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Design and testing of a delta wing glider at low altitudes

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Abstract

The paper describes an assessment study of a delta wing glider using fuselage integrated electronics to transfer real time data of wind speed, atmospheric pressure and GPS coordinates. In this paper the design of an efficient option for collecting meteorological data has been proposed. Emphasis is given on the design of the delta wing glider to accommodate the electronics inside the fuselage and also the aerodynamic stability of the glider. The delta wing glider is a non-propeller driven subsonic airplane with two wings, two elevons, a rudder and fuselage fold enabling the safety and proper functioning of the electronic sensors. The fully deployed wingspan is 320 millimeters. All the electronic sensors are powered by a battery which is also integrated with the circuit inside the fuselage. The operational scenario of the glider is described, including the deployment procedure and various environmental conditions while testing. The main purpose of this project is to provide a cost-effective option for the collection of various local meteorological data.
Keywords: delta; glider; meteorology; sensors; GPS; anemometer;

1. Introduction

Climatology and Weather Forecasting is important since it helps determine future climate expectations. Due to the harsh conditions of weather at different geological locations, different types of instruments are needed but they always are not reliable. They are very sensitive, difficult to operate and we cannot always expect an accurate result. Hence small gliders can be used as a much more reliable approach to collect local meteorological data. The World Meteorological Organization's (WMO) Aircraft Meteorological Data Relay (AMDAR) Panel was established in 1998 for a worldwide application of the inherent observing capability of aircraft. Since the beginning of flight, weather observations taken from aircraft have made an important contribution towards understanding the current state of the atmosphere so that better weather forecasts can be made [1]. Commercially this suffers from aplenty of downfalls; such aircraft observations are costly and requires high maintenance. Many companies and cities in the world like United Kingdom, Chicago and London are already searching for a new and reliable piece of equipment for data collection [2]. This small glider can be used in daily lives for data collection and with different modifications can be used in various other fields. Designing and manufacturing a glider is a tough task, this glider has a lot of space for improvements in terms of designing. However, one hurdle must be overcome first that is the cost must go down.

The manufacturing cost of this project may vary from $100 to $120 depending upon the material cost which constantly changes in the market. The cost also depends on the types and availability of sensors. If we combine the original cost with manufacturing and maintenance it reaches a figure of $150, which is cost effective. Furthermore, there is always a probability that the life cycle of the glider is practically less than calculated. With each use the reliability and accuracy decreases. However, investing in such a device is not all bad as it makes local and global data collection much simple. Accuracy of the data obtained depends on the quality and proper functioning of the sensors. With the correct method of deployment and proper execution, data can be obtained in real time with various software's or GUI's.

This paper illustrates a delta wing glider which uses various sensors, batteries and PCB for its operation and functioning [3,4]. It can be easily used and utilized by various companies as well as in day to day lives. The important part of this glider is that the user can carry the entire system from one place to another as it is designed to sustain harsh weather conditions. It can be used when the weather is sunny, cloudy, windy or even if it's raining. After understanding the various challenges, authors faced during the designing phase, authors focused on various parameters like weight, aerodynamic stability, volume required by sensors for proper functioning and placement, Graphic User Interface (GUI) for receiving real time data and a suitable transmitter to transmit data without any loss of packets. It uses rechargeable batteries hence it does not require a constant power supply. The proposed glider can be used in day to day lives because of its reduced price, simple design and almost negligible maintenance cost. This design contains power supply, sensors, microcontrollers, nichrome wire and parachute along with its design framework. This glider is an initiative to make data collection easier and more convenient hence, it can be used as a reliable and safe tool in the field.

2. Design Methodology

The glider unit can be subdivided into three aspects of designing: Mechanical structure, Sensor integration and back-end Coding with GUI.

The mechanical aspects include the material selection, its inspection which is suitable for the manufacturing of the fuselage and wings. The material required should have high impact strength, it should have good chemical resistance, durable and tough but most importantly it should be easily available and economical [5].

The second part of the glider consists of the sensor selection and its interfacing circuitry. It is powered using a rechargeable battery with a voltage regulator. This provides a non-fluctuating DC supply to the microcontroller. Figure 1 shows an elaborate operation execution plan for the glider including the mechanical and electrical subsystems.

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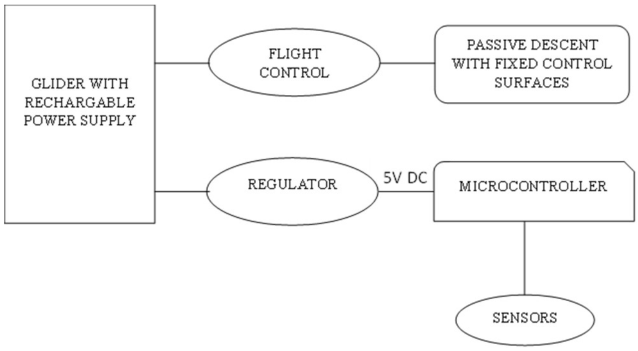

Fig. 1. Operation Execution Block Diagram

A combination of various sensors for measurement of temperature, air speed and pressure are soldered together with the microcontroller on a custom-made PCB for better space management and compact sensor placement which in-turn helps in responsive communication of telemetry and storing large data sets or arrays. The back-end coding is done to collectively send the sensor data processed by the microcontroller in forms of packets in a timely ordered yet real-time format which is managed by the GUI. The GUI is always in communication with the microcontroller in the glider and is coded to provide null values if no telemetry is obtained which acts as an indication of whether any mishaps has occurred before, during or after the flight. Figure 2 provides the data path of the obtained values starting from the sensors and ending at the ground station control.

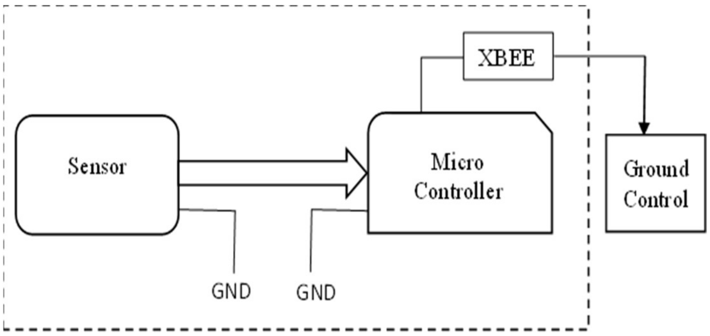

Fig. 2. Sensor Interfacing

Features of the proposed delta wing glider:

- The basic expectation from the proposed delta wing glider is to collect various local meteorological data without much dependency on complexity, time, skill or environment in which the flight is to be performed.
- It is also supposed to send processed data to the portable ground station without any loss of telemetry.
- It is economical and easy to operate.
- It is portable and self-powered till some extent.

Air Pressure Sensor: To make the delta wing glider cheaper, the air pressure sensor used is BMP 280 as it is compact in size, cheaper and easily available. It has a wide pressure sensing range (From

300 – 1100 Pa). The shared I2C bus on it gives an added advantage of less wiring with high bit resolution.

Temperature Sensor: The sensor used to record temperature data is BMP 280 because of its high sensitivity to temperature changes and less price.

GPS Sensor: The Adafruit Ultimate GPS Sensor was used because of its compact size, low power consumption and external antenna compatibility. GPS module is used to locate the glider using a simple co-ordinate system for further retrieval and inspection.

Voltage Sensor: A simple voltage divider is made via on board integration of resistors on the PCB. It has less weight and an adjustable operating range so as to minimize the chances of short circuiting or fire hazards.

Air Speed Sensor: The selected sensor is MPXV7002DP with a pitot tube. It has very good compatibility with microcontroller and the pitot tube is perfect for measuring air particulates in the atmosphere.

Microcontroller: The microcontroller selected for this project is Teensy 3.6. the reason for selection is because it has sufficient interfaces available for assimilating other above-mentioned sensors, low power requirements and has extensive compatibility with Arduino IDE which makes the programming easier.

Camera Selection: A miniature TTL Serial JPEG Camera was used while experimenting. It recorded video at 30fps with a resolution of 640x480 pixels which is sufficient for recording purposes.

Framework: The designed structure is planar and simple in design in the shape of a triangle when viewed from the top. Delta winged design was chosen because of its stability at low altitudes for a non-propelled glider. It is made of affordable Polyethylene terephthalate glycol (PETG) [5] which can be easily drilled to incorporate any small changes. The manufacturing process is 3D printing of various parts and simple assembly of the parts with nuts, bolts and various other fitting mechanisms.

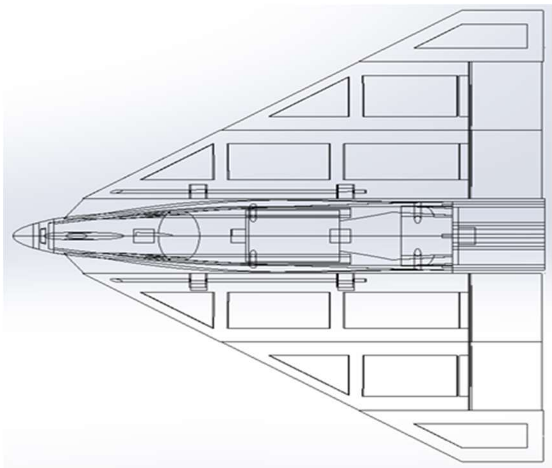

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Fig. 3. Design Structure of delta wing glider

Battery: The batteries are rechargeable, reducing the environmental pollution and cost offered by use and throw batteries. They are light weight and easy to integrate with the on-board PCB for better power management.

Telemetry: The antennas used for data transmission are 10 cm omni-directional antennas coupled with XBee Pro 60mW [6].

3. STRUCTURE OF GLIDER

Figure 3 shows the design framework of the glider. The design was carefully selected and various iterations in designs were made after carefully analyzing the aerodynamics of the glider. The reference and basis of this design were made from XFLR5 analysis software and past research done on it [7]. It has the battery section, the electronics section which holds all the electronic sensors and the parachute compartment section along with control surfaces as shown in figure 4.

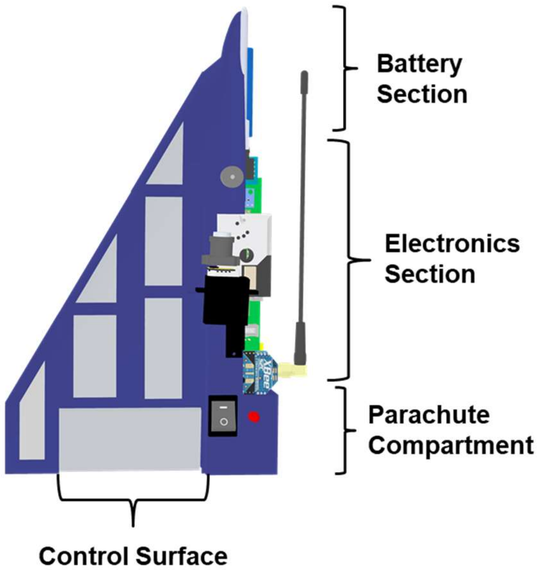

Fig. 4. Mechanical Layout of Components of glider (half)

The entire framework is assembled from two parts of the fuselage and two parts of the wings. The parts are 3D printed using PETG since it has high tensile strength (about 650 MPa) and is lighter compared to other materials of the same class [5]. After various testing and simulations, the glider design was able to withstand a shock load 300 N/mm^2 under ideal conditions. PETG also makes the design machinable and small changes can be incorporated easily. The fuselage has 3D printed slots in it which are used to hold the PCB in place so as to prevent damage during any sudden jerk.

The fuselage also has a parachute compartment as shown in figure 4 on the back side which acts as a house to hold the parachute and release it after the glider's descent is completed. The parachute is used to slow down the descent of the glider after it reaches a height of 200m from the ground [8]. The parachute material is rip-stop nylon cloth.

A spring and a plate are used to deploy the parachute placed inside the parachute compartment.

During the glider's descent the spring will be coiled thereby storing kinetic energy below the plate. It is held in position by tension in the phishing line. The plate further acts as a connecting point of the parachute string knots with the glider. From figure 3 we can see that the parachute compartment has slots for a sliding mechanism incorporated with the plate ensuring smooth deployment.

Fig. 5. Delta Wing glider

The airfoil selection for the wings was NACA 2408. For low altitudes it provided high lift to drag ratio and a low drag coefficient. The angle of attack for the wings (α) was 6º for optimum results [9]. The sweep angle for the delta wing glider was 57.9º since it showed good results from Mach number 3,50,000 to 10,00,000 [9].

Figure 5 shows the final design of the delta wing glider integrated with all the sensors and circuitry with the mechanical structure.

4. DESCENT RATE CALCULATIONS

a.) First a helium balloon is used to take the glider to a height of 1000 m:
A nichrome wire mechanism with a phishing line is used as release mechanism for the delta wing glider while testing.
One end of the phishing line will be connected to the thread of the helium balloon and the other end to the back of the glider and nichrome wire will be coiled around it.

Once the required altitude is reached, the GPS sensor will send a signal to the microcontroller to pass current through nichrome wire of gauge 20. It can reach a temperature of 316ºC with 5 Amp current [10].

b.) To calculate the radius of rotation, descent angle and Lift-Drag forces on the glider:

The vortices which are formed at the tail of the glider are neglected due to its negligible influence in the aerodynamic stability since the size of the glider is very small compared to an actual aircraft [11].

To calculate the descent angle of the glider in a helical motion, according to the requirement, the basic assumption we made is that the glider will require 330 m to make one full 3D revolution about the helical axis (2 turns) with a diameter of 500 m as shown in figure 6.

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With such a large value of sweep angle in the design coupled with the low altitude flying requirement and slower velocities, there will be no changes in the roll and yaw moment of the glider [12].

The major assumption here is that during the descent of the glider, its air flow field over the surface area remains the same and no changes are made to its Mach number and Reynolds number [13].

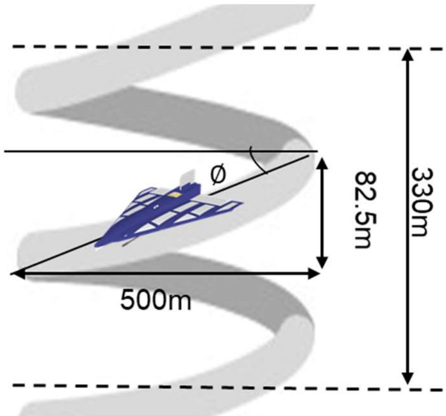

Fig. 6. Descent Simulation

The angle of descent (Ø) can be found using basic trigonometric properties:

$$\tan(\emptyset) = 82.5/500$$

$$\therefore \emptyset = 9.37°$$

From the free body diagram shown in figure 7 [14]:

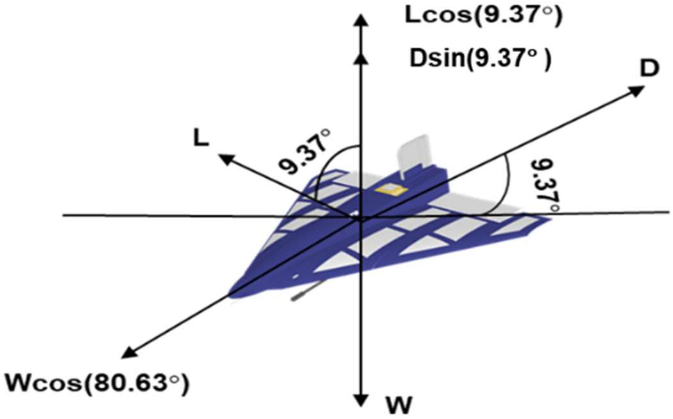

Fig. 7. Glider Free Body Diagram

$$Lcos(9.37°) + Dsin(9.37°) = W \ldots \textbf{(i)}$$

$$Lsin(9.37°) = Dcos(9.37°) \ldots \text{(ii)}$$

Solving the above 2 equations, we get:

L = 4.35 N & D = 0.718 N

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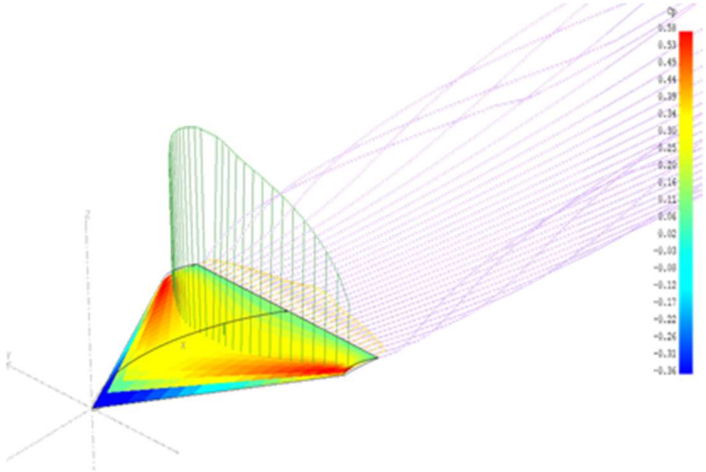

Fig. 8. XFLR5 Analysis

Now from figure 8 which was analyzed in the software, the following data can be concluded:
There is no leading-edge vortex formed and the downward air stream has no effect on the drag forces influencing the glider [9].

W is the weight of the glider **(0.3 kg)**
ρ is the density of air **(1.15kgm^{-3})**
A is the projected area of the glider wings from XFLR5 analysis **(0.061 m^2)**
L is the lift force of the glider **(4.35 N)**
D is the drag force of the glider **(0.718 N)**
C_L is the lift coefficient of glider found from XLR5 Analysis **(0.153)**
C_D is the drag coefficient of the glider from XLR5 Analysis **(0.025)**
Using the formula for lift,

$$\text{Lift force } (L) = \boldsymbol{\frac{1}{2}\rho v^2 C_L A}$$

The horizontal velocity (ν) of the glider comes out to be **28.47 m/s.**

At 1000 m after the separation, the total available height for gliding will be **800 m,** we are assuming the gliding time to be **120 seconds**.

$$\therefore Vertical\ Velocity\ (v) = \frac{Downward\ distance(d)}{Total\ Time(t)}$$

$$= 800/120 = \boldsymbol{6.67\ m/s}$$

c.) To calculate the required parachute diameter for safe descent, we use basic formulae:

$$Area\ (A) = \frac{\pi D^2}{4} \ldots\text{(i)}$$

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Where, D is the diameter of the parachute here

$$\text{Drag force } (D) = \frac{1}{2}\rho v^2 C_D A$$

v is the vertical velocity of the glider after parachute is deployed which is assumed to be **5 m/s.**
A is projected area of the parachute
C_d is the drag coefficient of material of parachute **(1.75)**

For a stable descent at a constant speed, acceleration will be 0 m/s^2 and the downward weight of the glider can be equated to the upward drag force produced by the parachute:

$$\therefore \qquad \frac{1}{2}\rho v^2 C_L A = mg$$

$$\therefore \qquad A = \frac{2mg}{\rho \, v2 \, Cd}$$

Here, Mass of glider (m) is **0.3 kg**
Acceleration due to gravity (g) is **9.8 m/s^2**
Velocity of the glider (v) is **5 m/s**
Coefficient of drag (C_d) is **1.75**
Density of air (ρ) is **1.15 kg/m^3**

Plugging in all these values, the projected area of the parachute comes out to be **0.1168 m^2**.
Using this value in equation (i), we get the diameter of the parachute as **38.57 cm**.

5. RESULTS

- The delta wing glider operates efficiently without any active system of interference, collects local atmospheric data values and transmits them to the ground station with minimum data loss (estimated error margin of 2%).

- The calculated Lift and Drag forces are in accordance with the data obtained experimentally and flight is achieved [15] (estimated error margin of 1.5%).

- The descent calculation estimates are in close proximity with the experimentally acquired values. The velocity-time graph of the glider during its descent is as shown in figure 9.

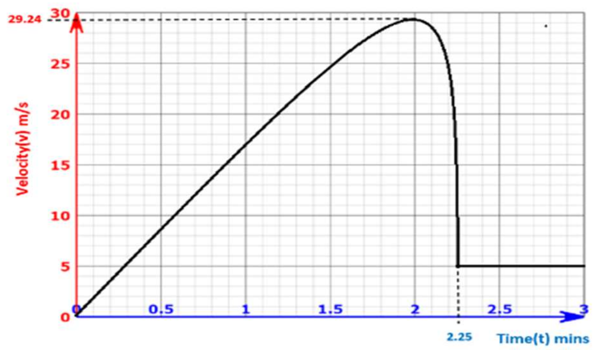

Fig. 9. Velocity-Time Graph of the Glider

6. CONCLUSION

The proposed delta wing glider successfully addresses the problems faced while collecting local atmospheric data in the metrological department and implements simple solutions to increase its efficiency and reduce data loss. It uses safe and reliable electronics which is environment friendly compared to its expensive counterparts. Hence this has a huge scope in the atmospheric data collection and make a huge impact in sectors of defense, industry as well as domestic households, if more such economical gliders are made.

7. REFERENCES

[1] https://public.wmo.int/en/bulletin/aircraft-observations/
[2] https://link.springer.com/chapter/10.1007/978-1-935704-20-1_3/
[3] http://www.cansatcompetition.com/
[4] https://www.nsin.mil/events/2021-07-26-polar-vortex/
[5] Szykiedans, K., Credo, W., & Osiński, D. (2017). Selected Mechanical Properties of PETG 3-D Prints. *Procedia Engineering*; 177: pp. 457-459.
[6] Aras, M.S.M, Ali, F. A, Azis, F. A, Abdullah, S. S, Aziz, M.A. A, M. Nur Othman (2013). Development of Wireless Data Transfer System on Unmanned Underwater Vehicles Application. *International Journal of Engineering Research & Technology (IJERT);* Vol 02, Issue 10: pp. 1323-1325.
[7] Muir Rowan Eveline, Arredondo-Galeana Abel and Viola Ignazio Maria (2017). The leading-edge vortex of swift wing-shaped delta wings. *R. Soc. open sci.;* 4:170077: pp. 2-4.
[8] https://www.britannica.com/technology/parachute/
[9] Matt Mckenna and Chris Greek (1989). The delta monster: an RPV designed to investigate the aerodynamics of a delta wing platform. *Nasa Technical Reports Server*; pp.1-1 – 2-3.
[10] http://hotwirefoamcutterinfo.com/_NiChromeData_files/1_Amperage.jpg/
[11] Mohamed Gad-el-Hak and Ron F. Blackwelder (2012). The discrete vortices from a delta wing. *AIAA Journal;* 23:6 pp. 962-964.
[12] Viswanath, P., & Patil, S. (1994). Aerodynamic characteristics of delta wing–body combinations at high angles of attack. *The Aeronautical Journal; 98*(975): pp. 159-161.
[13] Stanbrook, A., & Squiref, L. (1964). Possible Types of Flow at Swept Leading Edges. *Aeronautical Journal; 15*(1): pp. 74-79.
[14] J.A. Menard and G.J. Matranga (2013). Approach and landing investigation at lift-drag ratios of 3 to 4 utilizing a delta-wing airplane. *Nasa Technical Reports Server;* pp. 12-14.
Lee, M., and Ho, C. (1990). Lift Force of Delta Wings. ASME. *Appl. Mech. Rev.*; 43(9): pp. 211–218