DBF Senior Design Proposal

1 Introduction

This year, the AIAA Design Build Fly Competition outlined one of the goals: to build an autonomous glider that separates from the main aircraft mid-flight and lands in a designated landing zone. Teams are scored based on several criteria, including the number of laps the main aircraft flies, the weight of the glider, and how close the glider lands to the landing zone. Our team, partnering with the Design Build Fly (DBF) Club of Notre Dame, has taken on the challenge of creating the glider for this project. The DBF Club is responsible for the structure and aeronautics of the glider. Our senior design group will handle the electronics for the project. These include a printed circuit board equipped with an ESP32 microcontroller that processes data input from several sensors and actuates the aircraft's control surfaces accordingly. The purpose of this document is to outline the specifications of the competition, how we intend to solve the problem, the features the glider will demonstrate, and the technologies available to help realize our solution.

2 Problem Description

The AIAA Design Build Fly Competition has a list of requirements and constraints on the glider aircraft that must be met in order to be eligible for the competition.

To begin, the glider can have a maximum weight of 0.55 pounds (250 grams). Teams are allowed to determine means of flight control and navigation. However, no radio controlled receivers are allowed to be integrated onto the glider. The glider must fit between the two external fuel tanks on the airplane and be secured to the airplane for all stages of flight, except for the mission during which it is launched. There is a minimum gap of 0.25 inches between any part of the airplane fuselage and the wings of the glider. The glider must have strobe lights that turn on after it is released from the airplane. No points will be received if the lights turn on before launch, or fail to turn on after launch.

The glider must be launched from the airplane at an altitude of 200-400 feet above the ground. To achieve bonus points, the glider must release itself from the airplane and execute a 180 degree turn. Then, using a descending or gliding pattern of choice, the glider will land on the ground. If the glider comes to rest within one of the landing zones as shown in Figure 1, bonus points will be awarded. The scoring calculation is shown in Equation 1.

$$Score = 2 + \#\, of\ laps\ flown + \frac{Bonus\ Box\ Score}{Glider\ Weight} \tag{1}$$

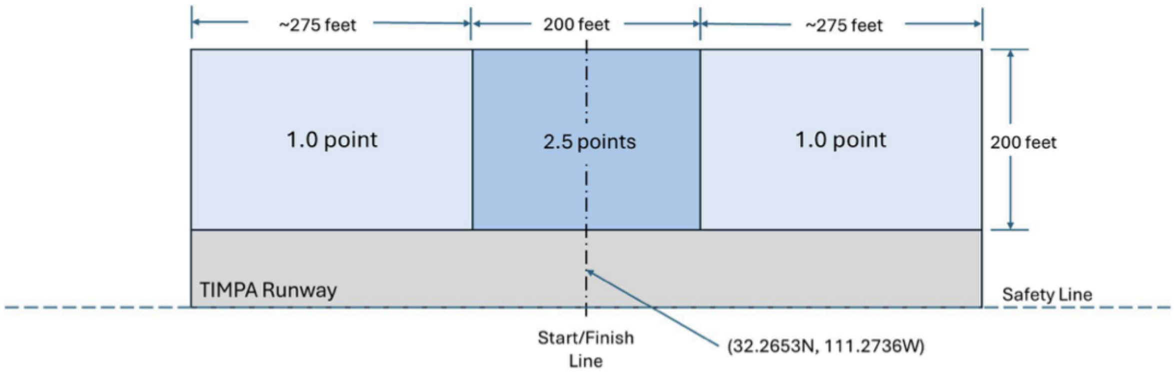

Figure 1: The Glider's Bonus Points Landing Box

The goal for our team is to allow the glider to receive as many bonus points as possible. Therefore, it is critical the glider lands in the highest-scoring landing zone, makes a successful 180 degree turn, and has a working set of strobe lights that both turn on at the correct time and are visible by the judges, while being as lightweight as possible.

3 Proposed Solution

This section gives a high level view of your proposed solution. You may find it useful to break down your solution into logical functions and describe these various functions that comprise your solution. As appropriate, include key technologies that you will need to get your solution to solve the problem.

As previously stated, our team is responsible for the electronics inside of the glider. To successfully complete this project and score highly at the competition, we need to implement several devices that work effectively and efficiently. At the center of our circuit board will be the ESP32 microcontroller. This will be responsible for the collection, processing, and outputting of data. Several sensors will be connected to implement data to this microcontroller. The ESP32 will process data collected from several sensors. These include an inertial measurement unit, differential pressure sensor with pitot tube (for airspeed), and GPS module. The sensors will be essential to the navigation and autonomous control of the glider. We will use a proportional-integral-derivative (PID) algorithm to determine precise adjustments required for stable flight and optimal control surface actuation based on sensor data. This algorithm will ensure our glider lands in the desired landing to achieve maximum bonus points from the judges.

On the output side, the ESP32 will be connected to 2 servo motors to actuate the control surfaces of the aircraft. Our glider will have ailerons and an elevator, which is determined to provide adequate control. The glider design forgoes an actuated rudder to save weight that would be added from an additional servo motor and the structures associated with it, but will have a vertical stabilizer for aerodynamic reasons.

Our solution effectively leverages the sensors, motors, and the ESP32 microcontroller to process data inputs and provide real-time control outputs to ensure reliable flight performance.

4 Demonstrated Features

Our design will demonstrate the following features:

Launch Mechanism

The launch mechanism handles the deployment of the glider mid-air. It must work reliably to ensure proper flight of the glider. This feature is critical for ensuring the glider transition smoothly from the main aircraft to autonomous flight. It is essential that the glider does not fail to launch, or launch prematurely.

Flight Control Surface Actuation

The glider will demonstrate precise actuation of the flight control surfaces (ailerons, elevator) using the data processed from the IMU, pitot tube, and GPS module. Proper flight control surface actuation is critical to execute the 180 degree turn, and controlled descent into the designated landing zone.

Strobe Lights

The strobe lights must reliably activate after the glider is launched from the airplane, as outlined in the competition requirements. This feature demonstrates the effective implementation of the sensors and programming to identify launch conditions and trigger the lights at the correct time.

Video of Landing Precision

The glider will demonstrate its ability to land in the designated scoring zone, specifically the 2.5 points as shown in Figure 1. This achievement will be essential to a competitive performance in the competition. A video of this landing will be provided, showing the successful integration of the included devices and navigation and control of the glider.

Optimized Weight and Power Systems

The glider will demonstrate its lightweight construction, using materials like XPS foam and carbon fiber to meet the maximum weight limit of 0.55 pounds (250 grams). It will also show versatility in power sourcing, being able to operate on either USB or 2S 300mAh LiPo battery power, ensuring reliable operation during competition. It is critical the electronics and PCB are made to be as lightweight as possible.

5 Available Technologies

There are several technologies available that will be necessary to realize our solution. These technologies are listed below, along with a brief description of what they achieve.

ABP2DRRT001PD2A3XX - This is a digital differential pressure sensor to read airspeed data. It is connected to a pitot tube and measures the difference between static and dynamic pressure from two ports on the pitot tube. This information is used to compute airspeed with a known air density provided.

NEO-M9N - This is a uBlox GPS Module. The GPS sensor will track the precise location of the glider and ensure it stays on course to the specified coordinates of the highest-scoring landing zone as provided in Figure 1.

BNO085 - This device is a 9-DoF Inertial Measurement Unit used primarily to determine orientation. It will be used in conjunction with the GPS and PID control of servos to ensure the correct navigation of the glider.

SD card - The SD card will be used like a black box for logging the sensor and servo data from our flight testing. This will be an important piece in the analysis and validation of the sensors.

MKS servos - The design features two servo motors that will be used to actuate the ailerons and elevator.

ESP32-PICO-V3-02 - The ESP32 will serve at the primary processing unit for the glider. This system-in-package version of the ESP32 is ideal because it integrates essential components like capacitors, a crystal oscillator, flash memory, and more into a single lightweight package. It is compact and efficient, and will effectively handle sensor data, process navigation algorithms, and control the servo motors for flight control adjustments.

XPS Foam - used for wings, tail, and control surface XPS Foam is a lightweight material that will be used for the wings, tail, and control surfaces of the glider. This product will play an important role in achieving a lightweight design.

Carbon Fiber - Carbon fiber will be used in the frame for the glider. It will provide the necessary structural support for the glider. Carbon fiber is ideal because it provides impressive durability characteris and is fairly lightweight.

2s 500 mAh LiPo - This lithium polymer battery will provide the power required for all the electronics components of the glider. Its lightweight design makes it suitable for this competition. The 2s configuration (7.4V nominal voltage) offers the right balance between the voltage and current to ensure stable operation of the circuit board.

Lastly, the above technologies have been certified as available on digikey.com, or another similar vendor (Mouser).

Hamlin 59140-010 & Hamlin 57140-000 - This proximity sensing pair will allow the ESP32 to detect if the glider has been launched. The detection is possible through the ⅛" plywood used to construct the main aircraft, which allows us to put the proximity sensor inside of it, decreasing the drag of the aircraft.

VLCS5830 - This 65,000 mcda LED is bright enough to be seen during the day, ensuring that the judges will see it turn on after the glider is launched. This is critical because the competition in the desert in Tuscon, Arizona.

6 Engineering Content

There are several engineering needs that our team must address for this project. Below is an outline of the engineering work required for this project:

Schematic Design - We need a comprehensive schematic that incorporates all of the necessary components including the ESP32-PICO-V3-02, the sensors, servos, power management system, and programming capabilities. This involves selection of appropriate components, assignment of the correct pins, and proper connections for power distribution.

Board Design and Layout - After the schematic is completed, the PCB needs to be designed. This includes optimizing the board layout for minimal size and weight. The routing tracks must also comply with the specifications of the components we used. Lastly, the board must pass all design rules and DFM checks to ensure manufacturability. Impedance control is important since a 50 Ohm chip antenna will be included for the GPS, which requires an impedance-matched trace and correct PCB layout.

Programming - The ESP32 microcontroller will require custom programming to process inputs from the sensors and control outputs to the servos. We will utilize FreeRTOS to manage task prioritization, task scheduling, and inter-task communication using queues and semaphores. I2C and SPI communication protocols will be implemented to interface with the GPS, IMU, pressure sensors, and SD card. Additionally, we will develop control logic for flight control surface actuation, including implementing a PID algorithm for precise servo control. Finally, we will configure data-logging functionality on the SD card to conduct post-flight analysis.

Testing - During the test phase, we will conduct ground and flight tests to validate the performance of our electronics and ensure proper functionality of the glider. This includes debugging sensor inputs, verifying the PID algorithm, and refining control surface actuation to optimize landing precision. Flight testing will also aim to allow the glider to land as smoothly as possible while not taking too long to land.

Integration into the Glider - The electronics will be integrated into the glider, ensuring secure mounting, proper weight distribution, and robust connections between components. This step involves collaborating with the structures team to maintain the glider’s structural integrity and meet the competition’s constraints.

7 Conclusions

Our team is developing the electronics for an autonomous glider to compete in the AIAA Design Build Fly Competition. This project involves creating a lightweight glider and a high-performing navigation system for precise flight control.

The purpose of this project is to build the electronic systems for a glider that deploys at 200–400 feet of altitude, activates strobe lights, completes a 180-degree turn, and maintains stability while landing in a designated zone. The goal is to achieve the maximum number of points at the competition. To achieve this, we will focus on implementing sensors and actuators for accurate flight control, using lightweight materials to meet weight limits, and processing and recording data for in-flight usage and post-flight analysis.

In this project, we will address the engineering challenges of schematic design, circuit board design and layout, implementation of a real-time operating system, integration into the glider, and post-construction testing.

This project is particularly exciting because it involves aspects of electrical, aeronautical, and mechanical engineering. It is also an exploration of autonomous flight systems, with potential applications beyond the competition. These applications could include unmanned aerial vehicles capable of performing operations such as remote sensing or search-and-rescue missions. By combining the experience our team has gained over the last four years, we hope to demonstrate a competitive and functional glider at the 2025 AIAA Design Build Fly Competition.