A PROPOSAL FOR A BRAZILIAN UAV RESEARCH NETWORK

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Abstract. *Since 1992, the Renato Archer Research Center – CenPRA has been acting in the aerial robotics research and development domain. R&D for aerial robots is characterized by multi-disciplinary activities that requires the integration of different engineering competencies, such as Mechanical, Aeronautical, Electrical, Control, Computer Science, Robotics, etc. These different competencies are not easily found in every research institution in Brazil, rendering effective aerial robotics R&D a difficult matter. A natural solution for this scenario is to build-up a cooperative network for aerial robotics R&D, where researches share competencies, resources, results and experiences. The purpose of this article is to show the aerial robotics R&D situation in Brazil, to stress the motivation for a aerial robotics R&D network in Brazil and, finally, to propose a methodology for the creation and operation of such a network.*

Keywords: *research network, UAV-unmanned aerial vehicle, research, development, open platforms.*

1. INTRODUCTION

There is a great interest in the utilization of UAVs (Unmanned Aerial vehicles), due to their potential application in varied tasks such as surveillance, advertising, monitoring, inspection, such as bio-diversity, ecological, climatological, and agricultural research or monitoring, among others exploration, and research roles (Elfes et al. 1998). The aircrafts being considered for this set of applications are airplanes, helicopters and airships, although there are references for miniaturized and unconventional aircrafts.

For UAVs in general, the technological evolution passes by the establishment of solutions that aggregates autonomy capacity to the aircraft, (e.g., reducing the constant need of a pilot on the ground, by the insertion of intelligence on the aircraft). This multidisciplinary knowledge spectrum goes from automatic piloting solutions to more complex levels such as: the incorporation of perception capacity and decision making throughout a mission; the use of sensory sources as vision, radars, etc; the cooperative operation between ground and terrestrial vehicles, etc. These capabilities have to be mapped on the integration of equipment, sensors, hardware and software, communication systems, equipment redundancy and fault tolerance, and so on.

Currently, UAVs share a small part of the aerospace market, but for the next decades the forecast is that it will happen a big increase of its importance in the market sharing.

In the world scenario, countries as USA, Israel, Australia, Canada and the European Community are the main actors. US roadmaps are available as the UAV Roadmap (2005) and NASA (2005). In countries as Korea, as an example, UAV programs have been structured, with the objective of inserting Korea in the group of countries that dominate this technology. In other countries it have been elaborating the rules for UAV flights, and there is open discussion about the integration of UAV flights with the manned aircrafts (UAV MarketSpace, 2007).

In Brazil, the first effort in UAV happened by 1980 and this was conducted by CTA (Centro Técnico Aeroespacial). Currently the number of UAV projects are about twenty. UAVs are strategic to Brazil, due to the Brazilian territorial extension, with regions without infra-structure that are not frequently observed, that have a high agricultural potential or with a high potential for the sustainable exploration of its resources and bio-diversity, and at the same time it is important to prepare the country to enter in this market. With the objective of structuring a national policy for this sector the Defense Brazilian Ministry issued the decree 606/MD in 11 March 2004, defining the importance of UAV for Brazilian defense.

Among the groups that perform research in UAVS, since 1992, Renato Archer Research Center (CenPRA) has been acting in the UAV research and development domain. First, from 1992 to 1995, CenPRA participated in the Gyron Tecnologia company effort to develop an unmanned helicopter - the Helix project. Then, in 1996, CenPRA started the AURORA Project - Autonomous Unmanned Remote mOnitoring Robotic Airship that focuses on the establishment of the technologies required to substantial autonomous operation of unmanned robotic airships for environmental monitoring and aerial inspection missions.

Based on this experience and on the interaction with other groups that is presented this paper with the objective of proposing a Brazilian network on education, research and development of UAVs. So, after this introductory section, this paper is organized as the following. In section 2 it is presented the technologies involved in UAVs, while Section 3 presents CenPRA experience on the development of UAV's. Section 4 presents a panorama of the Brazilian initiatives on the area and Section 5 presents a proposal for the research network. Finally, Section 6 presents the conclusions.

2. COMPETENCES INVOLDED IN THE DEVELOPMENT OF AN UAV

Ideally an UAV can be a very sophisticated robot, incorporating the state of art of robotics technology, that is the integration of Electrical, Control, Computer Science, Mechanical and Aeronautical Engineering.

In this section it is considered two main axis in UAV research and development: robotics (grouping electrical, control, computer and robotics and aeronautical (grouping aeronautical, materials and mechanical engineering). Since there is an intersection and interdependence between them, this separation simplifies, without losing the generality the appreciation of the competences involved on UAV.

2.1 Robotics

Depending on the robotics technology used, an UAV can have the following degrees of autonomy as showed in Table 1. These levels can be seen as different robot capabilities in an evolutive approach for UAV development (Ramos, 2002 and 2003).

Table 1: Scenario for the evolution of robotics UAV's.

Scenario	Capability
1- Remote piloted UAV	A pilot commands the actuation devices directly on the ground, that visually follows the flight evolution by direct observation or indirectly by images generated by on board cameras on the vehicle.
2- Teleoperated and telemonitored UAV	The command of actuation devices is operated directly by a pilot on the ground, and its situation is given by a set of on board sensors (telemetry data) and on board cameras
3- Supervised robotic UAV	Capacity of executing repetitively a set of programmed movements commands and the observation of its situation is given by a set of on board sensors that are transmitted by telemetry.
4- Autonomous robotics UAV	Capacity of executing and changing plans in function of information given by a perception system, from information issued from on board sensors. The mission specification is given in a high level of abstraction, in interaction with an operator on the ground, that has also access to the telemetry and mission data, sent to the ground by the vehicle.

Considering a robotics point of view, the UAV development, requires a set of components (Ramos, 2002 and DePaiva, 2006), that are used to build the capabilities mentioned in Table 1, given to the vehicle the specified autonomy. These components can be classified in three interdependents functionalities: robotics, support to the implementation and support to the development, as can be seen in the sequel.

The robotics resources are:

i) aircraft stabilization, movement control and navigation;
ii) mission planing and control, and;
iii) perception and sensory interpretation in different complexity levels.

As support resources for the implementation we have:

i) On board and ground infra-structure for components integration and for processing;
ii) real time software;
iii) aircraft-ground bi-directional communication system;
iv) ground station for registering the telemetry data and human-interface for the vehicle operation;
v) robotics software architecture and
vi) solutions for redundancy and fault tolerance.

As support resources for the development we have:

i) mathematical modeling and identification methodologies;
ii) computer aided simulation and control design environment, and;
iii) environment for development and operation.

2.2 Aeronautical Engineering

An UAV must have mechanical and aerodynamics characteristics that allows its use as a robotic vehicle. This includes:

i) aircraft adequate to the operational requirements;
ii) capacity to carry the load corresponding to the operational and mission equipments;

iii) propulsion adequate for an specified flight condition; and
iv) maneuverability adequate to the operation in different meteorological conditions.

Besides the characteristics of a robot, an UAV must obey the typical methodologies of Aeronautical Engineering including those associated with flight safety. In this case it must be considered features related to aeronautical certification as:

i) project;
ii) components;
iii) vehicle, and ;
iv) operation and maintenance.

These certifications are based on internationally accepted standards, that defines directions for aircraft certification and operation. Related to the UAV certification, there is not consolidate standards, as the FAA for manned aircraft. A lot of countries have been trying to established his own rules for UAV certification as Australia (CASA101, 2007) and South Africa (UAVM-cert, 2007). If the unavailability of international standards for the certification and use of UAVs has been a barrier for the dissemination of civil use of these vehicles, in other side there are some signs as the discussion of this theme in several forums (UAVM-2007). The existence of normalization groups preparing the proposition of UAV standards, and the existence of standards ready to use in other countries, gives the perspective that an internationally acceptable standard will be established in a near future. Another relevant element in this context, the integration and harmonization of UAVs with manned vehicles are still in the initial phase of discussion.

3. CENPRA'S EXPERIENCE ON THE DEVELOPMENT OF UAVS

The objective of this section is to present CenPRA's experience in the development of UAVs, that can be used as a reference for a proposal for building a network for education, research and development in UAVs. CenPRA's activities in UAVs R&D have started in 1992, first with Helix project (helicopter), then since 1996 with the development of AURORA project as we show in the following.

3.1 Helix project

Helix project (Figure 1) had as focus the development of an unmanned robotics helicopter for inspection. The project was developed by the company Gyron Tecnologia from 1991 to 2000. From 1992 to 1995 it was a cooperative action involving Gyron, CenPRA and the Federal University of Santa Catarina (UFSC).

The main sponsors of Helix were CNPq, SEBRAE, FIESC and SOFTEX.

The project developed a prototype of an unmanned helicopter, the on board and ground systems, and the communication infra-structure. CenPRA participated in the develpment of:

i) mathematical modeling, simulator and development environment;
ii) on board system based on transputer and microcontrollers; and
iii) design and test of control strategies in simulation.

Figure 1 shows the Helix helicopter in the left side and the helicopter simulator developed for this project in the right.

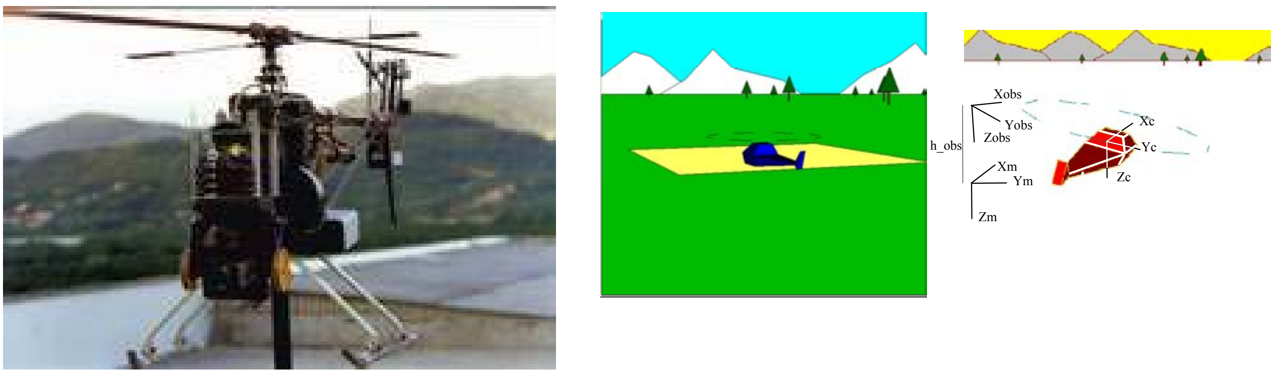

Figure 1:Helix Helicopter (left) and the helicopter simulator developed for this project (right)

3.2 AURORA project

AURORA project, has as focus the development of autonomous robotics technology for UAVs, using unmanned airship as platform, with the objective of environment monitoring, inspection and surveillance (Elfes et all., 1998), (Ramos, 2002), (De Paiva et. all., 2006).

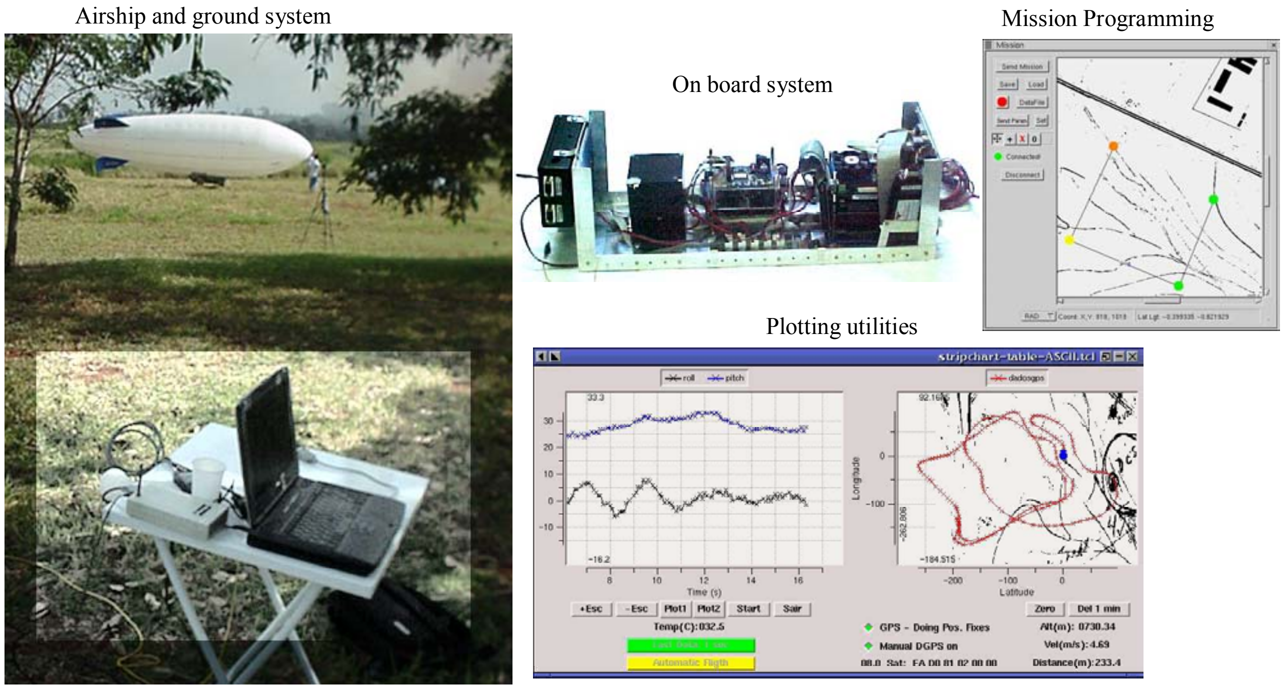

Figure 2: AURORA Main components

The system is composed by an airship of 10.5m long and 10Kg of load capacity. The following components were build for AURORA:

i) hardware, sensory infra-structure, software (real time using open standards) and communication infra-structure for the ground and on board systems;
ii) automatic control strategies based on sensors as GPS, compass, inertial sensors and wind sensors;
iii) mission programming tools;
iv) environment for software development.

In the current stage, the robotics airship is capable of autonomously following pre-defined trajectories defined by the operator in terms of way points and altitude profile in cruise flight. These results were obtained from 2000 to 2002 (Ramos, 2001) and they are one of the first autonomous flights for airships reported in the literature.

Among the current developments we have:

i) methodologies for control and navigation, based on non-linear techniques, for all the operation phases including take-off, vertical landing, hovering and cruise flight;
ii) methodologies for servo-visual control, including objects following based on structured targets as straight lines (transmission lines, pipelines) and its evolution for unstructured targets;
iii) strategies for sensor fusion, mapping and auto-localization methodologies;
iv) reactive and deliberative robotics software architecture to support mission programming and execution.

Figure 2 shows AURORA main components. On the left appears the airship and ground station CPU, on the top center appears the on-board system. In the center bottom is the plotting utility and in the top right the mission programming interface.

AURORA project has cooperations with DCC/UFMG, FEEC/UNICAMP, INIRIA(French), IST and ISR (Portugal) and CMU (USA). It has as main financial sponsors CenPRA, FAPESP, FAPESP/INRIA, CNPq, CAPES, CNPQ/CTPETRO and PROTEM_CC/CNPq.

Besides the technological-scientific that results from the current efforts on R&D, AURORA looks for sponsoring for the evolution and the construction in Brazil of a greater airship and to install inside it the solutions that were established, becoming this bigger aircraft capable of more effective applications.

4. BRAZILIAN UAV PROJECTS

The first UAV initiative in Brazil belongs to CTA (Technological Center for Aeronautics) by 1985. Since then, the number of UAV research and development, projects and initiates is arriving to twenty.

This section gives a panorama of UAV activities in Brazil. This panorama is not exhaustive and the information given were obtained through authors interaction with researchers from other groups or by bibliographic references or by search in Internet.

Table 2 is a summary of Brazilian UAV initiatives in Brazil, and more information is given in the following.

Table 2. Summary of Brazilian UAV initiatives

Project	Year	Objective	Results
ACAUÃ	1984 1991	Remoted piloted UAV	Airplane (Acauã) and booster for radio control
AEROMOT	1986	A drone K1AM	Airplane and electronics, stabilized flight
Helix	1991 - 2000	Unmanned Helicopter for inspection	Aircraft, on board and ground systems, model simulation, and control
AURORA	1997	Unmanned Airship for inspection and remote monitoring	on board and ground systems, model, and autonomous flight
AERODESIG	1999	Radio controlled airplane	Model aircraft for competitions
ARARA	1999	Unmanned airplane for inspection and monitoring	Aircraft control and modelling
FITEC	2003	airplane	Aircraft, on board and ground systems
AGROROBOT	2003	airplane for spraying	Aircraft
CESAR-ITA	2004	airplane for power line inspection	Aircraft, on board and ground systems
SiDeVAAN	2004	airplane for inspection	Aircraft, on board and ground systems, control and autonomous flight
CARCARAH-EXPANSION	2004	Helicopter for power line inspection	on board and ground systems modelling and control
VANT CTA	2005	Infrastructure for UAV	on board and ground systems and control
EPUSP-Mecatr.	2005	airplane	Aircraft, on board and ground systems
UAV-UFBA	2005	Infrastructure for UAV	on board system
ITA	2006	airplane	Aircraft, on board and ground systems
UAV EEUSP-SC	2006	airplane	Aircraft, on board and ground systems, simulation and control
Watch dog / Flight Solutions	2007	airplane	Aircraft, on board and ground systems
UFRN	2007	Helicopter	on board and ground systems and control

ACAUÃ /CTA - Acauã - It is pioneer Brazilian UAV project developed by CTA from 1984-99. In this project was developed the aircraft and the amplifier for a regular radio control and performed radio-controlled flights (D´Oliveira, 2005).

AEROMOT - since 1986 has been developing the drone K1AMa – a product that has digital stabilization in roll and pitch, allowing remote commands in distances closer to 70Km (Jotz, 2005).

Helix /GYRON Technology - 1992-2000, it was detailed on section 3.

AURORA / CenPRA/MCT - 1996, It was detailed on section 3.

ARARA / LCMC/USP-SC - since 1999 has been developing with EMBRAPA (Brazilian research center for agriculture). It includes the development of the airplane, on board and ground systems, mathematical model and control systems. Arara aircraft has been used in several autonomous flights using the UAV for agricultural applications as crop monitoring (Jorge, 2005).

AERODESIGN - since 1999 students from several engineering schools, perform the project, construction and flight tests of unmanned airplanes for the competition in Aerodesign (Aerodesign, 2007), as a consequence the Brazilian teams succeed in several opportunities in the Aerodesign international competition.

FITEC - is developing an UAV as an internal program since 2003, with the goal of dominating the technologies related to UAV. In this context built an airplane, equipped it with an on-board system and ground system and performed some flights (Borges, 2005).

AGROROBOT / PRINCE - aircraft model manufacturing company, developed an airplane for spraying in agricultural applications, with FAPESP financial support (Prince, 2007).

CESAR-ITA - started in 2005, with the final tests programmed to the end of 2006, it is a cooperation between CESAR (IT Center) and ITA for the conceptual study of an UAV applied to the inspection of electrical power lines with the financial support of CHESF (electricity generation and transmission) (ITA-CESAR, 2007).

SiDeVAAN / UFMG - Started in 2004 involving the departments of Computer Science, Electrical and Mechanical Engineer of UFMG. In march 2007, performed the first autonomous flight with all the systems designed by the group (Estado, 2007).

CARCARAH /UNB- Expansiom - The goal is to study the use of an unmanned helicopter in the inspection of power lines. It is sponsored by Expansion, a company related with electrical energy transmission (Carcarah, 2007).

VANT / CTA - This project integrates CTA, CTEX (Army) and IPqM (Navy) and AVIBRAS (company) for the development of the Control and Navigation system to be used by the different projects of the Brazilian Defense Ministry. This project is developing the on-board, ground and communication systems, and aspects of aeronautical engineering to design the control system (D´Oliveira, 2005 e 2006).

EPUSP-Mechatronics - It involves EPUSP Mechatronics students, that since 2005 have been developing an UAV, ground and on-board systems (Br-auav, 2005).

UAV-EEUSP-SC - It includes the aircraft design, on-board, ground systems, mathematical model. simulation and control algorithms (Uaveesc, 2007).

UAV-UFBA - It is a MSc work developed in 2006 at UFBA, about an on-board infra-structure for and UAV using a 8051 microcontroller (Filardi, 2005).

ITA - It is a MSc work developed in 2006 at ITA, that builds an aircraft, the ground system and used off the shelf components as a GPS that incorporates an attitude sensor and altimeter, and used cell phones as the base for the communication system. (Rangel, 2006).

Watch dog / Flight Solutions - It is a start-up company that is a joint venture of Flight Technologies (FT).and Advanced Composite Solutions (ACS). FT has experience with UAV on-board and ground systems, mainly with the VANT-CTA project and the other, ACS, in the construction of the aircrafts used in the SiDeVAAN project (Estado, 2007).

UFRN - It is initial phases of an unmanned helicopter.

The previous summary shows that the number of UAV initiatives in Brazil is approximately twenty in an interval of 20 years. Some of these initiatives are recent and others are being structured. As results, the projects developed aircrafts, on-board and ground systems, control algorithms and methodologies for autonomy.

When it is considered the military side, this is covered by the VANT project conducted by CTA. In the civil side, mainly in education and research, we observe a set of works without any articulation or integration.

This insulation in the civil area comes as an opportunity to look for a greater synergy among the groups, with the objective of incrementing the evolution in this area. The author's perception that a path in this direction is to build an UAV network for education, research and development.

5. CREATION OF AN UAV EDUCATION, RESEARCH AND DEVELOPMENT NETWORK IN BRAZIL

The development of technologies associated to UAVs and the formation of human resources for this task, asks for a synergic actuation for optimizing the investments and the results, accelerating the dominion of this technology in Brazil. Figure 3, presented by the authors to Brazilian Ministry of Science and Technology (2002, 2003 and 2004), to the Defense Ministry (in 2003) and to São Paulo Secretary of Science and Technology (2002), constitute a feasible model, based on a strategic organization, associating industry, academy, users and government..

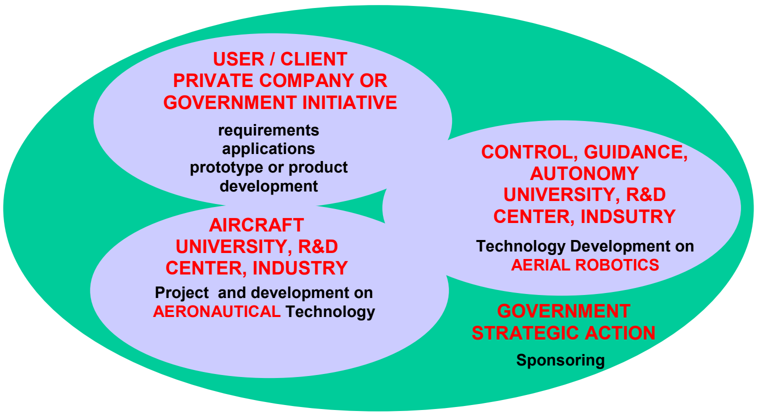

Figure 3. Strategy for the development of UAV in Brazil.

Based on the examples of thematics networks in Brazil as Genoma, Proantar, Systems on Chip, Brazil-IP, Manet, etc., we propose the creation of a Brazilian Network for the education, research and development in UAVs. This network would have three axes:

1- In Short Term the creation and the availability of:

a) project and construction plan of unmanned aircrafts to be used by the network;
b) an open hardware and software platform for the on-board, ground and communication resources to support the development of UAVs;
c) basic support resources in the form of aircraft mathematical models and simulators, base algorithms for aircraft stabilization, control and guidance;
d) the use of Internet for information sharing, interaction, classes, videos, etc.

2- In medium and long terms the establishment of a strategy for gradual, shared and complementary development in the different technologies used for an autonomous operation of these aircrafts, and also group of aircrafts, working and behaving cooperatively.

With the purpose of structuring the actions related to the items (1) above and mainly those related to item (2), it would be important the realization of a Workshop about UAVs, with the following topics:

- The presentation of UAV projects, systems and avionics sensors for UAVs being developed in Brazil.
- The presentation, under the application point of view of potential users of UAV technology, represented by its relevance and nationalwide inclusion;
- The presentation of representatives of Ministries and sponsoring organizations with direct relation to the subject, defining the policies for the sector and perspectives for financial and strategic structuration;
- The discussion about the creation of a network for education, research and development in UAVs, and definition about its structuration, establishing the objectives, work plan, actuation, etc.;
- Mapping of the competences available in the country including areas with a low number of researchers, with the objective of defining cooperative actions and the priority for people formation;
- The discussion about actions and sponsoring strategies for the creation of a national policy in the UAV sector.

6. CONCLUSION

This article presented a general view of unmanned aerial vehicles, the technological domain and requirements involved in their development and the situation of this sector in Brazil. From this panorama, it was pointed an opportunity of increasing the synergy among the groups actuating in this area.

In this context it was proposed the formation of a Brazilian network on education, research and development of unmanned aerial vehicles and defined a strategy for its development. The next steps and the resulting definitions pass by the involvement and building of consensus among the actors involved in the UAV field in Brazil.

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