2nd Annual AUVSI Student UAV Competition 2004

Ucakcilar Report

Istanbul Technical University

June 2004

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1) INTRODUCTION

The Association for Unmanned Vehicle Systems International (AUVSI) Student UAV competition is being held for the second time in 2004. The aim of this competition is to stimulate and foster interest in unmanned aerial vehicle systems, technologies and careers. As the "UCAKCILAR" team, we decided to participate in the AUVSI Student Competition '04. Our main goal is to learn about autonomous systems and to be able to use them efficiently. Being the first ones from Turkey to participate in this kind of a competition, we also encourage people to attend these kinds of competitions and to come up with new designs and systems in order to keep advancing in this area. Our team which has participated in AIAA's Design Build and Fly Competitions beforehand, aims to improve its experience and knowledge while preparing for this autonomous motion based competition.

In this writing, the specifications of the systems used, the reasons for choosing those systems, and the work we have done to determine the mission requirements are stated.

2) THE TEAM

Uçakçilar team consists of 10 Istanbul Technical University students. Gökhan Koyuncu and Murat Yuksel are master students in Aerospace and Aeronautical Engineering who pioneered the foundation of the team. Resat Hakan Avcı is a master student in Mechatronic Engineering. Altug Tufekcioglu, Ezgi Karacaoglu, Gonca Basak Bayraktar, Engin Dikmen, Serkan Kale and Batu Zambak are undergraduate students in Aerospace and Aeronautical Engineering. Mehmet Ali Guney is an undergraduate student in Electronic Engineering.

Gökhan Koyuncu, Murat Yuksel, Serkan Kale, Ezgi Karacaoglu and Altug Tufekcioglu has attended AIAA's Design Build and Fly Competition several times. Their knowledge and experience on the uav systems guided the team throughout the work.

Resat Hakan Avci is the major helper of the team with his knowledge on various electronic systems.

Other than the students, the team has an uav pilot Can Arbak, providing the team with proper test flights and his opinions on the characteristics of the uav's flight.

3) SCHEDULE

Having hard time finding sponsors, we had very short time left to work on our project. By the time we could actually start acquiring our material we were already in the beginning of May, but we worked very hard to achieve our goals.

September '03 - December '03	Search for sponsorship Foundation of the team
December '03 - February 04	Search for sponsorship Discussion on the mission Division of labour
February '04 - April '04	Search for sponsorship Search for camera Order the autopilot Development of strategy Discussion on the mission
April '04 - May '04	Getting the micropilot Buying the camera Development of strategy Construction of the aircraft Search for hotels
May '04 - June '04	Reservation of plane Reservation of hotel Getting visas Rental of the car Test flights of our uav Improvement of our uav
23 June '04	Flight to U.S.

4) BUGDET

We had serious sponsorship problems; therefore, we had to cross out many things from our list. Finally we came up with the following expenses:

Description	Cost
Attendance fee	500$
Autopilot customs tax	500$
Digital camera	400$
Aircraft expenses	550$
Flight test	250$
Hotel	1260$
Rental of a car	400$
Fuel	100$
Travelling expenses	8800$
Food	1040$
Visa	700$
Custom expenses	400$
Total	14900$

All of the funds were provided by our only sponsor: Sollac Arcelor Group. Out of these 14,900$ only 1450$ were spent for the construction of our uav.

5) MISSION

As the AUVSI Student UAV Competition states, the aircraft is bound to take off and fly with an autopilot and fulfill 2 different missions while passing through specific waypoints. There can be 5 to 10 waypoints which will be announced on the day prior to the competition. The 2 different missions consist of an “optical target” and a “military vehicles” target. The optical target includes white stripes of various widths which are painted over a black asphalt area of approximately 10 ft × 10 ft. The vehicle target includes unknown number of stationary simulated military vehicles within an area of 200 ft × 300 ft. The uav is to provide photos of both targets which enable us to determine the measurement of the stripes’ resolution and the number, the orientations, and the coordinates of the military vehicles. The uav is to fly within 50 ft to 400 ft AGL during the mission. Transition to manuel control is permitted for landing.

6) VEHICLE REQUIREMENTS

Although an optimized aircraft design with a proper autopilot is a must in order to be successful in this competition, we had to follow a simpler way considering the difficulty of finding adequate sponsors, our inexperience with autopilots, and the shortage of time.

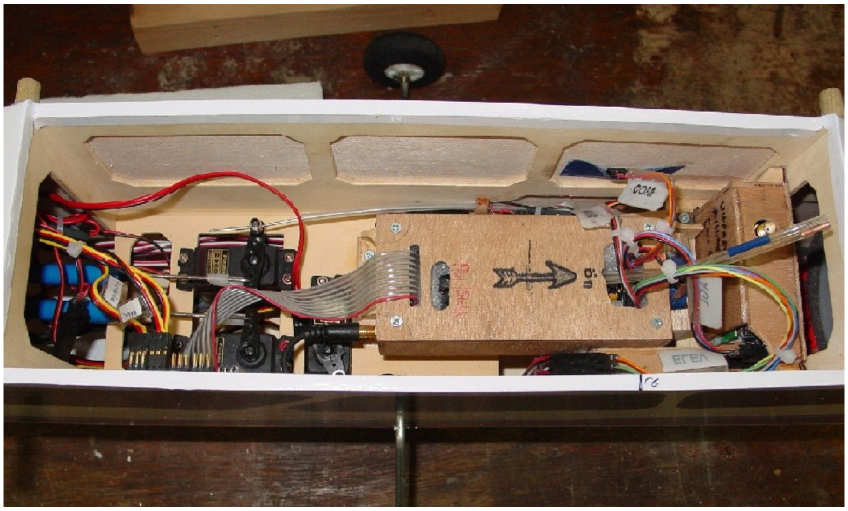
Since we perceived the hardware integration of the autopilot to be the challenging part of the project, we decided to use a commercially off-the-shelf (COTS) airframe that has proven handling and stability properties instead of designing from scratch.” Adopting this approach also saved us engineering development time in our tight schedule. We decided to use 40 trainer which was comparibly cheaper, had enough stability, ease of construction, and enough space to include both the autopilot and the camera. The autopilot we chose was the “micropilot” as the micropilot company provided the participant teams sponsorship. The micropilot’s default configurations were determined based on a 40 trainer, so buying one also saved us from dealing with those configurations.

We used our already existent RC receiver and servos that were purchased for the former AIAA competitions. The digital camera was chosen based on the researches of the team members and the knowledge of Can Arbak (the uav pilot), and it was obtained with the money we got from our one and only sponsor in Turkey (Sollac Arcelor Group).

7) PHYSICAL CONSTRUCTION AND INTEGRATION

7.1) Overview

Optimization of the placements of the autopilot, the gps antenna, the AGL sensor, the receiver, the servos and the digital camera was made, keeping the aerodynamics of the aircraft and the functioning of the items efficient as posssible. The requirement not to disrupt the center of gravity was considered and applied so that the point of center of gravity was only slightly altered but within the permitted CG zone. Therefore, the characteristic of the flight of our uav was kept stable.



A box was made for the autopilot and the AGL sensor circuits from wood and foam rubber to guarantee the security of them in the occurance of an accident. Substitutes for the possible breakable parts of the aircraft were made, and were used incidently.

In order to increase our test flight endurance we wanted to increase our fuel capacity. However the autopilot ended up taking more space than was initially budgeted for and an auxilary fuel tank to provide the additional fuel became infeasable.

Even though it did not meet the sensor range requirements, we decided to place the AGL sensor under the fuselage. It could have been put under the wings but the wings were fragile and were more likely to break during the test flights, so the idea was abandoned. The AGL sensor needed at least 8 inches from the ground when the uav was stationary; hence, a new landing gear was constructed since the already existent landing gear was not long enough to provide the necessary distance.

The GPS antenna is placed close to the tail of the uav and a hole on the fuselage is made for its cable to get inside the fuselage and connect to the autopilot.

The receiver is put far back inside the fuselage and away from the autopilot and the GPS antenna in order to eliminate interferance. The location of CG is checked after the receiver is fixed.

A pitot static tube was made using two different diametered metal tubes. Four wholes that make 90 degrees with eachother were made on the wider tube. These wholes were located 8 $\times$ diameter length (3mm) = 2.4cm away from one of its open ends. On other end of the same tube, 1 hole is made. Then the narrower tube is put through the wider tube and soldered at the ends so to close the open ends of the wider one without plugging the open ends of the narrower one. The narrow tube is longer than the wider tube and is soldered in a way that at one end they are lined together and at the other end the narrow tube sticks out of the wider tube. Then, another tube which is smaller in length is carefully soldered to the 1 hole on the wider tube without plugging the hole. The sticking bit of the narrow tube is bent so to stay parallel to the soldered tube on the wide tube. The production of the pitot-static tube is then completed. The pitot-static tube is placed half way on the left wing to prevent it from getting plugged by exhausted oil, for the motor's exhaust pipe faces the right side of the uav's fuselage. In order to get accurate results, the pitot-static tube is fixed parallel to the cord meanline and perpendicular to the leading edge.

A system which always keeps the digital camera facing directly down is also discussed about. Some ideas seemed feasible but unfortunately beause of the time shortage we still haven't come to the point of application of one. We are to have something done by the competition date if everything goes as we expect them to.

As a result, the 40 trainer is designed to provide the safety criterias and finish the mission successfully. The first flight test is done on 20th of June, 2004. And we realized that the loads put were a bit heavy for a 40 trainer, so we decided to carry on with a 60 trainer.

The new 60 trainer uav is constructed in a day. It has enough space for all the payloads we planned to put inside the uav. Except for the slight changes in the locations of the integrated units, there is a major change in the location of the AGL sensor. This time the AGL sensor is placed far from the exhaust, under the right under wing tip instead of under the fuselage. This way more space for the digital camera is provided while balancing the weights on the wings (the pitot-static tube is put on the left wing).

Having data link between the autopilot and our ground station is necessary; eventhough, not mendatory. We are planning to buy 2 receivers to provide us with this opportunity.

Also, one way data link with the digital camera is considered. No final decission is made yet, but there may be 2 more receivers put or a parallel connection with the autopilot's receivers made to get visual data.

Unfortunately, we are not able to provide more information on our latest uav for only the construction is done by the report's due date. But we believe it suits our plans well and we'll be able to achieve our goals per using it.

7.2) Power

Our trainer has 2 power supplies which are the same. They are 5 celled 6 volt packages providing 2300 mA current. One of them is connected to he autopilot, and the other is connected to the servos. 6 volt battery is chosen for it is the maximum amount the servos can take. By working at the maximum voltage, the servos can operate faster and stronger. 6 volt battery is also enough for the autopilot. The battery could have been up to 27 volt for the autopilot, but it is not wise to choose a heavier battery when the lighter ones are satisfactory.

7.3) Propulsion

A 0.40 cu.in. two stroke engine is used in our first uav for it consumed small amount of oil, and was sufficient for the 40 trainer. In our second uav 0.60 cu.in. engine is used since the 0.40 cu.in. engine is not satisfactory for a 60 trainer.

7.4) Autopilot

Micropilot MP2028g is selected as the uav's autopilot. The major reason for this preferance is the Micropilot Company's sponsorship provision when our budgetting problems are considered. The micropilot seems sufficient for our mission.

To communicate with the autopilot, both HORIZONmp ground control software provided by Micropilot and the Hyperterminal provided by windows is used. Hyperterminal generates reports from the sensors used and lets us to reset the sensor values, while HORIZONmp allows us to create and load our flight programs and configure the sensors and servos. After setting up the compenents mechanically, all the other adjustments are made by HORIZONmp. Since we are not using a data link yet between the ground station and the uav during flight, we are not able to observe and interact with the uav via HORIZONmp software. But we are planning to use a data link, so this situation will be different by the competition date and we'll be able to observe our uav in our ground station.

As the uav flies, the errors between the desired and current values of system outputs are controlled through a standard PID controller. There are 11 feedback loops used by the MP2028g to fly the uav. It senses the differences between the desired and the actual values of the system inputs and outputs. Since the MP2028g came programmed with gains suitable for a 40 trainer, no changes are made to fly our first uav which is a 40 trainer itself. But because of the mendatory preferance of a 60 trainer we are bound to change these default values.

7.5) Ground station

A pc inside which Hyperterminal and HORIZONmp are installed is used.

7.6) Optical systems

Canon A70 which is appealing for its price and satisfactory features is chosen as the digital camera. It's features are stated below:

Max resolution	2272 x 1704
Effective pixels	3.9 million
Sensor photo detectors	4.1 million
Zoom wide (W)	35 mm
Zoom tele (T)	140 mm (4 x)
Digital zoom	up to x3.6
Auto Focus	Yes
Manual Focus	Yes
Normal focus range	50 cm
White balance override	6 positions & manual preset
Aperture range	F2.0 - F3.0 / F8
Max shutter	1/1250 sec
Viewfinder	Optical
Battery	Canon Lithium-Ion & charger
Weight (inc. batteries)	490 g (17.3 oz)

7.7) Servos

Futaba S9001 coreless servos that weigh 1,69 oz, apply 54,2 oz / in. torque and has a transit time of 0.22 sec / 60° are used.

7.8) RC controller

Futaba 9 channel PCM RC controller with fail safe mode is used.

8) MISSION STRATEGY

8.1) Overview

A typical mission is envisioned as follows: The autopilot launches the aircraft, it passes the specific waypoints by following the waypoint navigation optimization algorithm developed by our team. While following this route, the pictures of the necessary areas are taken by the digital camera per the commands provided by the autopilot. When the mission is over, the uav lands under manual control of our pilot Can. After landing, the data is transferred from the autopilot to our computer and the calculations are made to determine the GPS coordinates of the military vehicles. Calculated information on the location of the military vehicles and the picture of the optical target will be given to the competition commitee.

8.2) Path planning

Optimization on passing through the waypoints using the shortest distance is programmed. The waypoints given by the competition committee and the waypoints we plan to pass in order to accomplish our mission will be the inputs for this program.

The uav is programmed to take 10 pictures while passing the center of both the optical target area and the vehicle target area. These photos will be sufficient because an adequate digital camera is chosen. This means the center of the target areas are other inputs for the waypoint optimization program.

8.3) Safety precaution

In the event of an unexpected behaviour of the uav, the uav pilot Can Arbak takes the control of the uav via the RC controller and lands it so to prevent any accidents possible.

9) CONCLUSION

This paper is a summary of Uçakçılar team's preparations for AUVSI Student Competition 2004. These preparations are actually the first steps of a long term project that will enable the team to design and integrate both the aircraft and the autopilot that will carry out such missions in the possible best way.

If it hadn't been for the hard time we had in finding sponsors everything would be different. But we did try hard to realize our plan in the best possible ways available. Now that we have experienced an autonomous system we are looking forward to enhance our technology in the following years. We are planing to make our own autopilot, form better algorithms and spend time on designing an optimum uav for these kinds of missions. Hopefully by next year we'll be able to concretize our ideas.