Aerial Mechatronic Systems for Collection of Atmospheric and Environmental Data

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Abstract—Currently, atmospheric and environmental monitoring also requires approaches based on robotic aerial mechatronic systems that can offer the advantages of onboard intelligent sensors. The accelerated dynamics of climate change generate risks that can be prevented by the acquisition, storage, transmission and processing of data taken under static, quasi-statistical and kinetic conditions at lower costs compared to piloted aircraft. The article presents an approach on atmospheric and environmental monitoring using a robotic aerial mechatronic system based on an airship UAV and a classic airborne UAV, launched using a ground-based launch device.

Keywords—Mechatronic system, LTA-FW architecture, sensors, environmental monitoring

1 Introduction

Robotic air systems fully meet the requirements to be able to catalog complex mechatronic systems through the synergistic integration of the following systems (at ground level and air vector level): command and control system, energy system, actuator system, sensor system and different computer applications [1]. Moreover, unlike artificial intelligence, which is another engine of the fourth industrial revolution, robotic autonomous air systems have surpassed the critical point of validating expectations on the transition curve, heading to the area of productivity not only in the military field, but also in the civil, commercial or hobby fields [2,3,4,5,6,7].

Increasing the capacity to adapt to the real or potential effects of climate change represents a strategic objective at national level. It can be achieved by carrying out the following specific activities: active monitoring, risk management in critical sectors, adaptation measures based on effects [8].

In the field of environmental monitoring, the use of these systems is not new [9-12], imposing itself by exceeding some limits of the traditional monitoring platforms (ground stations, aircraft, satellites) through versatility, efficiency and accuracy [13-17].

The proposed technical and procedural solution (MAPIAM) solves the need for efficient monitoring by using personalized technologies [18] for the information and data collection stage. MAPIAM is a recoverable and manageable system capable of collecting and transmitting meteorological data in real time from areas not covered by conventional monitoring methods. The availability, accessibility and format of this data facilitates the elaboration of microclimate predictions needed in different fields of activity.

2 Mechatronic System Description

The architectures consisting of a lighter-than-air system (LTA) and a robotic air system (fixed-wing type - FW) were developed with the purpose of exploiting the autonomy performances offered by LTA and the relatively high speeds offered by the robotic air systems carrying sensors used in data acquisition (e.g. image, sound, temperatures, contaminated atmosphere).

The innovative MAPIAM system, whose architecture is based on the LTA configuration - deployment device - FW, eliminates the technical and procedural vulnerabilities identified in the specialized literature: UAV clamping device with a complicated architecture (beam, clamps, mat), which increases probability of failure in operation [19]; releasing the UAV from the balloon through the free fall procedure raises problems of resistance of the UAV structure and its flight control [20].

2.1 Description of the release device

Use The launching device is the result of the theoretical and experimental achievements of the authors in the field of robotic air systems. This eliminates the disadvantages of the launch devices and methods described above by constructive simplicity and trigger automation by means of the autopilot on board the fixed wing robotic air system. The technical problem that the invention solves is to print the desired launch direction and rapid static or free launch without affecting the resistance structures of the heliostat and the robotic air system.

The main components in accordance with the operational flow are presented schematically în Fig. 1.

The device for remote controlled deployment of heliostat fixed wing robotic aerial systems has an aluminum rod type heliostat (1) and two identical 8 mm diameter aluminum guide elements (2). Two identical wing fastening elements (3) each made of two ABS clamps (4) and an aluminum pipe with a diameter of 12 mm (5) slide on the guide elements (2) and a mechanism consisting of a servomechanism with 5V power supply from the autopilot battery (6), shaft (7), safety ring (8), seat (9) and cord type cable (10) ensure remote controlled release.

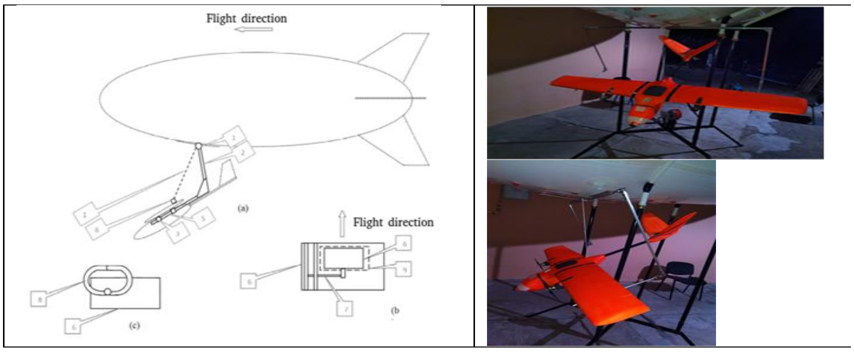

Fig. 1. Diagram of the release device: (a) as a whole, (b) remote control release mechanism, (c) servomechanism

By applying the invention, the following advantages are obtained: the problem of remote control of the deployment of the robotic air system is solved without the need for reconfiguration by equipping with other elements; the release device is based on a simple and scalable architecture; the possibility of launching at any time on the climb path and environmental conditions; very short lead time; very low production costs, provided that the connection elements are made using 3D printing technology.

2.2 UAV-LTA description

The UAV blimp is a 2014 design and a 2017 manufacture, with four-tire polyurethane tire and equipped with electric propulsion, see figure 2 and table 1 [21]. The air system contains the airship type air vector, a portable command-control (C2) station and a manual docking device.

The blimp is guided using a 6-channel RC system (2.4 GHz), 433 KHz (100 mW) telemetry and 5.8 GHz image, the technical characteristics are shown in table 1. The UAV-LTA aerial vector is equipped with 3 electric motors.

Fig. 2. UAV-LTA

Table 1. Technical characteristics and flight performance

Characteristics	Value	Characteristics	Value
Length /diameter	5 / 1,7m	Gas	Helium; loss 0,3% / zi
Envelope	poliurethan 100 microns / 8 m^3	Speed	0 ÷ 20 km/h
Payload mass	1,2 kg	Autonomy	1 h
Helium mass	1,35 kg	Range	20 km
Total mass	7 kg	Ceiling	3000 m
Propulsion	3 x electric	Battery	3 x LiPo 11,1 V de 3A
Command	6 channels	Automat pilot	48 channels

The main type of missions that can be accomplished is the acquisition of data in static / quasi-static mode and at low speed, as follows: image data with EO-IR sensors or FLIR camera; telemetry and atmospheric data, such as: temperature, humidity, dew point, air quality, wind direction and intensity; noise level data.

2.3 UAV-FW description

Nimbus is an aircraft manufactured by the MFD (MyFlyDream) company in UAV concept, an electric twin-engine, with rectangular wing placed on top and V. V-shaped fuselage. The materials used are: carbon fiber (rear fuselage), EPO foam (wings, fuselage and hinges) and plastic and metal (assembly elements), see figure 3.

Fig. 3. UAV Nimbus

Due to its flight characteristics (see table 2) Nimbus can carry out a series of missions, as follows: acquisition of telemetry and image data, available in the delivery version due to the on-board radio-electronic equipment (GPS, autonomy); acquisition of atmospheric data, depending on the environmental sensors placed on board (temperature, humidity); acquisition of data on trajectory 3D behavior and structural behavior based on sensors placed on board [16,17].

Table 2. Technical characteristics and flight performance

Characteristics	Value	Characteristics	Value
Span / length	1,8 / 1,3m	Propulsion	2x electric 12V
Max speed	130km/h	Battery	6S, 16A
Max mass / payload	5,5 / 1,5kg	Command	2,4 Ghz, 6channels
Ceiling	3500m	Autonomy	1,5 – 2,5h

3 Flight Mission with The Data Acquisition

3.1 Preparing the mission

The tests carried out aimed to streamline the procedures for acquiring the climate data of the overlying areas. For this purpose, a data acquisition system equipped with a humidity and temperature sensor was connected, connected to an acquisition board. The data transmitted by the sensors is read every 2 seconds, being synchronized with the spatial positioning data provided by the GPS sensor.

The command to trigger readings by the acquisition board was made by interconnecting it to the autopilot module. Thus, through the mission planning interface, actions can be established that can be performed at certain WP (way point) or between WP, actions that are transmitted in the form of a PWM signal to the acquisition board.

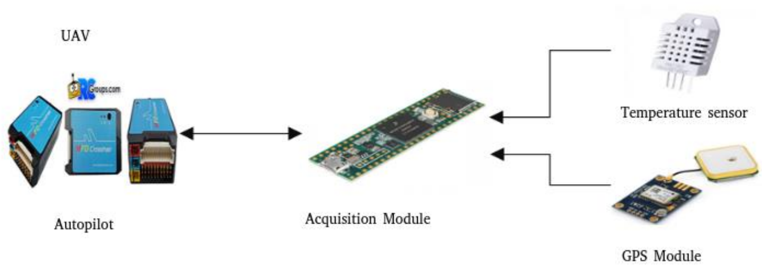

Fig. 4. Connection diagram

In this way, 3 methods of data acquisition were planned and executed. This procedure consists in raising the UAV-LTA system to a predetermined altitude, expanding the UAV and entering it on the path of predefined automatic missions.

3.2 Types of data acquisition missions

Pattern with parallel paths and altitude change: The flight pattern with parallel paths and the altitude change is intended to probe the atmosphere on a surface as wide as possible at different altitude levels [22].

During the experiment, 3 routes were planned (Figures 5 and 6) with the starting point of the mission being WP8 -150m AGL, and the starting point of the readings in WP7, the altitude difference being 50m along the route.

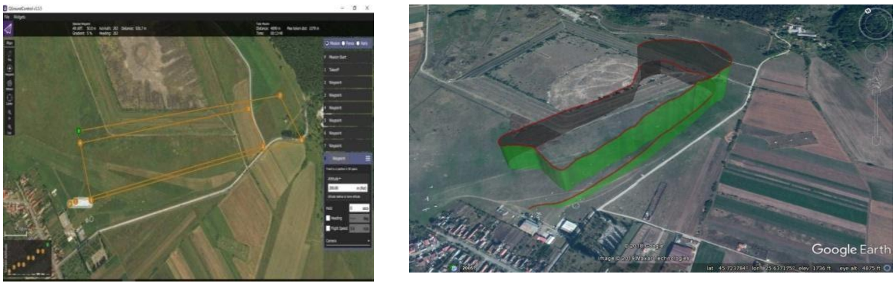

Fig. 5. The flight path

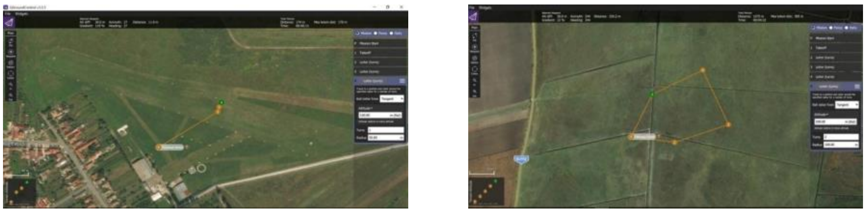

Fig. 6. The flight location

The figure 7 shows the temperature and humidity data collected every 2 seconds, the data being spatially located using GPS.

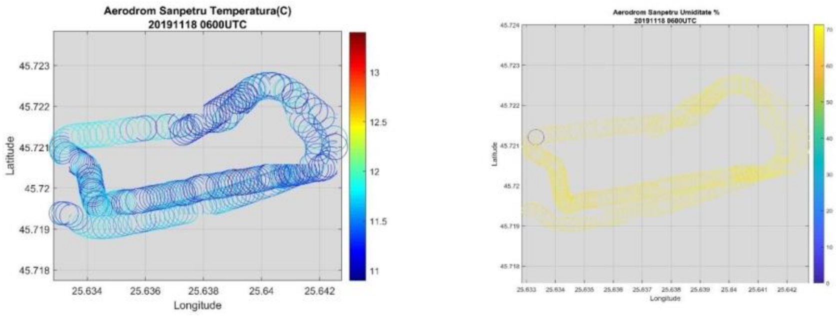

Fig. 7. Temperature and humidity values

Spiral flight pattern and altitude change: The spiral flight pattern with the change of altitude is useful in collecting environmental data on an air column at the vertical point of interest (figure 8).

Fig. 8. Spiral flight pattern and altitude change

The procedure consists of launching the UAV from a predetermined altitude, and its registration on a downward spiral flight path with a predetermined radius. The humidity and temperature data collected during this procedure can be viewed in the graphs in figure 9.

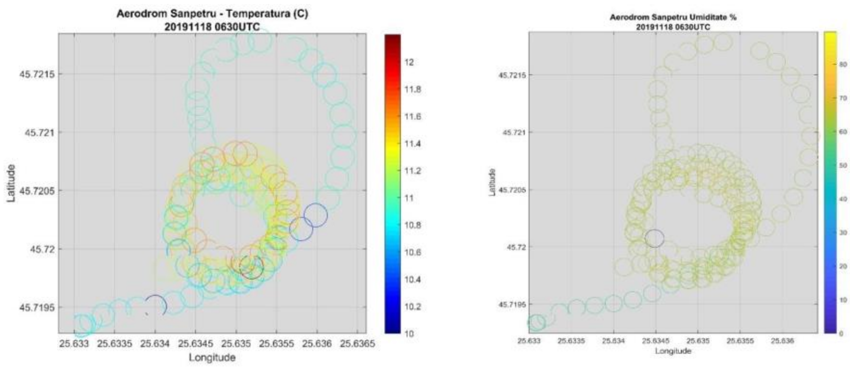

Fig. 9. Temperature and humidity values

Pattern with fixed points and altitude change: The fixed-point flight pattern (Figure 10) and the altitude change is a more complex procedure that allows a quick probing of the atmosphere over different points of interest. The advantage of the mission is that it can be realized on different flight levels, in a very short time.

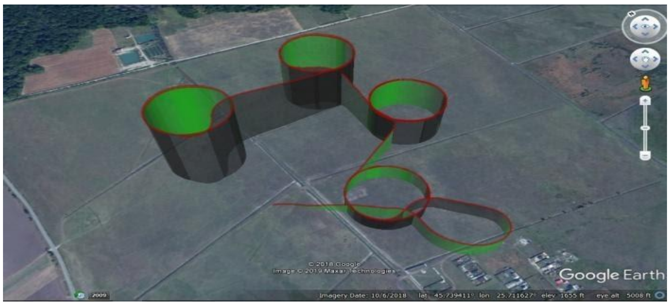

Fig. 10. Pattern with fixed points and altitude change

The data collected during this type of mission are shown in the graphs in figure 11.

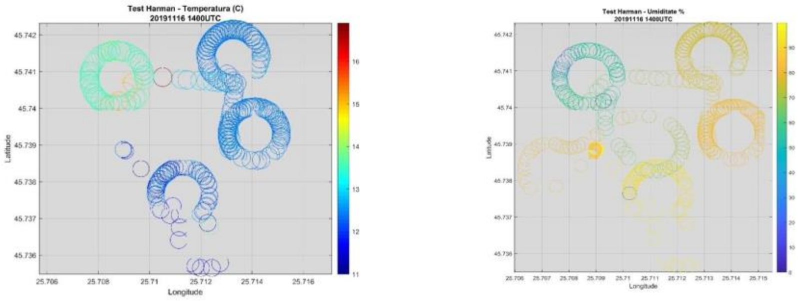

Fig. 11. Temperature and humidity values

4 Conclusion

The article is based on a series of experimental researches and stages of preparation of the two UAVs integrated in the UAS that generated a patent proposal. The aeromechanical characteristics of the two types of UAV-LTA aircraft UAV-FW have requested approaches on system risk management to avoid the occurrence of incidents during the integration of radio electronic systems in the laboratory, during the centering and operation tests in static regime and during missions to acquire atmospheric and environmental data. The three types of missions addressed reveal the real possibilities of the mechatronic system regarding the accuracy of the temperature and humidity data acquisition offered, which can be extended to a package of atmospheric sensors (wind speed and direction, solar radiation level) and environment (PM10, VOC, CO).

The robotized aerial mechatronic system used can offer optimal conditions for sampling atmospheric and environmental data in a low-cost concept in terms of modularity and scalability, depending on the mission requirements. The current level of equipping of the mechatronic system used provides the upgrade possibilities necessary for command and control optimization for the future expansion of the mission range. For a good coverage of data collection in the areas of interest, a mixed approach of types of missions and flight regimes is recommended under the conditions and measures of flight safety.

In the context of climate change, new imperatives are emerging for environmental monitoring: the need for accurate data in short time areas of small and difficult to access areas. Robotic air systems fully meet these requirements, and the proposed MAPIAM architecture has the advantage of being able to be reconfigured quickly for other types of applications than environmental ones: air quality, agriculture, topometry.

Future research directions include, on the one hand, the analysis of the influence of the air mesh on the environmental parameters monitored in the fixed-wing and multi-rotor variants, and on the other, the availability and accessibility of real-time data.

In the context in which the use of robotic air systems in environmental monitoring applications has confirmed technologically and economically, the legal challenge still remains: the legislative framework cannot keep up with the technological progress in the field.

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