



Small Glider

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Design Objectives

Low-speed, stable glider flight

Zero 3D-printed components

Modular assembly system

10 meter max flight distance

Objectives Achieved

Low-speed, stable glider flight

Modular assembly system

10 meter max flight distance

Airfoil Evolution

NACA 2412

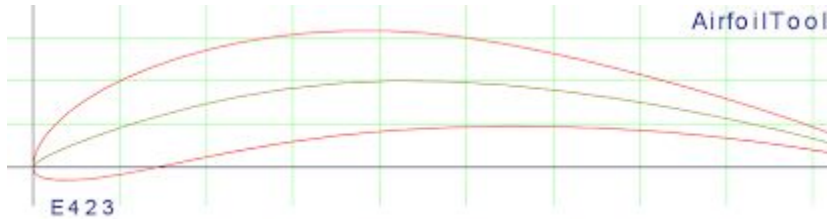
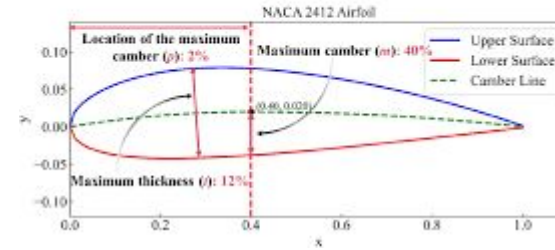
Initial design

→ **S1223**

Final design for enhanced low-speed lift

NACA 2412

m p t



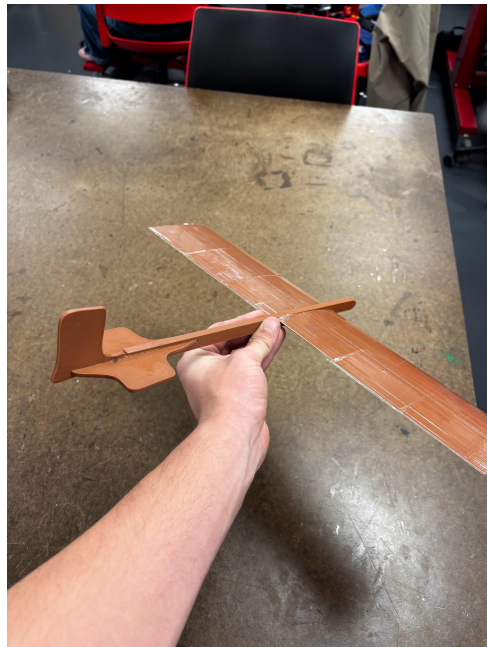
Design Process

Phase 1: Concept Validation — Simple geometry tests verified basic flight principles and established dimensional scaling. Rapid prototyping methods tested aerodynamic hypotheses. (3D printed prototype)

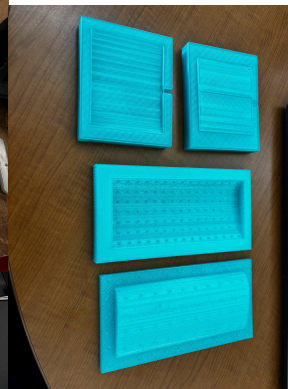
Phase 2: Manufacturing Reality — Mid-stage versions exposed molding constraints. Thin walls, living hinges, and complex geometries revealed the gap between CAD and reality. Most design effort occurred here. (Mass manufactured iterations of the initial design)

Phase 3: — Final iteration balanced manufacturability with performance. Design compromises prioritized consistent production over theoretical aerodynamic optimization. (Final Material designs, Simpler Geometries, and quick fasteners)

Plane Evolution



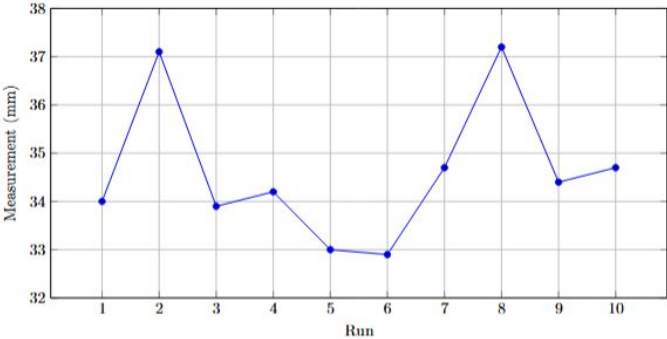
Molded Parts



Wing Measurements

Run	Wing (mm)
1	34.0
2	37.1
3	33.9
4	34.2
5	33.0
6	32.9
7	34.7
8	37.2
9	34.4
10	34.7

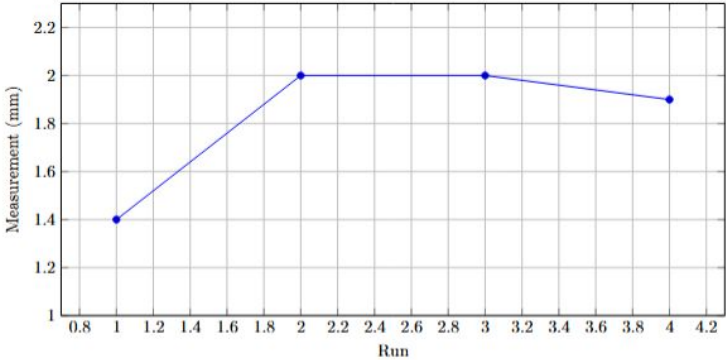
Statistics:
Mean: 34.61 mm
SD: 1.59 mm
Q1: 33.95 mm
Q3: 34.70 mm
IQR: 0.75 mm
Lower Bound: 32.83 mm
Upper Bound: 35.83 mm
**Outliers: Run 2 (37.1 mm),
Run 8 (37.2 mm)**



Vertical Tail Measurements

Run	V. Tail (mm)
1	1.4
2	2.0
3	2.0
4	1.9
5-10	-

Statistics (n=4):
Mean: 1.83 mm
SD: 0.27 mm
Q1: 1.58 mm
Q3: 2.00 mm
IQR: 0.43 mm
Lower Bound: 0.93 mm
Upper Bound: 2.65 mm
Outliers: None



Horizontal Tail Measurements

Run	H. Tail (mm)
1	3.6
2	3.4
3	3.3
4	3.0
5	3.2
6	3.0
7	3.0
8	2.9
9	3.1
10	3.1

Statistics:
Mean: 3.16 mm
SD: 0.23 mm
Q1: 3.00 mm
Q3: 3.35 mm
IQR: 0.35 mm
Lower Bound: 2.48 mm
Upper Bound: 3.88 mm
Outliers: None

Fuselage Measurements

Run	Fuselage (mm)
1	6.5
2	6.5
3	6.5
4	6.5
5	6.4
6	6.5
7	6.5
8	6.5
9	6.5
10	6.5

Statistics:
Mean: 6.49 mm
SD: 0.03 mm
Q1: 6.50 mm
Q3: 6.50 mm
IQR: 0.00 mm
Lower Bound: 6.50 mm
Upper Bound: 6.50 mm
Outliers: Run 5 (6.4 mm)

Stand Measurements

Run	Stand (mm)
1	34.1
2	34.3
3	33.8
4	33.4
5	34.6
6	33.7
7	34.2
8	33.4
9	35.0
10	34.1

Statistics:
Mean: 34.06 mm
SD: 0.51 mm
Q1: 33.70 mm
Q3: 34.30 mm
IQR: 0.60 mm
Lower Bound: 32.80 mm
Upper Bound: 35.20 mm
Outliers: None

Component	Quantity
Stands	10
Vertical Tails	10
Horizontal Tails	10
Fuselages	10
Wing Parts	40
(20 wings × 2 parts per wing)	
Dowels	20
Total Parts	100

Part Consistency and Measurement

All parts were measured using calipers for most components and rulers for extended wing geometry. The wing measurements showed the highest variability ($SD = 1.59$ mm) with two outliers (Runs 2 and 8), directly attributable to the thermoforming process and human error required for the 40 wing parts. Each wing consists of two mating halves that must be precisely aligned and trimmed, introducing natural variation. In contrast, automated processes like 3D printing (fuselage, $SD = 0.03$ mm) and injection molding (horizontal tail, $SD = 0.23$ mm) demonstrated significantly tighter tolerances with minimal post-processing requirements.

Cycle Time and Production Analysis

Assumptions

- Product: 1 fuselage, 2 wings (4 halves), 1 vertical tail, 1 horizontal tail, 1 stand.
- Injection molding: one part at a time.
- 3D printing: all 10 fuselages in parallel (50 min batch).
- Vacuum forming: 3 molds per cycle.
- Analysis for 10 gliders steady-state.

Fuselage (3D Print)

$$t_f = \frac{50}{10} = 5 \text{ min}$$

Injection Molded Parts (per glider)

$$t_{\text{vert}} = \frac{7(10)}{10} = 7 \text{ min}$$

$$t_{\text{horiz}} = \frac{5(10)}{10} = 5 \text{ min}$$

$$t_{\text{stand}} = \frac{4(10)}{10} = 4 \text{ min}$$

$$t_{\text{injection}} = 16 \text{ min}$$

Wing Manufacturing (per glider)

$$t_{\text{vac}} = \frac{40/3 \text{ sheets} \times 2}{10} = 2.67$$

$$t_{\text{cut}} = \frac{40/3 \text{ sheets} \times 10}{10} = 13.33$$

$$t_{\text{seam}} = \frac{20 \text{ wings} \times 10}{10} = 20$$

$$t_{\text{wings}} = 36.0 \text{ min}$$

Final Assembly

$$t_{\text{assembly}} = 0.3 + 1 + 1 + 0.17 = 2.47 \text{ min}$$

Bottleneck

$$\max\{5, 16, 36.0, 2.47\} = 36.0$$

Wing manufacturing

Production Rate

$$R = \frac{1}{36.0} = 0.0278 \text{ parts/min}$$

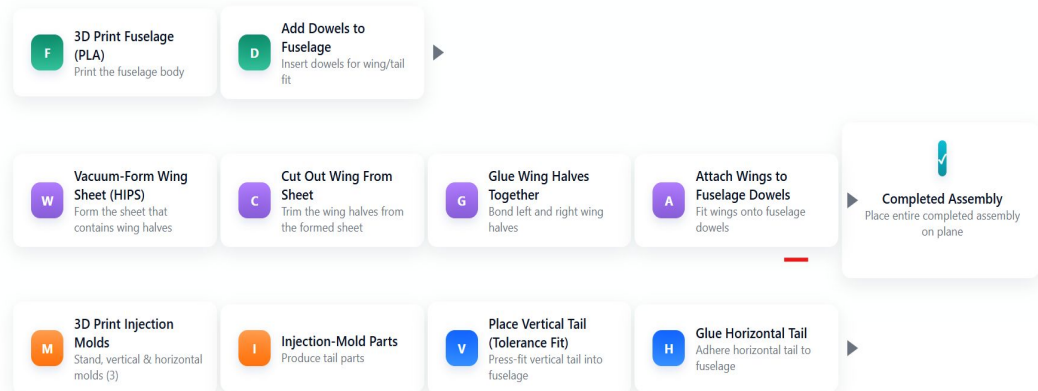
1.67 gliders/hr

Work-in-Process (Little's Law)

$$T_{\text{flow}} = 5 + 16 + 36.0 + 2.47 = 59.47$$

$$WIP = RT_{\text{flow}} = 1.65$$

WIP ≈ 2



What I learned

Thin parts can't be injection molded

I would only attempt to make a Polypropylene living hinge again if I were to have an aluminum or steel tool, as the PETG 3D-printed mold was difficult to make something consistent.

I would choose a mechanical fastener for the horizontal and vertical tail instead of adhesive.

I would design a better ballast centering arrangement.

Planes are hard to make.

Final Design

