Symposium on Applied Aerodynamics and Design of Aerospace Vehicle (SAROD 2011)
November 16-18, 2011, Bangalore, India

FIRST PILOT VIEW (FPV) FLYING UAV TEST BED FOR ACOUSTIC AND IMAGE DATA GENERATION

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ABSTRACT

The objective of this project is to design and implement a low cost FPV Flying UAV suitable for generating Acoustic and Image data to verify and validate the different types of algorithms developed by the researchers and Scientists working on UAVs and MAVs. The MIT Chennai team developed an Unmanned Aerial Vehicle System, providing the capability to support an 800 grams remote sensing payload. The system architecture utilizes wireless communications for manual flight control, gathering sensor information's and real-time vision guidance using long range video telemetry. Together these components provide the necessary information for the pilot to successfully complete the mission objectives. Also MIT Chennai team offer services for characterization of design with open loop control and flight evaluation of the UAV test bed provided by NAL.

Key words: FPV, UAV, Airplane Design, Performance, Flight Stability, Flight Dynamics, Automatic Control, Simulation, Prototyping, Flight Testing.

1. INTRODUCTION

Military and civilian applications of unmanned air vehicles (UAVs) have dramatically increased in recent Years. Within the spectrum of existing UAVs, small, low-cost vehicles are finding use in a number of niche applications. Small UAVs are especially appealing for use in research projects focused on remote sensing applications because they are inexpensive to build and repair. Moreover, there are highly capable, commercially available autopilots which can transform an ordinary radio control (R/C) aircraft into a sophisticated flight control system test bed. Experimental systems play a crucial role in validating newly developed Control algorithms. The system is focused with a view toward flexibility, anticipating wide range of possible applications; an immediate objective is to generate the data for the Acoustic Vector Sensor and other sensors.

Important considerations for UAV's are often payload capacity, endurance and navigation. Also, the sponsor indicated that payload flexibility, future airframe development and commercially available components are the drivers for design decisions. Monetary budget and sponsor (NAL) requirements are also taken into consideration. The final design allows a pilot to complete remote sensing tasks at a maximum altitude of 500 Meters and maximum range of 3 km from the base station.

2. SPECIFIC TASKS

(i) The aircraft system and the ground control station will be portable and requires a pilot and an observer.

(ii) An UAV is stabilized in using onboard Flight stabilization system. The directional control will be done by the ground station pilot through long Range FPV system and by using rudder control only.

(iii) An UAV will carry a camera/acoustic sensor. Videos captured would be fed back to the ground station by radio link. The ground station/onboard records flight imagery/acoustic data signal.

(iv) Ground Control Station to Navigate, Control and Guide the UAV as per desired path as well monitor the health of UAV system..

(v) A payload bay is provided to support the 800 grams pay load requirements for the equipment/sensor

3. DESIGN AND SELECTION OF THE SYSTEM

The role requirements, as defined by the NAL, place demands upon the system which determine the shape, size, performance and costs principally of the air vehicle, but also of the overall UAV system which operates it. Some of the more important parameters considered in this work are,

1. Payload
2. Endurance
3. Radius of Action
4. Speed Range
5. Launch and Recovery
6. Overall System
7. Environmental Conditions

4. DESIGN AND ANALYSIS OF AIRFRAME

This section describes the trade-off while coming for the selection of the airframe from the information's described from the previous sections. Diverse designs were considered but after the few crashes with the experimental airframes and available time, so it is decided to go with following configuration for the ease of constructing and also to fulfill our requirement

4.1 Airframe Specification

Length	1180 m
Wing span	2000 mm
Wing area	35.5 dm^2
Weight	1300-1800 kg
Wing loading	36.6 g /dm2
Aspect Ratio	≈8
Tail span	61 cm
Root chord	24cm
Tip chord	14 cm
Dihedral angle	8 deg
Camber thickness in root	4 cm
Camber thickness in tip	1.3 cm
Range	Less than 3 Km
Endurance	30 – 60 minutes
Service ceiling	500 meters

4.2 Airframe Representation

A very meticulous work is required when modeling the inside part of the fuselage, in aiming to house the electronic devices properly. When all 3D parts are ready, one can verify the position of the center of gravity, which is suggested to be placed at the 33% of the wing airfoil's length. If it is not the case, supplementary masses should be applied for the proper balancing of the plane, which may result in reduction of useful payload, consequently all design process shall be repeated from the start.

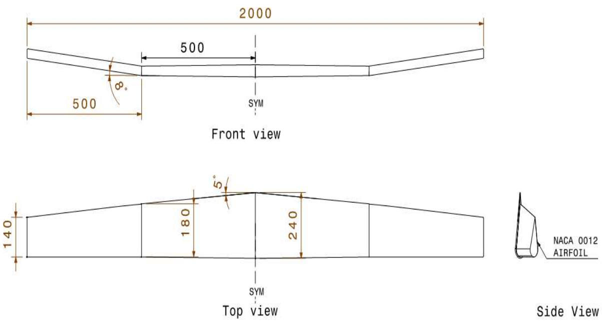

Figure 1. Three views of wing

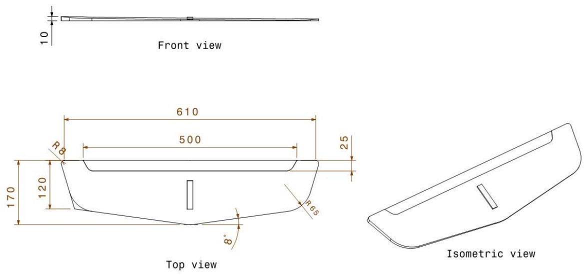

Figure 2. Three views of tail plane

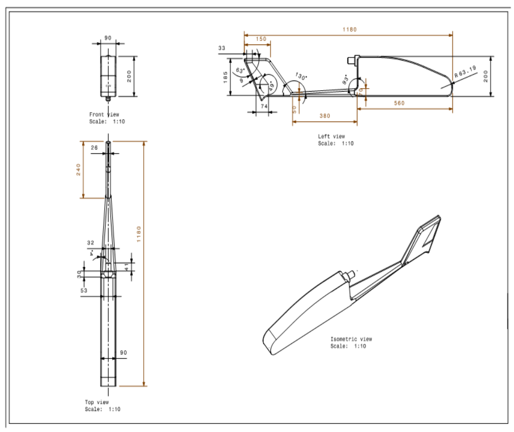

Figure 3. Three views of fuselage

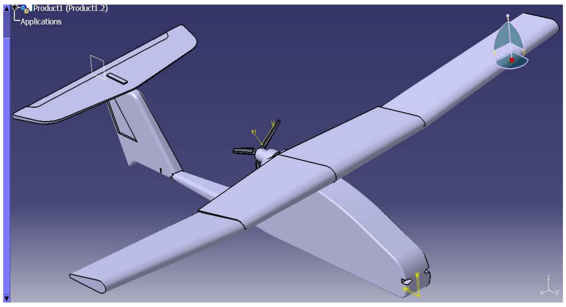

Figure 4. Isometric view (with NACA 0012 wing)

5.AERODYNAMIC & PERFORMANCE CHARACTERISTICS

The stalling speed of the aircraft is the minimum speed the UAV that can produce lift at maximum lift coefficient C_{Lmax}, also it's the minimum speed in which flight is possible.

$$V_{stall} = \sqrt{2\frac{\left(\frac{W}{S}\right)}{\rho} \Big/ CL} \quad (1)$$

5.1 Minimum Power

$$P_{\min} = D_{mp} V_{mp} \quad (2)$$

$$V_{mp} = \sqrt{2\frac{\left(\frac{W}{S}\right)}{\rho} \Big/ C_{Lmp}} \quad (3)$$

$$C_{Lmp} = \sqrt{3\frac{C_{DO}}{K}} \quad (4)$$

$$D_{mp} = \frac{W}{\left(\frac{C_L}{C_D}\right)_{mp}} \quad (5)$$

$$\left(\frac{C_L}{C_D}\right) = \sqrt{\frac{3}{(C_{DO} \cdot K)}} \quad (6)$$

5.2 Range

The total range is the distance an aircraft can fly between takeoff and landing, as limited by fuel capacity, which can be calculated as.

$$R = \left(\frac{\eta}{c}\right)\left(\frac{C_L}{C_D}\right)\ln\left(\frac{W_0}{W_1}\right) \quad (7)$$

5.3 Results for Flow Analysis

On the first run FLUENT and CFX (For full wing) were used with initial condition 20m/s free stream velocity in the x-direction, a temperature of 300 K, and a pressure of 1 atm. Once satisfactory results for α= 0 were obtained, the grid was refined in an effort to capture the physics of the flow around the airfoil more accurately. We ran for different angles-of-attack on Design foil and XFLR. Then the final pressure and velocity variations are compared as shown below.

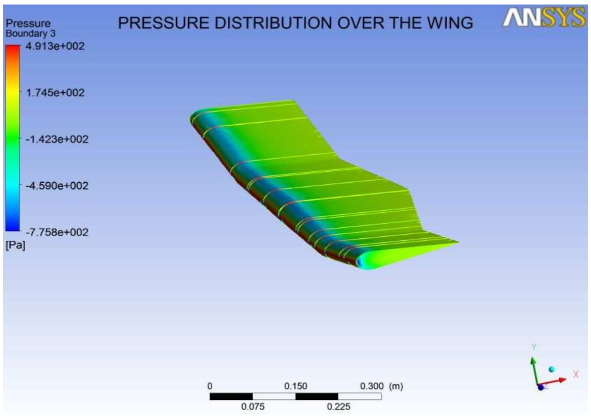

Figure 5. Pressure Distribution over the polyhedral wing

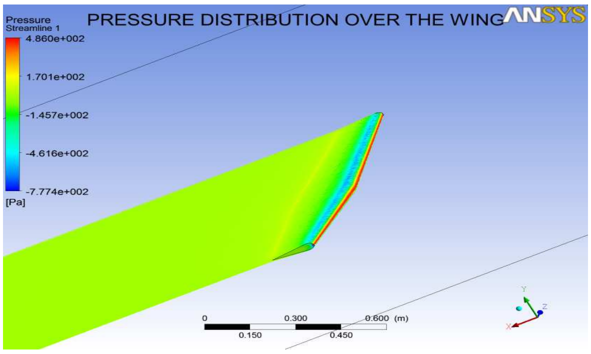

Figure 6. Pressure Distribution over the Dihedral wing

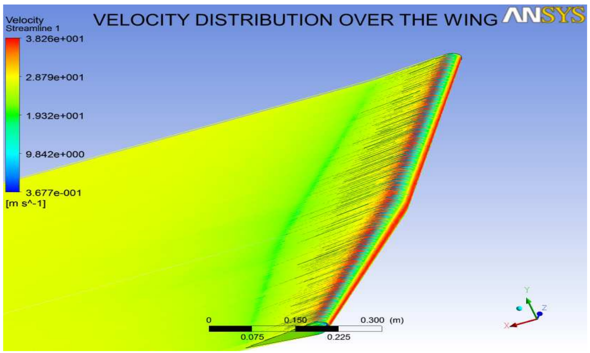

Figure 7. Velocity Distribution over the Dihedral wing

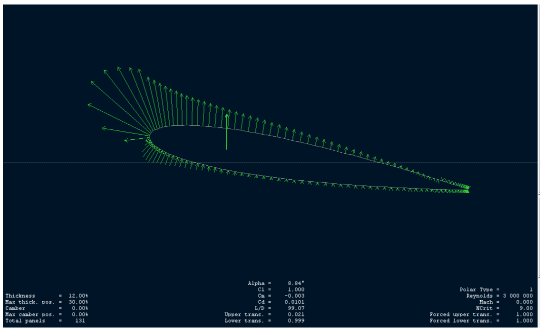

Figure 8. Ppressure variation at α = 8 deg

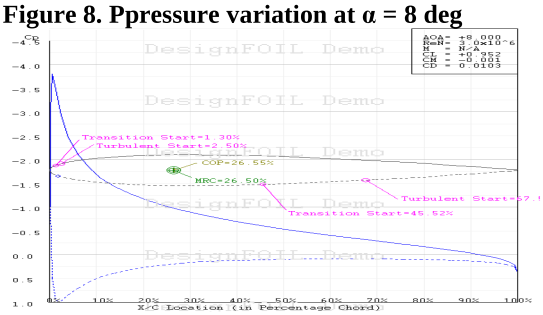

Figure 9. c_p variation at α = 8 deg

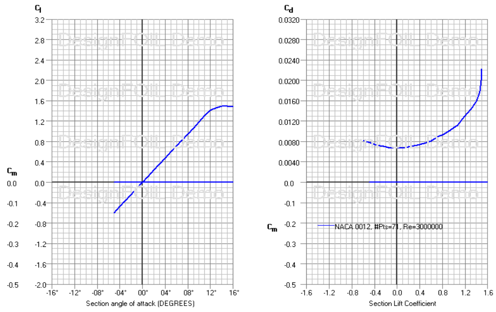

Figure 10. Drag polar curves (for NACA 0012)

6. FABRICATED MODEL

The Figure 11 shows the fabricated prototype model of this project.

Figure 11.

6.1 Weight Break Up for the Fabricated Model

SERIAL NO	ITEM	MAKE	WEIGHT (gms)
1	Airframe	Foam	794
2	Propeller	1860 GWS (3 Blades)	15
3	Motor	A 30-12XL	177
4	ESC	X-55-SB-Pro	45
5	Battery	11.1/5000mah/3S/25C	630
6	RW Servo	HS- 82 MG	19
7	LW Servo	HS- 82 MG	19
8	Ele Servo	HS- 82 MG	19
9	Rud Servo	HS- 82 MG	19
10	Rx	FUTABA 2.4 Ghz	12
11	Miscellaneous	Connectors and rods and others	120
	TOTAL		1869

7. INTEGRATION OF FLIGHT STABILIZATION SYSTEM

The FSS utilizes a 3-axis gyroscope and tri-axial accelerometer to form an accurate drift free attitude stabilization system. The unit also utilizes Global Positioning System (GPS) and a barometric altitude sensing for accurate 3-dimensional positioning of the aircraft. By combining attitude control and positioning, a comprehensive inertial navigation system and autopilot is provided in a small compact light-weight package. The unit calculates the aircraft attitude in 3-dimensions and detects any changes to the models horizontal position. If attitude change occurs, controlling signals will be sent out to the planes ailerons, elevator and rudder to counter that change. By continuously doing this, the plane is kept in a state of stabilized equilibrium, resulting in a smooth level flight.

7.1 GPS, Barometric Sensing and Autopilot

Upon initial boot up, the unit will search for GPS positioning signals. When a minimum of 5 satellites have been detected, a fixed position is established. The unit will record that position as the return to launch (RTL) point.

The on-board barometric sensor and GPS altitude readings will be combined to establish an accurate relative-altitude of the aircraft.

When the Autopilot Mode is activated via a spare channel, the aircraft will automatically turn and fly back to the take off point (RTL). The aircraft altitude will be constantly maintained. After reaching the home position, the plane will automatically circle with A radius of 120m.By using the same autopilot algorithm the pilot can also activate an auto circling flying pattern at a fixed altitude any where he wishes.

7.2 Device Functions

Constant stabilized flight in any condition – the FSS will automatically level the flight attitude of an UAV in any weather condition. The unit can be activated throughout the flight duration, from take off to landing.

Emergency Recovery – in case you lose orientation or you feel the aircraft is out of control, activate the unit and let go of the control sticks. It will immediately bring the plane back to stabilized level flight.

First Person View (FPV): For long distance flying or FPV, the unit will take over the job of leveling and stabilizing the plane. Just point the plane where you want to go and generate the image Data.

7.3 Schematic Diagram of Balance and Navigation Control

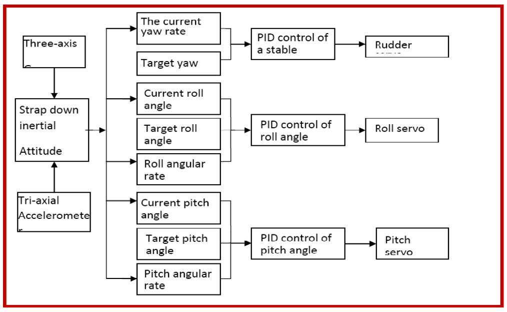

Figure 12

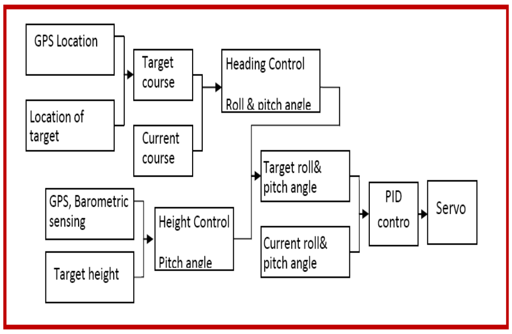

Figure 13

7.4 Field Flight Tests

Demonstration and testing on the developed system has been carried out. Performances and efficiencies of various subsystems, repeat experiments also conducted. Log sheet also developed for noting the evaluation test data.

Figure 14. Fabricated model-Hand launch

Figure 15. Fabricated model flying mode

Figure 16. Fabricated model landing mode

7.4 Image Data Generation at Various Range and Altitudes

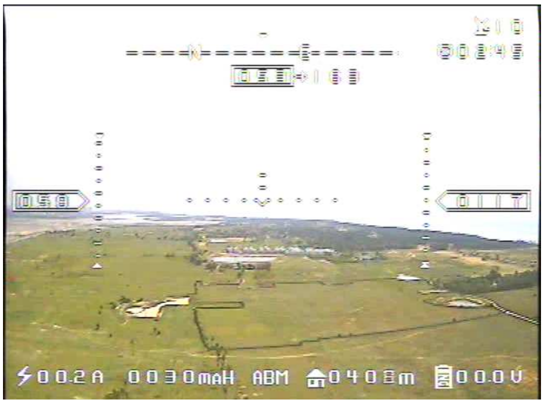

Figure 17. Range:408m, Alt:117m

Figure 18. Range:636m, Alt:174m

Figure 19. Range:2846m, Alt:300 m

Figure 20. Range:3008m, Alt:352 m

Figure 21. Range:3280m, Alt:363 m

8. CONCLUSION

According to the project plan, Airframe fabrication and integration of Avionics components has been completed. All the simulation works were done for various configurations of wings as described in our results to match our requirements. Until now 20 flight trials have been conducted in two different fields (Kovalam and MIT annexure) to test airframe model performance in different kind of environment. During the initial testing the fabricated model not responded properly due to poor thrust line alignment and other minor power system problems. Also we can't get steady climbing rate when we reduce the throttle. After making required adjustments it is performing well and meets the performance. Integration of Avionics components ie, flight stabilization system, OSD system, Long Range RF Unit, Video transmitter and receiver, Antenna Tracker System, Front facing camera also completed. Imaging data generated for various range and altitude.Some flight trials using Acoustic Vector

Sensors also conducted. At the end of this work, a low cost surveillance system based on FPV-Flying UAV is ready for flight trial services and testing.

ACKNOWLEDGEMENTS

The authors are grateful to The Vice Chancellor, Anna University and The Director, Centre for Aerospace Research, Madras Institute of Technology, Anna University for providing organizational facilities for carrying out this research work at Madras Institute of Technology. We would like to express our sincere thanks & gratitude to The Director NAL for providing sufficient funds for this sponsored research work. We also express special thanks to Sree Sai Aerotech Innovations Pvt.limited,Chennai for the successful conduct of Flight Trials. We would like to convey our thanks to Shri.Sadasivam, V.S.Chandrasekhar B.P.Shasidhara and R.Uthirabalan, Scientists Aeronautical Development Establishment (ADE), DRDO, Bangalore for their inspiration and encouragement and wishes to all the Avionics students

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