAL APPLICATIONS

DRONES: ASPECTOS GENERALES Y APLICACIONES SOCIALES

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Abstract: Drones, officially called Unmanned Aerial Vehicle UAV, for its acronym in English defined as a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry payload. They have been mainly used in armed conflicts, but today quality of life of communities. This research paper seeks to give the reader an overview of general aspects and social applications of drones, particularly evolution, development, regulation, technical standards, and implementation in the Americas region; moreover, a guide for the implementation of future projects and applications for the benefit of society and development of the region is also provided.

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Key words: Aircraft, Applications, Airspace, Modeling, Regulation.

Resumen: Los drones, denominados oficialmente como vehículos aéreos no tripulados, (UAV) por sus siglas en inglés, se caracterizan por no llevar a bordo operador humano, su modelamiento es aerodinámico, por lo que es capaz de mantener un nivel de vuelo controlado y sostenido, y hacerlo autónomamente a través de software o controlado de forma remota. Debido a que su uso se da principalmente, en conflictos bélicos; se hace necesario considerar otros campos de acción que aporten al mejoramiento de la calidad de vida de las comunidades. Por lo anterior, el presente artículo de investigación busca que el lector tenga un panorama sobre aspectos generales y aplicaciones sociales que pueden realizarse con drones, particularmente su evolución, avances, regulación, normas técnicas e implementación en la región Américas; y orientar así la ejecución de futuros proyectos y/o aplicaciones en beneficio de la sociedad y el desarrollo de la región.

Palabras Clave: Aeronave, Aplicaciones, Espacio Aéreo, Modelamiento, Regulación.

1. Introduction.

Drones are small Unmanned Aerial Vehicle, remote-controlled and a great ability to be used in many social areas. Today, the development of technology has

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allowed to popularize its use and to develop innovative technology initiatives. While it was the arms industry who was responsible for the technological development of UAVs, at present - thanks to innovation and to lower the cost of manufacturing, the drones have been used in other areas, for example: search and rescue of missing civilians; farm activities and fumigation; exploration of oil, gas and minerals sites; telecommunications signal coverage; or inspection power lines, aerial photography, crimes fighting facilitation.

However, the general information, applications and regulations remain still limited. Therefore, this paper shows a review for research purposes to determine a baseline of current UAVs in some regions of the world. Accordingly, the paper is structured as follows: first a brief state of the art on the origins and development of UAVs; then, a physical and mathematical modeling is illustrated; then, details are specified about the technical operation of the Drones. After, this article describes some regulations & policies adopted for the Drones followed by the illustration of some applications and relevant social impact; some perspectives are observed at regional and local level; finally some conclusions are given.

2. State of the art

Unmanned aviation had its beginnings in models manufactured by European inventors such as George Cayley (Mathematician English) in 1809, Felix du

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Temple (Navy French Officer's) in 1857, among others. The origin of UAV is given with the invention of aerial torpedoes; but the UAV experienced a rapid development thanks to technologies such as guided bombs, radio-controlled models, aircraft reconnaissance and combat aircraft [1]. In the late nineteenth century American pioneers like the Wright brothers designed and manufactured an aircraft that although controllable, not able to fly by itself but launched by a catapult with very short flights sufficient to test steering systems and control thereof [2]. Thus conventional aviation develops rapidly during the First World War [3].

Around 1916 it was held the first UAV[1] device, this one allowed the development of new control systems and navigation improving designs and flight times on aircraft. Successful first controlled flight of an unmanned aircraft was done on March 6th, 1918: this one was a de a biplane bomber known as unmanned aerial torpedo Sperry; made of wood, using a guidance based on the knowledge of wind speed and target distance , needed to establish engine characteristics and speed to reach the target [4]. But it was not until World War II where the evolution of the drones was rapid, applying radio remote control technologies that served to convert aircraft as PB4Y-1 and B-17 into aircraft pilotless which had systems

1 **UAV -Unmanned Aerial Vehicle-:** United States Department of Defense (DoD) defined UAV as powered aerial vehicles that do not carry a human operator on board, uses aerodynamic forces to generate lift, can fly autonomously or be piloted remotely, be recoverable and able to carry a lethal loaded or not. It’s not considered UAV to ballistic missiles, cruise missiles and artillery shells.

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guided through television images [5]. During the 60s, Unite States Air Force begins the AQM-34 program with Firebee designed from the start as a pilotless aircraft, whose reliability was 83%. Between 1964 and 1975 were sent over 1000 UAVs of this type in surveillance missions on the Asian territory [6]. In the 90s, with the availability of GPS and digital flight control systems (DFCS), it was possible to develop the first model of a VTOL (Vertical Take-Off and Landing): the Yamaha R50 [7].

Moreover, thanks to the inventiveness of a young Mexican and with the help of Open Source platforms such as Arduino (2009), 3D Robotics company, pioneer in the region and worldwide in the development of civilians UAVs, produces over 15,000 autopilots per year, for IRIS +, AERO and SOLO models, in the production plant located in Tijuana Mexico, also has offices in the US where over than 150 employees has been hired [8].

In Latin America efforts have been made to develop programs and UAVs. These systems are still at an early stages of operation. By the end of 2001, under the extraordinary meeting of the South American Defense Council of UNASUR, defense ministers agreed to create a working group to study the development and production of prototypes UAVs in the region [9].

In Colombian case, in 2005 the Colombian Air Force (FAC) acquired the first unmanned aerial vehicle VTOL model of Neural Robotics Company in order to

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study and practise the operation of this technology resulting in the development of research and design of UAVs. For this reason in 2010 an initiative of joint work between the FAC and CIAC was born for the design and manufacture of the first prototype of UAV known as IRIS (Figure 1) [9]. It is estimated that the amount of investment for the development of this project amounted to USD $ 1,000,000 [10]. In addition, the FAC in 2006 acquired the Boeing Scan Eagle, American made, used in ISR missions (intelligence, surveillance and reconnaissance) to support in operations against armed groups [11]. At the beginning of 2012 the Colombian government acquires drones Hermes 450 and Hermes 900 Israeli-made, designed for operations with autonomous takeoff and landing, [12].

Figure 1. Iris, First Colombian UAV. Source [8]

Moreover, other Colombian institutions begun to design and operate their own drones. The Efigenia Aerospace Company developed, between 2009 and 2010, the EJ-1B Mozart model, with a flight range until 10 hours [13]. The Elevation Engineering Company was the first company in Colombia to design, build and operate an UAV for marketing applications, successfully performing more than 280 flights over the country's topography. For 2007 the company used its own

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UAVs for taking high-resolution aerial photographs for mapping purposes, later used in the maps of Google Earth [14].The Advector Company, today has a fleet of Drones developed by the team of engineers in Advector, with which already had made more than 550 flights that offer services as: Panoramas and 360º views, Digital models in 3D, Precision agriculture with Drones of the category: Araknos V2 Koleópteros Buteos LTE and Ground Control Station [15]. Finally, interdisciplinary groups, like SIRP group (Intelligent Systems, Robotics and Perception), Faculty Engineering of Javeriana University, has advanced studies with autonomous aerial platforms able to interact with people and other machines dynamic environments [16].

3. Physical and Mathematical Modeling.

The reality representation of a UAV in operation requires that integrates geometric modeling, static modeling and dynamic elements; thus is possible consider their real capacity during flight.

3.1. Geometry, Stability and Control.

Its necessary to establish a model characterizing the aircraft behavior in flight and determine data relating to the position, such as longitude, latitude, altitude and rotation angle [17]. Table 1 shows the main variables for the modeling.

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Longitude	Degree value indicating longitude on earth.
Latitude	Degree value indicating latitude on earth
Altitude	Meters value showing the distance above sea level.
Rotation Angle	Degree value about turns made by the UAV, in each axes (x, y, z).

Table 1. Modeling variables UAV. Source [17].

The control and stability functions in a UAV are: direct, guide and maintain speed in the required position [18]. This requires taking into account the relationship of forces and moments affecting varying flight control surfaces of the aircraft (Figure 2). Each control surface associated with their own axis, providing a moment that generates a force and a relative movement to such balance shafts. These three areas are identified like ailerons, elevator and rudder. In Figure 3 shows each axis in Pitching, Rolling and Yawing moment, [19].

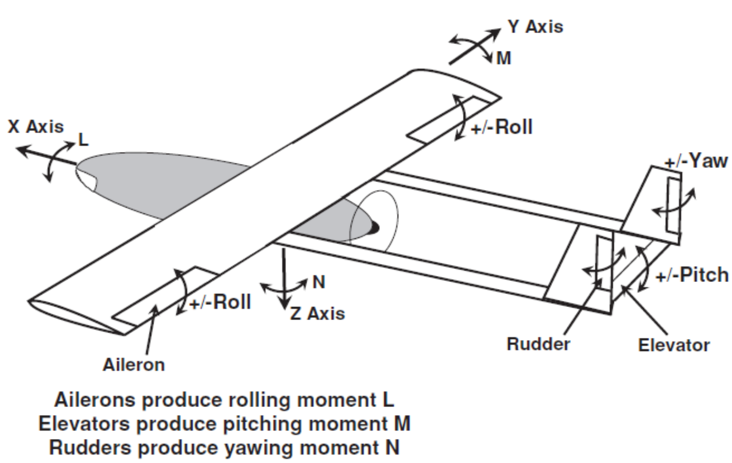

Figure 2. Forces and moments for a UAV, fixed-wing. **Source [19].**

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Figure 3. Forces and moments of a UAV, rotary-wing. Source **[20].**

The ailerons provide roll moment; the tailplane provides Pitch moment; and the rudder provides Yaw moment. Each of these axes can define the maneuvers that a drone is able to perform during operation, see in Table 2:

Pitch	Roll	Yaw
Movement performed by the UAV around the transverse axis, this one extends from end to end of the wings of the aircraft, this allows you to change the orientation, raising up or lowering the tip of the plane, producing a change in altitude.	Movement that occurs when there is a variation around the longitudinal axis of the UAV. This axis extends from tip to tail, causing a tilting movement of the aircraft to the left or right.	Spins around the vertical axis of the UAV, this axis passing through the center of gravity of the aircraft, being perpendicular to the longitudinal and transverse axis. This movement can correct the course of the aircraft.

Table 2. Moments of UAV. Source **[20].**

3.2. Mathematical model.

According to paragraph 3.1; the mathematical model is obtained from the characterization of the equations of forces and moments on the aircraft. For this purpose methods and Euler-Lagrange Newton's laws are used [21] should

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consider that UAV like a solid body of mass m_T, in a framework I, with a total force $\hat{F}$ and three moments, [22].

$\varepsilon = (x, y, z)$ (1)

Movement angles, yaw, pitch and roll, are used to find the orientation of a mobile system relative to another:

$\eta = (\Psi, \theta, \emptyset)$ (2)

Where:

$q = (\varepsilon, \eta) = (x, y, z, \Psi, \theta, \emptyset) \in R^6$ (3)

Then, different types of energies are established:

Kinetic energy:

$T_K = \frac{1}{2} mv^2$ (4)

$T_K = \frac{1}{2} m_T \dot{\varepsilon}\dot{\varepsilon}$, (5) Where:

m_T = mass aircraft

Rotational energy:

$T_R = \frac{1}{2} I\omega^2$ (6)

$T_R = \frac{1}{2}\dot{\eta}\, I\dot{\eta},$ (7)

Where:

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$I =$ inertia matrix

ω= angular velocity

Potential energy:

$T_p = mgh$ (8)

$T_p = m_T gZ$ (9)

Where:

Z = aircraft altitude

g =gravitational force

3.2.1. Euler-Lagrange Model.

For find the total force of system, the Euler-Lagrange model is used due to his computational efficiency is better than other methods used [21]:

Relate, equations (5), (7) and (9) to define the Lagrangian:

$$L(q,\dot{q}) = T_K + T_R - T_p = \frac{1}{2} m_T \dot{\varepsilon}\dot{\varepsilon} + \frac{1}{2}\dot{\eta}\, I\dot{\eta} - m_T gZ \quad (10)$$

Euler-Lagrange equation's, with the forces generalized is:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q} = \begin{bmatrix} F_\xi \\ \tau \end{bmatrix} \quad (11)$$

Translational force is expressed as:

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$F_\xi = M_R \hat{F}$, where:

Translational force is expressed as:

where:

$\hat{F}$ = force applied to the aircraft.

M_R= rotational matrix, aircraft orientation.

τ = Yaw, Pitch and Roll moments. Figure 3 is obtained:

$\hat{F} = \begin{bmatrix} 0 \\ 0 \\ u \end{bmatrix}$; $u = \sum_{i=1}^{4} f_i$,where:

f_i = Engine force.

Euler-Lagrange equation's for the translation movement is:

$$\frac{d}{dt}\left[\frac{\partial L_{trans}}{\partial \xi}\right] - \frac{\partial L_{trans}}{\partial \xi} = F_\xi \quad (12)$$

$$m\ddot{\xi} + mgE_z = F_\xi \quad (13)$$

Finally, the force equations for the three axes are obtained:

$$m\ddot{x} = -u \sin\theta \quad (14)$$

$$m\ddot{y} = u \cos\theta \sin\emptyset \quad (15)$$

$$m\ddot{z} = u \cos\theta \cos\emptyset - mg \quad (16)$$

3.2.2. Newton's Method.

The symbol τ represents the three moments of the aircraft on three axes, [22]:

For the Yaw moment:

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$\tau_\Psi = \tau_1 + \tau_2 + \tau_3 + \tau_4 = \sum_{i=1}^{4} \tau_i$ (17)

τ_i = Torque of each engine i

$\tau_d = k_\tau {\omega_i}^2$

For the Pitch moment:

$\tau_\theta = (f2 - f4)l$, where: (18)

$(f2 - f4)l$= lift force between engine 2 and 4.

For the roll moment:

$\tau_\emptyset = (f1 - f3)l$, where: (19)

$(f1 - f3)l$ = lift force between engine 1 and 3.

Lift force of single engine is expressed as:

$f_i = k{\omega_i}^2$ (20)

i= number of aircraft engines

ω_i= angular velocity engine i

Total lift force of aircraft is expressed as:

$$T_f = \sum_{i=1}^{4} f_i = k\sum_{i=1}^{4} {\omega_i}^2$$

T_f = Translational force

For the upward movement of aircraft must be fulfilled:

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$$L_T = \sum_{i=1}^{4} k{\omega_i}^2 = 4k\omega^2 \qquad (21)$$

$$4k\omega^2 > f_g = -mgE_z$$

Applying Newton's second law:

$$I_M \omega_i = -\tau_d + \tau_i$$

If ω_i = 0:

$$\tau_i = k_\tau {\omega_i}^2$$

$$\tau_T = \begin{bmatrix} \tau_\Psi \\ \tau_\theta \\ \tau_\emptyset \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{4} \tau_i \\ (f2 - f4)l \\ (f3 - f1)l \end{bmatrix} \quad ; \qquad (22)$$

Where:

l = distance between engine and gravity center.

Finally, the matrix with the angular velocities of the aircraft is obtained:

$$\tau_T = \begin{bmatrix} \tau_\Psi \\ \tau_\theta \\ \tau_\emptyset \end{bmatrix} = \begin{bmatrix} k_\tau({\omega_1}^2 - {\omega_2}^2 + {\omega_3}^2 - {\omega_4}^2) \\ lk({\omega_2}^2 - {\omega_4}^2) \\ lk({\omega_3}^2 - {\omega_1}^2) \end{bmatrix} \quad ; \qquad (23)$$

Where:

$\tau_\Psi, \tau_\theta, \tau_\emptyset$ = generalized moments (yaw, pitch y roll).

Consequently, it infers how rotation and translation movements to be performed by any type of aircraft in space, added by the set of external forces applied to center of mass, provide a representation or mathematical model able to

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determine how the position changes are made in flight, design, layout and type of engines to use to achieve liftoff, lift and landing of the aircraft..

4. Drone's technical Operation.

In the Figure 4, the drones are classified into two categories according to their most common technical features, [23]:

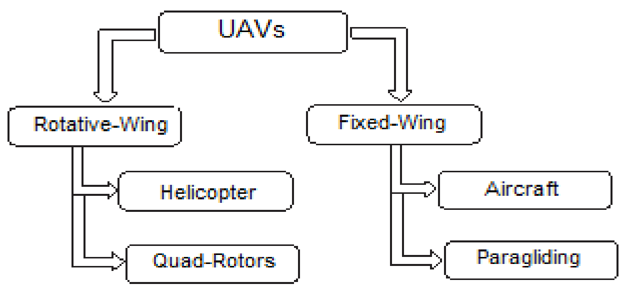

Figure 4. UAV types. Source [23].

The following section outlines the function of each of the main subsystems. Each of these will be discussed separately, always remembering that they do not exist isolated, but form part of a complete system. Integration of the subsystems into a total system is addressed [24].

4.1 Control Station (CS).

The CS will usually also house the communication systems with other external equipment. These may include means of acquiring weather data, transfer of information from and to other systems in the network, also it contains communication systems and data link (Line of Sight) used for sending information with other external systems [24].

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4.2. The Payload.

The type and performance of the payloads is driven by the needs of the operational task. These can range from: sensor systems EO / IR; laser designators; and, radar systems. There are different types of payload, as shown in Table 3:

Electro-Optical System	Video System	Radar System
Daylight camera-thermographic camera.	Use a video system with a greater range capability, employing a longer focal length lens with zoom facility, gyro-stabilized and with pan and tilt function with a mass of probably 3–4 kg.	Use a high-power radar having a mass, with its power supplies, of possibly up to 1000 kg.

Table 3. Payload Type's Source [24].

Some, more sophisticated, UAV carry a combination of different types of sensors, within a payload module or within a series of modules. The data from these several sensors may be processed and integrated to provide enhanced information, or information which could not be obtained using a single type of sensor. For more information, see [24].

4.3. The Aerial Platform.

The aerial platform has different sizes, from 15 cm to 40 m wingspan; different support systems (fixed wing, rotary wing); and with different powertrains (gasoline engines, turboprop engines, electric motors, etc.). The platform also incorporates the positioning and navigation systems, energy sources, fuselage

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structure, communications and mechanisms necessary for flight control allow the aircraft plan, fulfill the mission and come back [24].

4.4. Communications.

The principal, and probably the most demanding, requirement for the communications system is to provide the data links (up and down) between the CS and the aircraft.. This subsystem includes: data link terminals (airborne and ground); satellite communications terminals; and communications equipment used as a repeater [24].

4.5. Power supply.

The batteries are elements responsible for supplying electrical power to the aircraft and other electronic devices during flight operation. The batteries are systems of chemical energy storage. In the drones for high performance rechargeable (e.g. LI-Po) batteries are used [24].

5. Regulations & Policies.

UAV have become a component of aeronautical systems of nations and therefore have enabled new commercial and civilian applications, solutions on safety and efficiency of operations in civil aviation continue to be implemented and improved [25].

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However, in recent years governments, aerospace and international watchdogs and regulation such as ICAO[2] and EUROCAE[3], set the task to understand and define the characteristics and common differences between manned and unmanned aircraft with the goal of integrating UAV non segregated airspace [26]. The integration of UAVs airspace is made possible by the development by ICAO of an international framework where the minimum safety levels in non segregated airspace and licensing are established in order to ensure the safety of people, goods and other air and land users [27].

The Federal Aviation Administration (FAA), entity that regulates and supervises aspects of civil aviation in the US under Public Law 112-95, 2012, established a plan of safely for integrate civil UAV's in national airspace, with the objective of generating a positive impact on the economy and the country's competitiveness, whilst ensuring compliance with privacy law's concerning the recruitment, retention and dissemination of personal information like photos, videos, or geographical coordinates [28] .

2 **ICAO:** International Civil Aviation Organization is a specialized agency of the United Nations. It codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth.

3 **EUROCAE:** The European Organization for Civil Aviation Equipment is a non-profit organization dedicated to aviation standardization since 1963, and develops standards for electronic devices in aircraft and ground systems

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Therefore, the FAA has confronted a number of challenges to address anticipated growth in demand for civilian UAV operations, for this reason has developed regulations governing the certification and operation of unmanned aircraft systems. Thus, from December 2015 anyone who owns a small unmanned aircraft must meet certain requirements to operate its aircraft and avoid civil and criminal penalties [29]; some of them are: be at least 13 years old, be a US citizen or legal resident, drone weight should be between 250g and 25kg and registered on an official website intended for it. Drones over 25kg, used for commercial or recreational (Figure 5) purposes, must complete a physical registration form and wait for the response of approval watchdog [30].

Figure 5. Business or Commercial UAV. Source [30].

Moreover, in 2015, the Colombian Civil Aviation Authority issued a regulatory circular providing guidelines for the process of a final regulation of remotely piloted aircraft systems (RPAS) as known in the country, where general requirements for airworthiness and operating the national airspace are established [31].

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In Colombian case there are two different uses for this type of aircraft: one for recreational use and another for commercial use. The use of drones in recreational aviation was already covered earlier in the Aeronautical Regulations of Colombia (RAC) arranged in section 4.25.8 of resolution Nº05545 of December 26th, 2003, where constraints and requirements were established for airspace use [32]. Commercial use is defined as one that generates a profit for the owner/operator of drones. Under this condition, the Aerocivil regulates its operation under the regulatory Circular Nº002 of September 27th 2015, where the mode of use and limitations in the operation of the aircraft are established: a) maximum weight of 25kg; b) operate in daytime and weather conditions visibility; c) not fly over buildings or on agglomeration of people; d) not exceed the height of 152 m, or away from the operator more than 750 m. In addition, e) the drone must be registered with the Aerocivil [33].

6. Some applications and social impact.

6.1 Aerial Power Line Inspection.

In Colombia, companies in the electricity sector are obliged to perform maintenance and monitoring of high voltage transmission lines and pilons and easement areas, like established in Chapter IV of the technical regulation of electrical installations (RETIE), the Ministry of mines and energy [34], in order to improve service and prevent failures or disconnections. Initially, electric

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companies performed inspection of lines by means of technical checking the status of each of the mechanical elements of the structure of towers by means of visual inspection tower by tower. This method generated unreliable diagnosis and risk to personnel working at heights from the ground [35]. To solve this problem, it was decided to equip the helicopters with HD video cameras that obtain images with more detail and a more complete record of all parts of the towers also with the possibility of taking thermographic images that identify hot spots on sections of the power line that could cause energy losses or risk of fire, [36]. However, the difficulty posed by helicopters to operate in inaccessible areas pushed to start the use of UAVs as an alternative for the inspections also allowing lower operation costs, reduction of risks for the personnel, and the reliability, robustness and ability to perform stationary flight on sections of the power lines with more detailed images [37]. In this case, the challenge is to overcome a series of conditions of reliability and performance, as in the inspection of very large sections, where travel demand by aircraft, autonomy sufficient flight permits complete the work , and loss of line of sight of the UAVs [38].

6.2 Medical Equipment Transportation.

The Multilateral Investment Fund (MIF), member of the Inter-American Development Bank (IDB) Group, approved a technical cooperation grant for

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US$539,980 to establish an innovative transport model for health inputs in rural areas of the Dominican Republic. The new project seeks to use unmanned aerial vehicles (UAVs, or drones) to improve the response capacity of First Level Health Centers in rural areas where the topography makes access to primary health services difficult. The initiative will be carried out by the business incubator Emprende[4], through direct collaboration with the technology manufacturer MATTERNET[5], which will contribute around US$613,000 in equipment and technology transfer [39]. Among the results that are expected to be obtained are: to increase the number of diagnoses and transport of HIV results; safe transport of blood samples; and reliable delivery of packets with emergency medicines. The drone used in this project has a carrying capacity of 2.2 pounds over distances up to 20 km with a single battery charge; in addition, its design allows loading and unloading quick and easy way [40]. This is the first project of its kind to be developed in Latin America highlighting the IDB and MIF's commitment to test new initiatives for engaging and inspiring the private sector to solve economic development problems in Latin America and the Caribbean.

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4 **Emprende:** Emprende is a Dominican non-profit institution created with the aim of supporting entrepreneurs who have an idea, a project, or a technological and innovative company that is in its formation stage or with little time on the market.

5 **Matternet:** Matternet is a technology start- up based in Palo Alto, California, developer of unmanned autonomous vehicles or UAV Drones. MATTERNET's vision is the establishment of transport networks by using UAVs to solve socio- economic problems, especially in areas of difficult access. Learn more at mttr.net.

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Therefore, with the help of the World Health Organization[6] (WHO) is expected to implement this type of initiative in other countries in the Americas region, where access to health services and health care in rural areas is limited [41].

This type of project would be very beneficial for Colombia, for example Guajira department, where Wayuu communities are scattered over about 15,000 km² of territory, making more difficult for this ethnic group access to the health system. This is critical case if one considers that in the last eight years the socio-economic situation in the region would have caused the death of 4770 children from malnutrition [42]. Surely, it could have prevented this humanitarian crisis if it had this kind of technological alternatives that allow sent medical and foodstuff supplies with drones immediately to the place of emergency [43]. Come back the drone, for example, medical samples for accurate diagnosis, like ambulance-drone Alec Momont [44].

In other point of view, for the Colombian case, with the use of UAV is expected to have a positive impact in the environmental field to be used for detection and protection of natural resources (flora & fauna), through continuous monitoring that would otherwise be expensive realize it.

Regarding the agricultural sector, methods of precision and the help of drones would help the country reduce productivity gaps compared to other countries in

6 **World Health Organization:** The World Health Organization (WHO) is a specialized agency of the United Nations that is concerned with international public health. It was established on 7 April 1948, headquartered in Geneva, Switzerland. The WHO is a member of the United Nations Development Group.

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the region and expand the agricultural frontier in a planned manner. Regarding general infrastructure of roads, like the 4G project that being built in the country, would make the communication and assistance during construction will be more efficient, For example, in an evaluation made in the Valle del Cauca department, only, it was found that working on these fronts would be generated in the first year, between 100 and 150 direct jobs and about 1,000 indirect jobs, especially in applications of post processing; and a turnover of about USD $ 2,100,000 [45]

7. Local and Regional Prospects.

Projections indicate that drones market globally will be dominated by the US, with a notable increase in the Asia-Pacific country [46]: The growth potential of this activity in Colombia among the countries of the Americas region is high, mainly due to the geographical characteristics and topography of the region, with a variety of altitudes and climates.

In the business sector has begun to see an increasing use of drones in: oil industry, agricultural industry and civil engineering, where for decades the domestic industry has preferred to provide themselves with foreign technology and employ Colombian companies to capture information.

This growth adds to the interest expressed by some of the developers of UAVs to begin to establish and advance research projects in the country providing not only scientific but also economic development [47]. This indicates that the region

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has a large field of development for the drones, in the application segment, design, production and operation of UAVs for the coming years the number and variety of drones has tremendously increased. Figure 6, shows how much Patent applications increase.

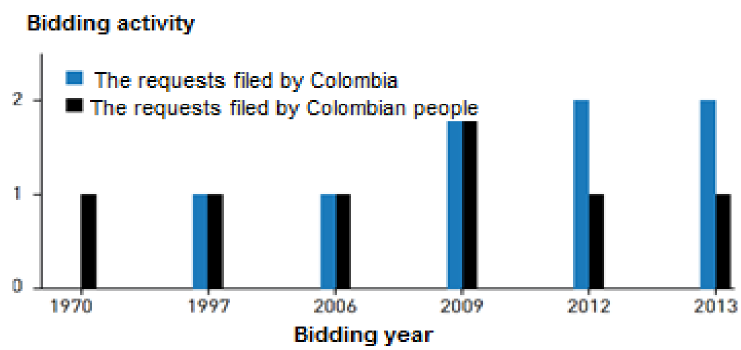

Figure 6. Patent applications. Source **[48]**

8. Conclusions.

This paper allows to conclude that to understand the operation of drones a mathematical modeling to estimate the behaviors during flight is required; moreover, factors for designing and equipping the aircraft for the development of some specific tasks have to be considered also for the characterization and determination of the control system to be installed for reliable use.

On the other hand, we can have a clearer picture of the evolution and development of UAVs that is expected in the coming years, given the opportunities for growth in this field taking into account the needed support with legal and regulatory frameworks as already done in Colombia and other

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countries of the Americas region. However, we still need to deepen the use of drones on topics such as inspection of high voltage lines; rescue; environmental protection; agriculture; and where it not defined yet such as medical support or first aid [49]

Innovators are making rapid advances and finding valuable solutions to difficult problems in the drone industry. In most situations, patents are the best form of intellectual property to protect drone technologies and companies in the industry have been obtaining large numbers of drone patents. However, trade secrets, trademarks and copyrights can also play an important role in a well rounded intellectual property strategy thus research groups at universities will play an important role in development of drones technologies mainly due to the transfer of knowledge and training that will provide new control robotics and mechanical systems.

On the other hand it can be concluded that: just like smartphones did a decade ago, Drone's usefulness bleeds from the consumer market into the commercial. That's because in drones we're now seeing the convergence of numerous advanced technologies cameras, computers, sensors, phones, the web, motors, electrical systems and custom hardware—with addition of a regulatory and legal framework [50]. Each Drone can be designed for a specific objective that is the most exciting thing about the current moment, however, no one is really sure

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where this all will lead. A few years ago, “drone” was a dirty word. Now seven billion people will figure out how to change the world with the technology created today. As 3D Robotics Said *¨Welcome to Life after Gravity¨.*

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