A CONCEPT OF SMALL FLYING LABORATORY BASED ON RC AIRCRAFT MODEL

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Abstract. Everything began in 2006 when a team of students from the Rzeszów University of Technology started to design an UAV model for a competition organized by the Association of Young Aviation Engineers (in Polish: SMIL: Stowarzyszenie Młodych Inżynierów Lotnictwa). Students were members of two students organizations at the Rzeszów University of Technology: Students Aviation Scientific Association (SASA) and EUROAVIA-Rzeszów. The design of aircraft aerodynamic structure is very successful. Two prototypes - discussed in this paper - have been made, the aircraft is under development. It has very good flying properties. Additionally, some avionics elements (camera, data transmission system) were successfully tested during flight. The designed avionics system is also described in the paper. The first successes decided that the aircraft will be developed as students' cheap flying laboratory for university research and education.

Keywords. Flying didactic laboratory, In-flight testing, UAV.

1 Introduction

Competitions for students are well known in many developed countries. The examples of aeronautical competitions are SAE aerodesign competition [1] and AIAA Design-Build-Fly [2] in USA or Air Cargo Challenge [3] in Portugal. They motivate students to use their theoretical knowledge in practice, participation in a competition makes them more creative. Sometimes results of their work are very interesting and useful. This kind of activity was observed at Rzeszów University of Technology. Everything started in 2006 when the team of students from the Rzeszów University of Technology started to design an UAV model for a competition organized by the Association of Young Aviation Engineers (in Polish: SMIL: Stowarzyszenie Młodych Inżynierów Lotnictwa). The competition took place in Bezmiechowa, Poland. The goal was to inspire the participants to find solutions useful in UAV applications. Participants were supposed to realize a project including tasks in the areas of flight mechanics, design, prototyping, control, navigation, data transmission and picture analysis. Such project enables students to use and verify the knowledge and skills acquired during the studying process. The designed UAV model system was to find the object in the area of 1000x1000 meters, identify its position with the accuracy of 25 meters (0.0002 deg of geographical latitude and longitude). The object to be found was 1.5x1.5 meter white square, with 30 cm black diagonals. The object was placed horizontally on the ground. In addition, the UAV model was to observe an immovable object (1 minute) and realize the desired trajectory (maximal tolerable deviation: 80 meters). The maximal take-off mass was 5 kg. For transportation, the aircraft had to be put into a box with dimensions 1000x300x350 milimeters. The aircraft dimensions were to allow its placing in the square 1500x1500mm [4]. Figure 1 presents the UAV model and the team taking part in the project.

Figure 1. UAV model designed and prototyped by students from the Rzeszów University of Technology during its flight and the student team with dr. Roman Świtkiewicz: a jury member in SMIL competition. From the left to right: Maciej Dubiel, Szymon Cyran, Grzegorz Łobodziński, Maciej Roga, dr Roman Świtkiewicz, Sebastian Majewski, Błażej Morawski.

Because of the model’s good flying properties, design enabling easy mounting of avionics, possibility of quick production and repair, a concept of small flying didactic laboratory based on the model was born. Below organizations taking part in the project and technical details enabling implementation of the model as a low-cost flying laboratory are presented.

2 Student organizations taking part in the project

Students taking part in the project are members of two student organizations at the Faculty of Mechanical Engineering and Aeronautics of Rzeszów University of Technology: Student Aviation Scientific Association and EUROAVIA-Rzeszów. Because of many interdisciplinary problems appearing in the design, in last months also some students from the Faculty of Electrical Engineering and Computer Science were invited to cooperate in the project.

2.1 Student Aviation Scientific Association

The Student Aviation Scientific Association (SASA) was founded in 1976 and with some small breaks it lasts till today, which makes it one of the oldest student organizations at the Rzeszów University of Technology. Originally, it was established to help students make their first steps in the air. But the in-flight training was not the only purpose of the Association. Additionally, the association offered students the possibility to built their own, little scaled flying machines. Importantly, once there was even an attempt to make a real aircraft. On the ground of the modelers workshop, the group of UAV designers has come into existence as an answer to the contest of young aviation engineers. The work on the project is one of the most important in the history of SASA.

2.2 EUROAVIA-Rzeszów

EUROAVIA-Rzeszów is a student organization at the Rzeszów University of Technology and is a member of EUROAVIA: association of aeronautical and space students. EUROAVIA is the European Association of Aerospace Students, founded in 1959. Presently there are 31 local groups in different cities in 17 European countries, with a total of about 1200 members. The association aims to stimulate contacts between students and the aerospace industry. It offers opportunities of acquaintance and exchange among students from different countries and represents European aerospace students at an international level [5]. EUROAVIA Rzeszów was registered as student organization at the Rzeszów University of Technology in academic year 2004/2005, and in these years it became an affiliated society of EUROAVIA. The society organizes many events, such as *Fly-In Rzeszów-Bezmiechowa 2005* (International Meeting of Aerospace Students), Scientific Student's Camp *Aerotechnika 2006*, *Annual Meeting of Euroavia Congress 2008*. Members of the EUROAVIA Rzeszów frequently visit companies connected with aeronautical industry in South East Poland, meet interesting people (e.g. the first Polish cosmonaut Mirosław Hermaszewski) and undertake many other activities. Students associated in EUROAVIA Rzeszów also realize research projects focused on aviation. The most important is the research concerned with problems of avionics for UAV model prepared with cooperation with Student Aviation Scientific Association.

3 Aircraft aerodynamic and structure design and technology

The UAV family from PR-1 to PR-3 is based on the concept of a mini aircraft which weighs less than 5 kilos and can be put into a transport box of specified dimensions. Moreover, it is expected to proceed a complex mission at least in a semi-autonomic mode. These conflicting requirements had significant influence on the aerodynamic appearance and structure. What is more, the satisfying weight-strength ratio had to be obtained.

The outer shape, presented in fig. 2, is a compromise between ergonomics and flying qualities. A wide central fuselage body of monocoque structure, made of glass and carbon epoxy fibre composites enforced with sandwich ribs makes a comfortable space for various electronic equipment and emergency parachute system. The nose bulkhead is removable and provides fitting for a camera. The plane has no special skid for landing but the fuselage structure is stiff enough itself. The wings, though seem to have large area, are short in span due to limitations imposed on total aircraft dimensions. The wing structure varies along its span, but in general it is integral, filled with polystyrene and balsa, partially enforced with ribs and covered with plywood. The wings are connected together to the fuselage by the composite spar, which additionally keeps the engines. The twin engine arrangement was motivated by landing conditions and location of the camera. The empennage of a large area is held by the o-section composite tailbeam.

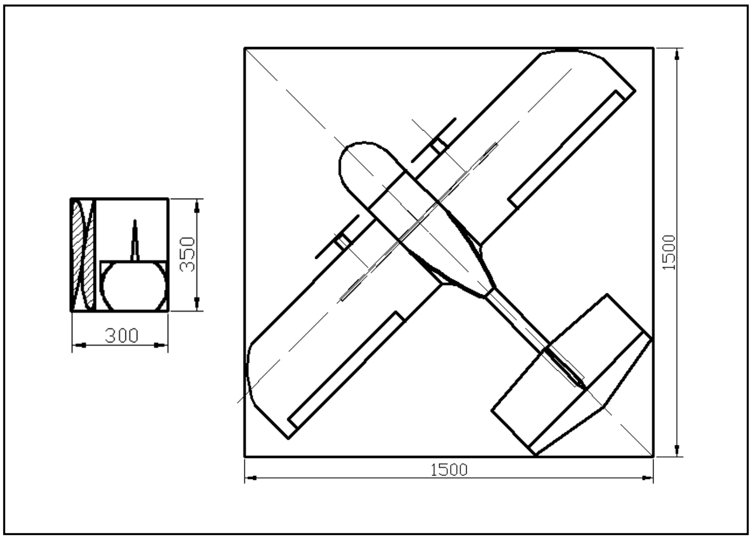

Fig. 2 The general geometry of PR UAV determined by specific requirements

Although the shape of the PR family aircrafts is rather similar, the structure and aerodynamics underwent essential changes during the project development. Starting from classic scale-modeling techniques and intuition, the sophisticated numerical methods like vortex method for airflow and finite elements method for structure are now implemented.

4. Avionic system

The avionic system is designed as an open system, with the possibility of development and elements replacement. The design of the system enables independent research for a few students teams. In general, it consists of two parts. The first part is an autopilot and measurement system unit, the second is a camera and data transmission system. Figure 3 shows the general scheme of the system.

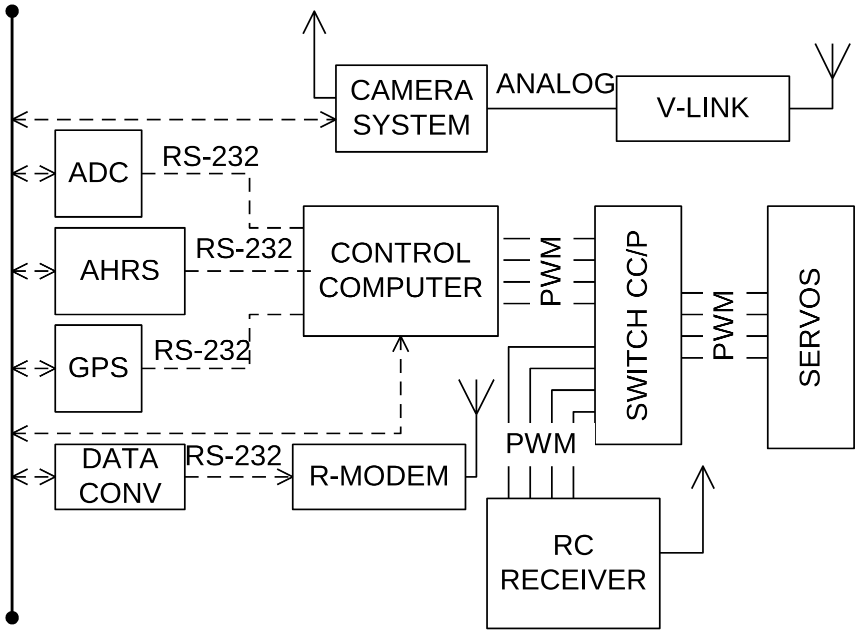

Fig.3. Gneneral scheme of autopilot and measurement system unit.

The control system consists of one main computer, one AHRS, one air data computer and one GPS receiver. This equipment makes it possible to implement control laws enabling attitude stabilization as well as track stabilization and autonomous navigation based on GPS. Communication between the main computer and measurement units is realized via RS-232 or CAN bus. Finally, as a major bus of the whole system, CAN bus is planned. As a transmission protocol CANAerospace standard will be used [6]. However, for first tests RS-232 standard is very helpful. RS-232 standard is also necessary for system tuning and preliminary laboratory testing.

As a main computer a microprocessor system with ARM processor and Linux Real Time operating system was chosen. The main computer is being prepared for the test by a group of students from the Faculty of Electrical Engineering and Computer Science. The chosen system is equipped with CAN bus interface, 8 RS-232, and analog-digital converters. It also enables registration of flight parameters in an in-built SD card. The use of 32-bit microprocessor system guarantees easy implementation and modification of control laws.

In the first phase of tests the Microstrain 3DM-GX1 AHRS will be used. It sends measurements of angular rates, accelerations, as well as calculated attitude and heading. Nevertheless, because of the implemented factory algorithm, the attitude from 3DM-GX1 cannot be applied in aviation. Since correction is switched on during the whole flight, accelerated flight (for example coordinated turning),

leads to significant errors. The solution is to use 3DM-GX1 as angular rates and accelerations measurement unit. In the future another AHRS unit, with CAN interface is planned to be used.
The air data computer (ADC) unit is being designed by members of the team taking part in the project. It will measure and calculate all air data necessary for flight control. For first tests, the ADC computer will use RS-232 communication. As mentioned, RS-232 enables easy testing with the use of a PC computer in laboratory conditions. Communication with the use of CAN bus will also be possible.

5. Concluding remarks

As shown in the article, the structure of the model is designed, prototyped and tested. The students' research concerned with the structure is now focused on technology, which enables very quick production and repair the aircraft model, as well as implementation of advanced designing methods. Also, elements of avionics systems, such as picture data transmission are ready for use and have already been tested during flight. Other avionic elements are during design and prototyping. SMIL competition strongly activated students working on the project. First year students from the Faculty of Mechanical Engineering and Aviation, as well as students from the Faculty of Electrical Engineering and Computer Science are interested in joining the project. Without the SMIL competition, probably it would have been much more difficult to collect a team for such a project.

After first successful flights, the concept to use the designed system as a small and cheap didactic flying laboratory for flight mechanics and onboard control systems testing was born. During educational process in the area of aviation, in-flight experiments are very often impossible because of financial limits, aviation law restrictions and organizational problems. Most of these problems do not exist when a model aircraft is used. With the use of the designed model, following didactic experiments can be made:

- flow visualization, connected with the flight parameters registration (attitude angles, TAS, IAS).
- experiments necessary for aircraft mathematical model identification;
- verification of chosen control laws.

Students practice in the area presented relies mostly on PC simulations and laboratory testing. Additional in-flight testing enables better activation of students. Additionally, during the preparation of in-flight testing students acquire practical skills in engineering.

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