

Glider Project - Report

First A. Author
Dylan Brenes

Second B. Author
Ezra Brooks

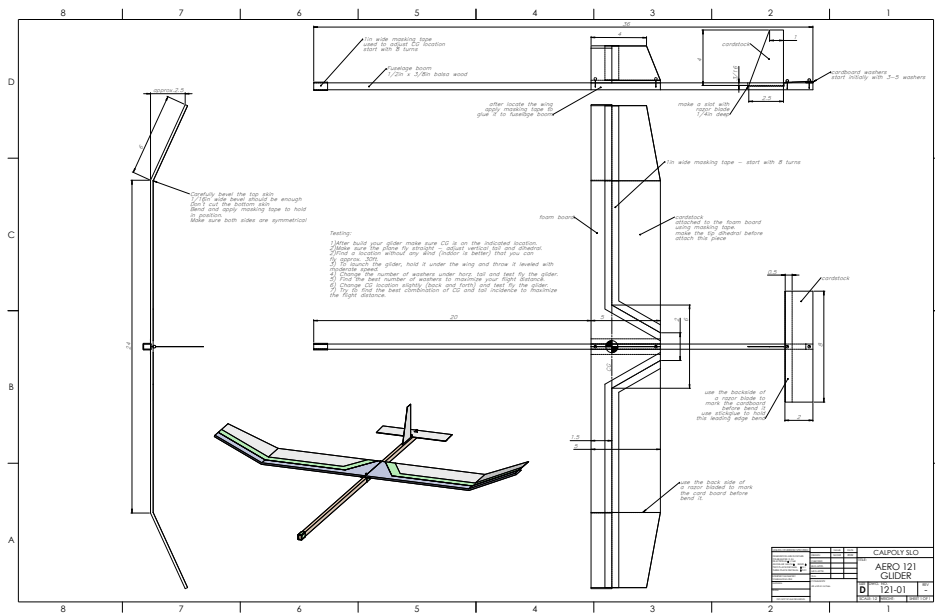
Third C. Author
Diego Diaz

Fourth D. Author
Libby Ikesaki

Fifth E. Author
Arjun Reyes

I. Introduction

THE glider project aimed to introduce the fundamentals of aeronautical engineering through hands on experimentation. There are two phases over the course of 5 weeks. The first phase includes building a standard glider. During this phase, groups perform tests to examine factors like the glider's center of gravity and the wing to tail angle (incidence) and how they affect their glider's flight characteristics. In the second phase, groups can either modify or build a completely new glider and apply what they've learned from the first phase to improve the new glider's capabilities.



II. Methodology

Set up/ Testing:

All members of the team worked at the same desk and shared materials. Teammates generally worked divided into smaller groups to work on individual components of the glider to complete test designs in a timely manner. However, these small groups were not completely isolated, and were constantly open to advice, criticism, and general support from the other subgroups. These subgroups' tasks could range from shaping the wing, drawing a new test design, researching real-world structures of gliders and fundamental principles of aerodynamics, taping and gluing parts together, adjusting the angle of the tail, or balancing the weight at the front of the glider.

After all the subgroups completed the part that they were working on, all joined back together to assemble the glider. In assembling the glider, the group created rough drawings and calculated numerous measurements to properly place the wing and angle the tail. Once the glider was completely assembled, the group went outside to begin testing, using the same thrower each time to minimize any variation throwing unless a change was warranted. While one member of the team threw, the other members of the team took videos, pictures, stood by to catch a stray flight, and recorded the measurement once the glider landed. All stayed engaged with the flight, observing it to notice any imperfections or future corrections that would be made after testing.

Materials:

Balsa wood was used to make the fuselage of the glider. While balsa wood is much less dense, and not as robust as other materials, it was light enough to allow the glider to fly, rigid enough to maintain the structure of the glider, and soft enough to cut to make adjustment as the group tested designs. The wings are made up of Styrofoam and industrial single-sided tape. The Styrofoam became the primary material to construct the wing because of its lightweight properties and its ability to be shaped based on the constraints we needed to overcome to achieve a longer flight. Painters' tape was primarily used to hold the wing together – to attach a separate piece of Foam Board to the main body of the wing to create an air foil - and set the dihedral at the proper angle.

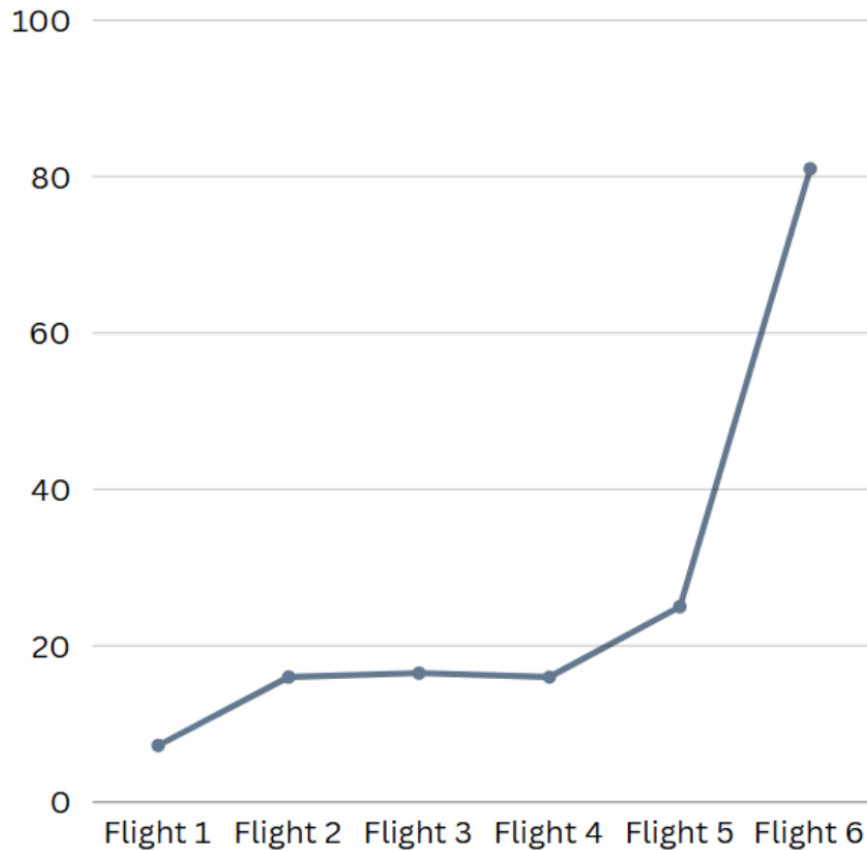
There are also two small pieces of balsa wood glued parallel to the wing in the center to establish rigidity and prevent breaking during landing. The wing is fastened to the top of the balsa wood fuselage by hot glue placed on either side of the fuselage where it meets the wing. The group decided to use hot glue as opposed to other fasteners such as pins or tape to attach the wing to the fuselage because it's a more permanent solution to keeping the wing stuck to the fuselage as there was difficulty with the wing falling off during testing. The wing was only glued to the fuselage once all major adjustments had been made, and the group was confident in the center of gravity. The tail of the glider is made of card stock. Cardstock is a bit more stiff than foam board, allowing it to stand upright. It is also heavier than foam board, balancing the weight added to the front to compensate for negative tilt.

Variables/ Reasoning:

The dependent variable of this project was the flight distance of the glider. Several independent variables had to be addressed to achieve the longest flight distance. The foremost independent variable in consideration was the center of gravity. This was the deciding factor in whether the glider would stay balanced during flight or not. If the center of gravity was too far forward, the nose of the glider would pitch down and the glider would fly into the ground. If the center of gravity was too far back, the nose of the glider would pitch up, causing it to fly straight up, losing any forward motion, and eventually falling out of flight. The team utilized several methods to compensate for these issues. Firstly, the team adjusted the position of the wing along the length of the fuselage since the wing carries a large amount of the total weight of the glider, so its positioning greatly affects the center of gravity of the glider. Secondly, to adjust the center of gravity of the glider, the team taped small metal washers to the nose of the glider. This helped with compensating for the weight created by the tail in the back end of the plane. It also helped keep the glider level if any external forces such as a gust of wind or poor throw caused the nose to pitch up.

Aerodynamics was a very influential independent variable that we had to consider while testing the glider. The team was primarily concerned with the amount of lift generated, or the lack thereof. To adjust for lift, the group manipulated the angle of the tail - which caused a positive or negative pitch to the back of the plane - and created an airfoil on the wing - which improved the airflow over the wing to generate high air pressure beneath the wing, and low air pressure above the wing. Next, the team had to account for the total mass of the glider. Having a low mass means that the glider doesn't have to generate as much lift to keep the glider in the air. Most of all, adapting the mass of the glider prevented confounding problems. By simply keeping the weight as low as possible, adjustments can be made without the fear too many variables are involved in one issue.

III. Results



Flight #	Length of Fuselage	Tip to Wing	Wing Chord	Dihedral Height	Tail Geometry
1	20 in	5 in	2.5 in	Conventional	8
2	10 in	5 in	2.5 in	Conventional	25
3	6 in	5 in	2.5 in	Conventional	25
4	20 in	2 in	0.5 in	Conventional	25+2 washers
5	15 in	4 in	0.5 in	T-tail	18+2 washers
6	2.75 in	13 in	4 in	2 in	T-tail with lower horizontal stabilizer

Table 1 Flight Data - Part 1

IV. Analysis/Discussion

What does the data tell us?

The initial testing configuration revealed critical insights into the performance of the glider. During the first test, with the front of the wings positioned 20 inches from the tip and utilizing three washers for weight, the glider flew a mere 7.25 feet. This indicated that the center of gravity (CG) was too far back, causing the glider to lift at the front and

Flight #	Weight of Tip	Distance	Air Time	Flight Speed
1	8	7.5 ft	0.61 s	12.29 ft/s
2	25	16 ft	1.59 s	10.06 ft/s
3	25	16 ft	2.12 s	7.5 ft/s
4	25 + 2 washers	16 ft	2.23 s	7.2 ft/s
5	18 + 2 washers	25 ft	1.59 s	15.7 ft/s
6	20 + 5 washers	81 ft	3.46 s	23.5 ft/s

Table 2 Flight Data - Part 2

subsequently fall backward. This highlighted the need to refine the CG positioning before making adjustments to the tail angle, as the center of lift (Cl) must be located behind the CG for stable flight.

In subsequent tests, adjustments were made to the wing placement. For example, after moving the wings to a position 10 inches from the tip, the glider achieved an improved flight distance of 16.5 feet, but the CG was still too far back, leading to similar performance issues.

By the second day of testing, the design was altered significantly, allowing for physical changes to the glider. Despite increasing the wing depth to improve lift, the glider only managed to fly 16 feet due to the small wing scale. On the third day, the wings were reconstructed to increase surface area, but the additional weight hindered performance, resulting in a flight distance of only 25 feet.

The final design incorporated significant improvements, with wings made entirely of foam and an optimized airfoil shape. This reconstruction enabled the glider to achieve a remarkable distance of 81 feet, an air time of 3.46 seconds, and a flight speed of 23.5 feet per second.

Final Configuration and Data Analysis

The final configuration was significantly enhanced compared to earlier iterations. With a fuselage length of 32.75 inches, a tip-to-wing distance of 13 inches, and a wing chord of 4 inches, the glider featured a T-tail design with a lower horizontal stabilizer. This configuration maximized the distance flown and represented a substantial leap in performance.

Optimal Glider

The ideal glider would closely resemble the final design, but improvements could still be made. The following modifications would be beneficial:

- 1) Minimize Weight:
 - Removing balsa wood supports on the wings could reduce weight significantly.
 - Reducing the number of tail wings while balancing the nose weight would help maintain the CG in the optimal range while decreasing overall weight.
- 2) Increase Lift:

- Enhancing the manufacturing quality of the airfoil would increase the effective surface area for lift generation.
- Increasing the depth of the wings by an inch could further improve lift characteristics.

3) Minimize Drag:

- Optimizing the airfoil shape through improved curvature could minimize drag and improve overall aerodynamic efficiency.

Shortcomings in Data/Measurement Setup

Several shortcomings were identified in the data collection and measurement setup, many of which were attributable to user error:

1) Inconsistent Tests:

- Variations in throwers impacted the consistency of results.
- Testing was conducted outdoors under windy conditions, which did not reflect the calm indoor environment expected during the competition.

2) Insufficient Data:

- Data logging was primarily conducted at the end of workdays rather than after each iteration.

3) Inability to Precisely Calculate CG or CI:

4) Lack of Prototype Documentation:

- There was a notable lack of photographic documentation for each prototype stage.

What Would Be Done Differently?

To enhance future iterations, several key adjustments would be made:

- 1) Testing environments should closely replicate competition conditions.
- 2) Emphasis on modeling and calculating the CG to optimize glider performance should be prioritized.

Additionally, focus would also be placed on refining manufacturing techniques, enhancing communication, and improving teamwork.

Documentation

In future projects, more extensive photographic documentation of each prototyping stage and detailed logs of changes between tests would be implemented.

Delegation and Communication

Establishing clear communication methods earlier would facilitate a more efficient production and testing process, ensuring that all team members contribute ideas and align on project goals.

Manufacturing and Planning

The team encountered challenges related to the precision needed for tasks such as chamfering wings to create dihedral angles. Greater preparation and practice with these techniques would benefit future projects. Additionally, recognizing that many manufacturing processes could be performed simultaneously would optimize time management in the lab, allowing for more opportunities for design, prototyping, and testing.

One final reflection involves the need for increased innovation and creativity in design. The team spent excessive time adhering to initial drawings instead of exploring more unconventional designs that could have led to better performance outcomes.

V. Conclusion

The journey of constructing the glider was full of trial and error, but one that provided key insights into the world of flight. By starting with a clear blueprint that built the framework for our basic glider. From there, the ideas took off, and the group decided to wing it and attempt to enhance the wing shape and overall aerodynamics. Moving forward with a plane foam wing effectively reduced the glider's overall weight and enabled it to soar gracefully through the air. This hands-on experience highlighted the critical importance of stability and structural integrity, which led to the reinforcement of the wing with lightweight balsa wood to enhance its rigidity. The final key change was strategically adding weights to the front to help find the perfect balance for the center of mass and lift, ensuring that the glider landed well during test flights.