Final Project Report

Undergraduate Qualifying Year Aerospace Group 5
University of Nottingham Ningbo China

This report outlines the design, analysis, and testing of a balsa-wood glider conducted by a student team. The project followed an iterative workflow including aerodynamic simulation, CAD modeling, and structural optimization. Through Ansys analysis and prototyping, fuselage drag was reduced by 15%, and the lift-to-drag ratio improved from 0.594 to 0.65. Flight tests under 3m/s and 4m/s launch speeds closely matched MATLAB predictions, with minor discrepancies attributed to neglected short-period dynamics and CG shifts. Lessons emphasized effective task division, structured reviews, and the need for improved modeling accuracy and manufacturing control.

I. Team Organization, Role Assignment and Teamwork

A. General Organization Mode

The project team was structured as a cross-functional engineering group progressing through five iterative stages: aerodynamic analysis, performance prediction, aircraft CAD modeling, structural analysis, and final assembling. Each stage informed the next, with continuous iteration loops.

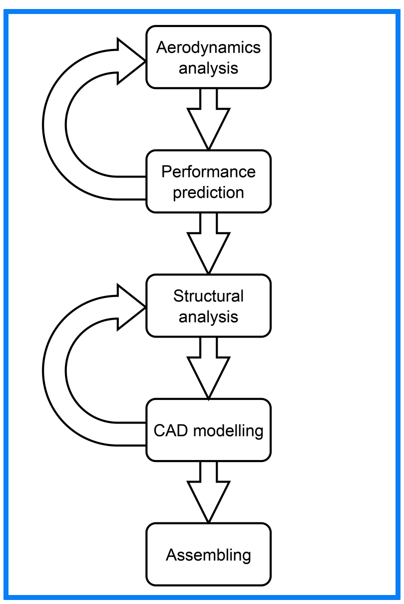


Fig. 1 Task and Organization in Project

These general five stages indicate the team's engineering workflow. They were not executed in isolation but cyclically refined through team discussions, periodical reviews, and real-time simulation updates. This iterative mechanism ensured alignment between aerodynamic objectives and structural feasibility throughout the project timeline.

B. Role Allocation by Engineering Task

Rather than assigning works to members regularly, roles were allocated based on task demands and expertise required at each stage.

- **Aerodynamic Analysis;** Yupeng LI did basic lift and drag prediction in Xflr5 and Ansys and Yang LIU took charge of further fluid-structure coupling simulations.
- **Performance Prediction:** Weihao Qin and Yupeng Li conducted simulations incorporating aerodynamic results into dynamic flight models under varied lift to drag ratio and try to cooperate with aerodynamics team to optimize the flight distance
- **CAD Modelling:** Xinjie Li and Yiwen Zou were responsible for 3D modeling of the glider using SolidWorks, ensuring dimensional accuracy for subsequent structural simulation and manufacturability validation, the work is also conducted with the structure team.
- **Structural Optimization:** Yang LIU and Yiwen Zou focused on the design and iteration of glider components, material selection and structural strength analysis.
- **Design Integration and Manufacturing:** Xinjie Li and Weihao QIN considered manufacturability constraints and assembled the glider with high quality.

C. Team Collaboration

1. Team members were flexibly paired based on task needs. For instance, Yupeng Li worked with both Weihao Qin and Yang Liu to tackle challenges that involved both structural and aerodynamic considerations.

2. A shared DHF repository to keep everything synced, from Ansys simulation files to SolidWorks models and

Gantt chart updates — ensuring everyone stayed on the same version of the work.

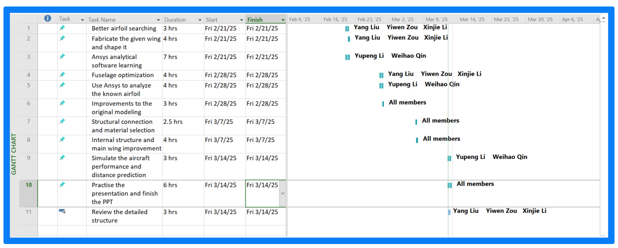
3. Design reviews were held regularly to sort out conflicts (like balancing fuselage drag with weight reduction). These sessions helped us come up with practical solutions such as adding reinforced side panels or using hollow fuselage structures.

4. When some issues couldn't be resolved in regular meetings, like wing-fuselage connection instability, we escalated them to full team workshops and discuss together. There, we quickly built and tested physical prototypes using rubber bands and wooden strips to find ideal working solutions through hands-on iteration.

II. Project Planning and Execution

A. Project Planning

For each stage of the project, such as the preliminary design and Critical Design Review (CDR) — our team developed detailed planning schedules to ensure effective time allocation and task execution. Gantt charts were used as the primary tool for task assignment and progress tracking. The following chart illustrates the task breakdown and team allocation during the CDR phase.



	Task Name	Duration	Start	Finish	
1	Better airfoil searching	3 hrs	Fri 2/21/25	Fri 2/21/25	Yang Liu Yiwen Zou Xinjie Li
2	Fabricate the given wing and shape it	4 hrs	Fri 2/21/25	Fri 2/21/25	Yang Liu Yiwen Zou Xinjie Li
3	Ansys analytical software learning	7 hrs	Fri 2/21/25	Fri 2/21/25	Yupeng Li Weihao Qin
4	Fuselage optimization	4 hrs	Fri 2/28/25	Fri 2/28/25	Yang Liu Yiwen Zou Xinjie Li
5	Use Ansys to analyze the known airfoil	4 hrs	Fri 2/28/25	Fri 2/28/25	Yupeng Li Weihao Qin
6	Improvements to the original modeling	3 hrs	Fri 2/28/25	Fri 2/28/25	All members
7	Structural connection and material selection	2.5 hrs	Fri 3/7/25	Fri 3/7/25	All members
8	Internal structure and main wing improvement	4 hrs	Fri 3/7/25	Fri 3/7/25	All members
9	Simulate the aircraft performance and distance prediction	3 hrs	Fri 3/14/25	Fri 3/14/25	Yupeng Li Weihao Qin
10	Practise the presentation and finish the PPT	6 hrs	Fri 3/14/25	Fri 3/14/25	All members
11	Review the detailed structure	3 hrs	Fri 3/14/25	Fri 3/14/25	Yang Liu Yiwen Zou Xinjie Li

Fig. 2 Sample Gantt Chart for CDR

B. Execution and Monitoring

- **Iterative Performance Refinement:** A structured aerodynamic workflow led to a progressive improvement in the glider's lift coefficient, increasing from 0.594 (preliminary) to 0.65 (validated). This was achieved through multiple design loops using Xflr5 and Ansys.
- **Quality Control:** Structural refinements — such as hollowed fuselage structures and reinforced side panels — reduced drag by 15%. These adjustments were informed by simulation results and validated by stress analysis.
- **Risk Management:** To evaluate potential structural risks, Ansys is used to carefully examine the structural strength of the glider. This analysis allowed us to identify critical regions that were likely to endure high loads during flight — such as wing root junctions and fuselage mounting points. These insights guided our reinforcement strategy before manufacturing.
- **Cross-Team Monitoring:** Each specialized team was responsible for reviewing the outcomes of adjacent teams at the end of every design and implementation phase. Constructive critiques were encouraged, for instance, the CAD team challenged structural assumptions based on manufacturability constraints, while the simulation team offered suggestions to refine geometry based on airflow results. This cyclical review process ensured coherence across aerodynamic, structural, and manufacturing domains.

III. Summary of Project Deliverables

A. CAD Design

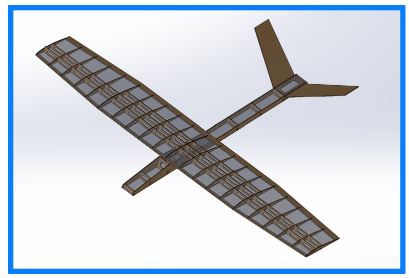


Fig. 3 Glider Modelling

The figure is the CAD design of glider with high level of completion. The detail of internal structure of the CAD model are shown in the following section.

B. Detailed Internal Structure

1. Spars and ribs connection

The integrated spar and rib cross each other, which not only ensures the stability of the parts but also facilitates installation

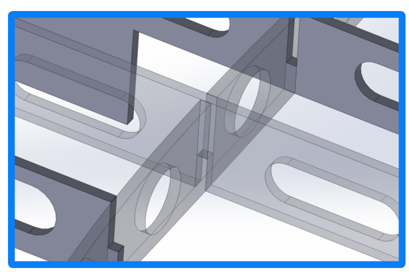


Fig. 4 Spar and Rib Connection

2. Main wing and fuselage connection

Two wooden pieces extend from the first and third spar to connect with the grooves on the fuselage. Meanwhile, insert a wooden strip into the fuselage to wrap the rubber band, thereby fixing the wings and the fuselage.

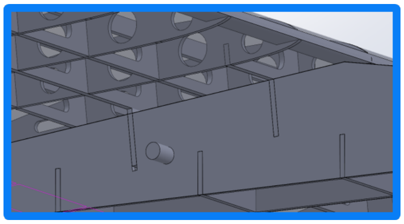


Fig. 5 Main Wing and Fuselage Connection

3. Tail and fuselage connection

Insert a wooden piece slightly wider than the fuselage at the tail end of the aircraft to bond the V-shaped tail wing and the fuselage.

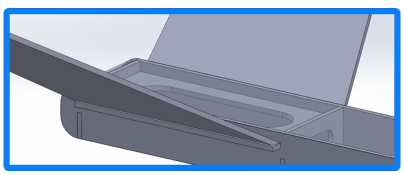


Fig. 6 Tail and Fuselage Connection

C. Final Assembled Glider

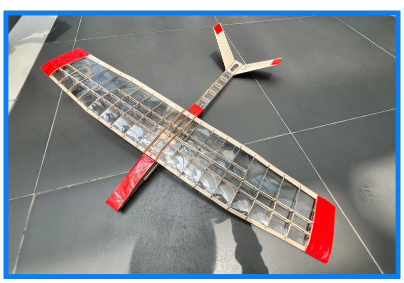


Fig. 7 Assembled Glider

The picture above shows the final manufactured glider, compared with the CAD design, the manufactured version shows virtually no difference compared with the CAD drawing.

Table 1 Basic Parameters

Wing span	1003 mm
Length	880 mm
Height	70 mm
Wing weight	44.18 g
Total weight	146.4 g

D. Improvements During Construction Process

1. Aerodynamics Consideration

Weight was added to the nose section, causing the center of gravity of the glider to be approximately located at a point four quarters of the chord length from the leading edge of the wing.

The tail end of the wing is raised by wooden pieces, and the front section is subjected to downward force by rubber bands, which is done to reduce the angle of attack during takeoff and prevent the aircraft from tilting forward due to excessive lift.

2. Structure Consideration

Wood strips were added at the connection point of the wing and the fuselage, which not only strengthened the connection point but also fixed the position of the wing.

The tip of the wing is reinforced with tape to ensure lateral sealing and to make the folded edge smooth. Use adhesive tape at the tail wing tip to reinforce and reduce the deformation caused by the wood grain.

IV. Test Data Analysis and Representation

This section presents result for static wing test and final flight test. The static wing-test results aim to show structural performance of the manufactured aircraft. In flight test result part, predicted and actual flight distances are compared, with discussion of key discrepancies. Data is conveyed effectively through graphs and tables, ensuring clarity and technical accuracy throughout.

A. Static Wing Test

Before the official static wing test, a fluid-structure coupling analysis is performed using Ansys. A simple analysis system is built to evaluate the structural reliability of the glider. The folloing flowchart is a simple description of the system:

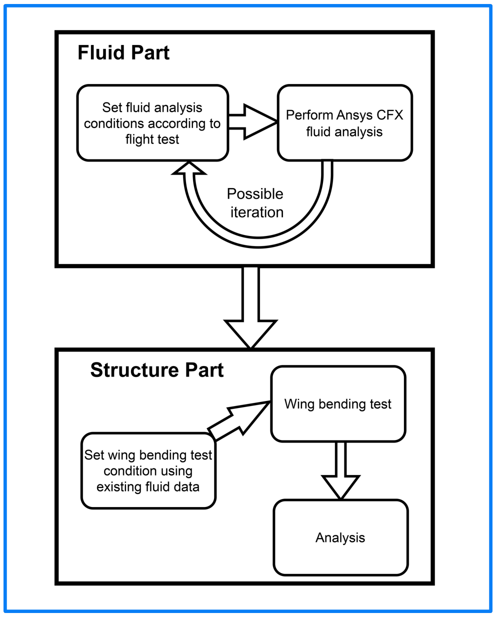


Fig. 8 FEM Flowchart

The test result is shown below. It is important to note that the test condition is different from that of the static wing test. The wing pressure under real flight conditions was simulated using CFD, and the resulting data were exported to compute the equivalent stress on the wing and fuselage. Given that the maximum equivalent stress occurs on the wing surface, and the material used is balsa wood, the maximum stress value of 2.7211×10^6 Pa is compared with the theoretical strength of balsa, approximately 5×10^6 Pa (Gibson & Ashby, 1999)). This comparison indicates that the designed glider possesses adequate structural strength. One of the wing rib is removed to alleviate structural redundancy.

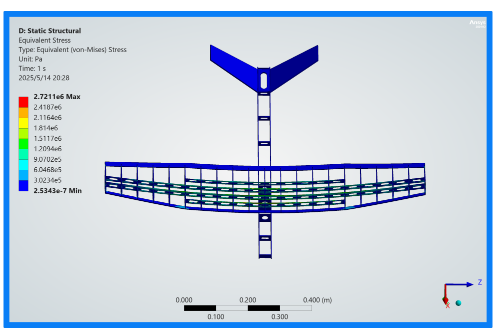


Fig. 9 FEM Test Result

While the previous FEM analysis evaluated the structural strength under idealized conditions, the subsequent wing bending test provides verification under more realistic, physical loading scenarios. In static wing test, the wing was mounted on a test bed such that both wingtips were supported and elevated above a reference surface. The vertical distance from the upper surface of the trailing edge (TE) midpoint to the reference surface was initially measured to be 14.7 cm. Loads were then incrementally applied to the center of the wing in steps of 10 g, ranging from 10 g to 240 g. After each load increment, the vertical position of the TE midpoint was recorded. The following table presents the deflection of the TE under each loading condition, along with its normalized value with respect to the wing span (L = 1.003 m).

Table 2 Normalized Deflection (δ/L) Wing Loading Test Result

Load (g)	Deflection (cm)	Normalized δ/L
10	0.05	0.00050
20	0.10	0.00100
30	0.13	0.00129
40	0.20	0.00199
50	0.20	0.00199
60	0.23	0.00228
70	0.30	0.00298
80	0.34	0.00337
90	0.38	0.00376
100	0.40	0.00396
110	0.42	0.00416
120	0.50	0.00486
130	0.55	0.00536
140	0.60	0.00586
150	0.63	0.00616
160	0.70	0.00686
170	0.73	0.00716
180	0.75	0.00736
190	0.76	0.00746
200	0.87	0.00856
210	0.80	0.00796
220	0.82	0.00816
230	0.84	0.00836
240	0.90	0.00895

The result indicates that the wing structure exhibits a nearly linear relationship between applied load and deflection up to 240g, demonstrating elastic behavior throughout the tested range.

B. Flight Test and Discrepancy Analysis

1. Test Data Presentation

The following table summarizes flight test data recorded under two different launching velocities (3 m/s and 4 m/s). For tests conducted at an initial launch speed of 3 m/s (Test 1 to Test 3), the actual recorded flight distances (7.88 m, 8.10 m, and 8.15 m) have been adjusted by a factor of 0.75 to remove the effect of landing roll distances. In contrast, the 4 m/s test was conducted at full speed (10.21 m), and this result was directly compared to our MATLAB code predictions presented during the Critical Design Review (CDR), which predicted a flight distance of approximately 10.1 m.

Table 3 Flight Distance

Speed	Test	Predicted	Measured	Actual
3m/s	Test 1	10.1m	7.88m	5.91m
	Test 2		8.10m	6.08m
	Test 3		8.15m	6.11m
4m/s	Test 4		10.21m	10.21m

2. Result Analysis

The flight test results indicated overall consistency and accuracy with our pre-flight predictions, validating the preliminary aerodynamic modeling approach and confirming the soundness of our general aerodynamic assumptions. However, two main sources of discrepancies were identified:

- **Modeling Simplifications:** The MATLAB simulation code used during the design phase considered primarily the longitudinal phugoid (long-period) mode, neglecting the effects of the short-period mode. This omission likely contributed to prediction errors, as short-period dynamics significantly affect immediate post-launch behavior and initial climb trajectory. Future modeling efforts could incorporate short-period modes explicitly, an approach recommended by D'Sa (2020), to enhance predictive accuracy.
- **Manufacturing Deviations:** Another source of discrepancy stemmed from slight deviations in the glider's manufacturing process, particularly related to the center of gravity (CG) offset and variations in overall mass distribution. These differences led to observable performance variations between the actual flight and theoretical predictions, underlining the importance of stricter manufacturing and assembly tolerances.

Addressing these two critical areas will further refine our future designs, leading to more precise modeling and better flight performance outcomes.

V. Lessons Learned

A. Lessons Learned

This part of the report mainly summarizes similar lessons learned by each group member.

- **Effective Time Management:** Breaking the project into clear milestones and allocating detailed time slots during the preliminary design week ensured that both PDR and CDR were completed on schedule.
- **Strength-Based Task Allocation:** Assigning work packages according to each member's expertise balanced the workload and maximized overall team productivity.
- **Theory–Practice Integration:** Continuously linking aerodynamic analysis with hands-on prototyping reinforced our understanding of flow–structure interactions and improved design refinements.
- **Computational Proficiency:** Demonstrated CAD and CAE skills accelerated detailed modeling tasks, contributing to high-quality glider geometry and reducing iteration cycles.

B. Future Improvements

- **Enhanced Dynamic Modeling:** Incorporate the longitudinal short-period mode into our MATLAB simulations (per D'Sa, 2020) to capture rapid attitude changes and improve distance predictions.
- **Stricter Manufacturing Tolerances:** Tighten CG placement and mass distribution tolerances to minimize performance deviations caused by assembly variances.
- **Built-in Schedule Buffers:** Add explicit buffer periods in the Gantt chart to absorb unexpected design changes and prototype iterations.
- **Formalized Cross-Team Reviews:** Establish standardized review checkpoints at the end of each design phase, where each group evaluates adjacent teams' deliverables and proposes targeted improvements.

References

D'Sa, R. (2020). Design of a transformable unmanned aerial vehicle (Doctoral dissertation, University of Minnesota). University Digital Conservancy. https://hdl.handle.net/11299/213120

Gibson, L. J., & Ashby, M. F. (1997). *Cellular solids: Structure and properties* (2nd ed.). Cambridge University Press.