California State University, Los Angeles
College of Engineering, Computer Science & Technology
Department of Mechanical Engineering
Department of Technology
ME 4972-01 / ETEC 4951

3-D Printed Aircraft

Team 3 (105C)
Luis Gutierrez Jr
Lloyd Macauling
Erik Ho
Luis Rivera

Professor/Advisor: Everardo Hernandez

3D-Printed Aircraft Competition Background

Each group/school will be designing a 3-D printed aircraft, using other resources to their benefit to complete the sketch/design of the aircraft

Project Requirements

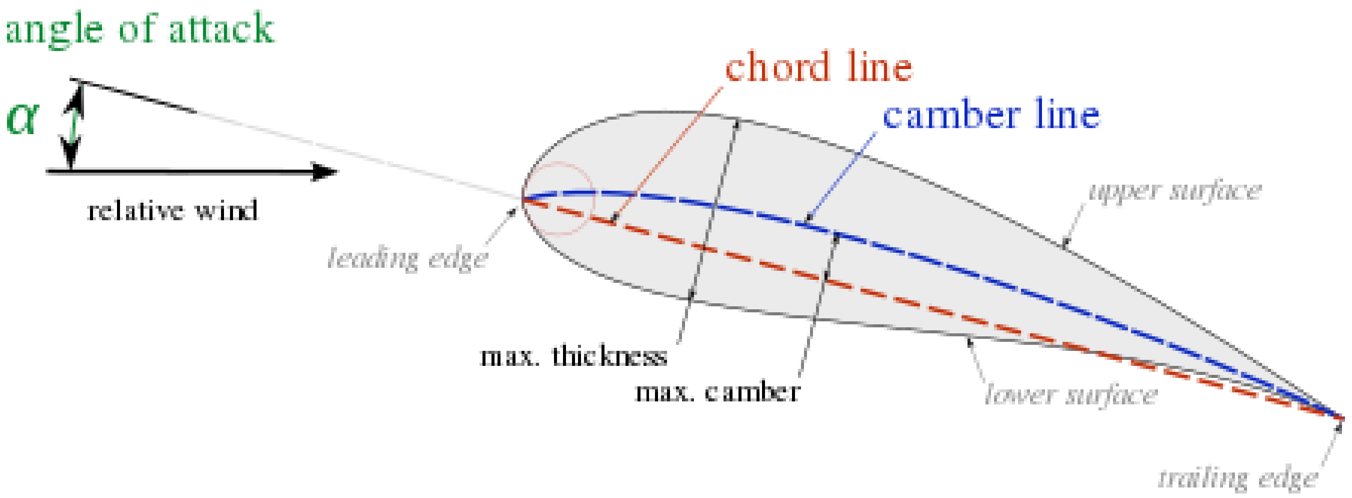
There is no weight or size restrictions in the design of the aircraft. The use of SolidWorks helps the team in build and simulation.

Fundamentally Safe

- The whole frame will be designed by each student and 3-D printed. Due to safety reasons each team is allowed to commercially acquire propellers and rotors.
- Parts such as hinges, actuators, system components etc. do not have to be printed.
- The aircraft will be powered by their engines for a total of 5 seconds reaching a height limit of 50 feet.
- The team that glides safely for a prolonged time will win the competition.

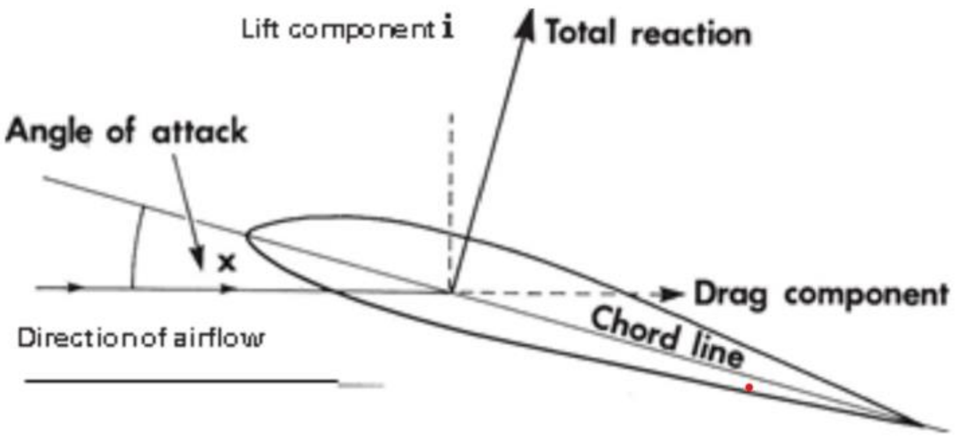
Air Foil

For a gliding aircraft, it is advised for wing to be thin/long with a lower lift coefficient, due to the change of airspeed (stability);Higher Aspect Ratio wingspaned^2/total area of wing



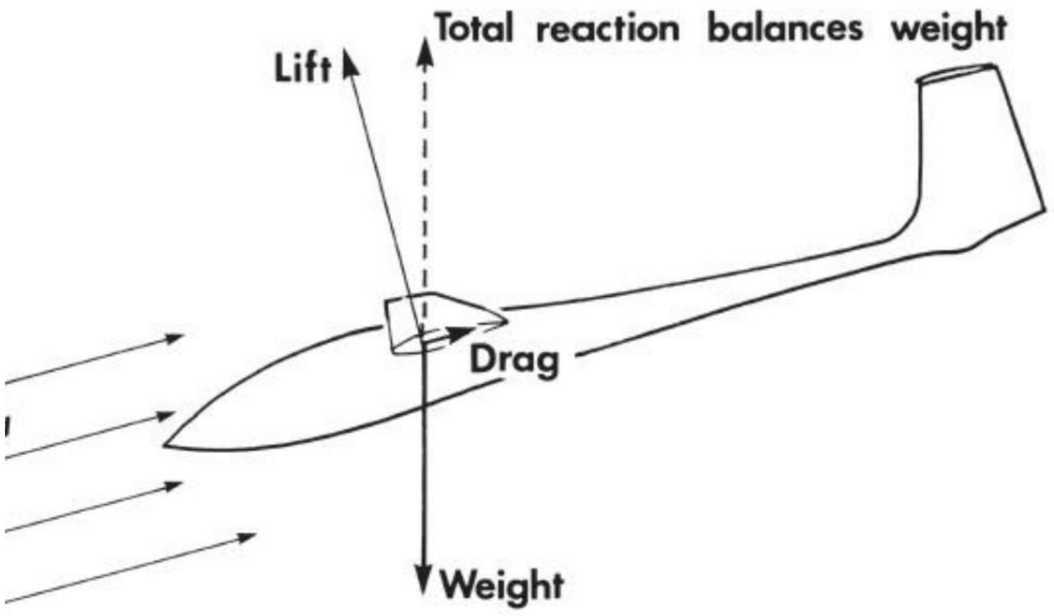
Air Foil

- Lift acts at the right angle of the air flow; drag is the backwards component parallel to air flow
- Lift/Drag correlates directly to the angle in which the airflow is in contact with the wing.
- Angle between direction of air flow and chord line is called Angle of Attack



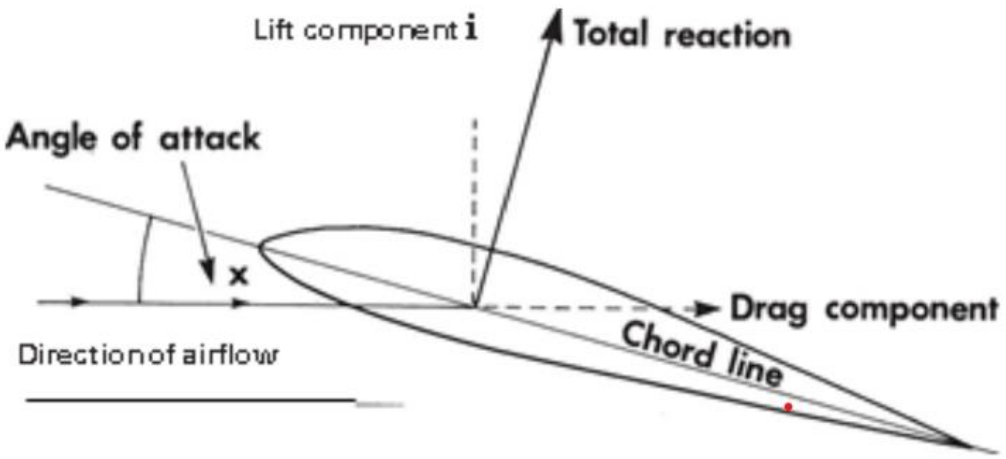
Air foil

- Large Air Foil will create much more drag
- Gliders: Values of airspeed and Angle of Attack-Lift Force is equal to the weight of the aircraft



Angle of attack

For most gliders to cover the most amount of ground staying still, the angle of attack must be around 7 degrees



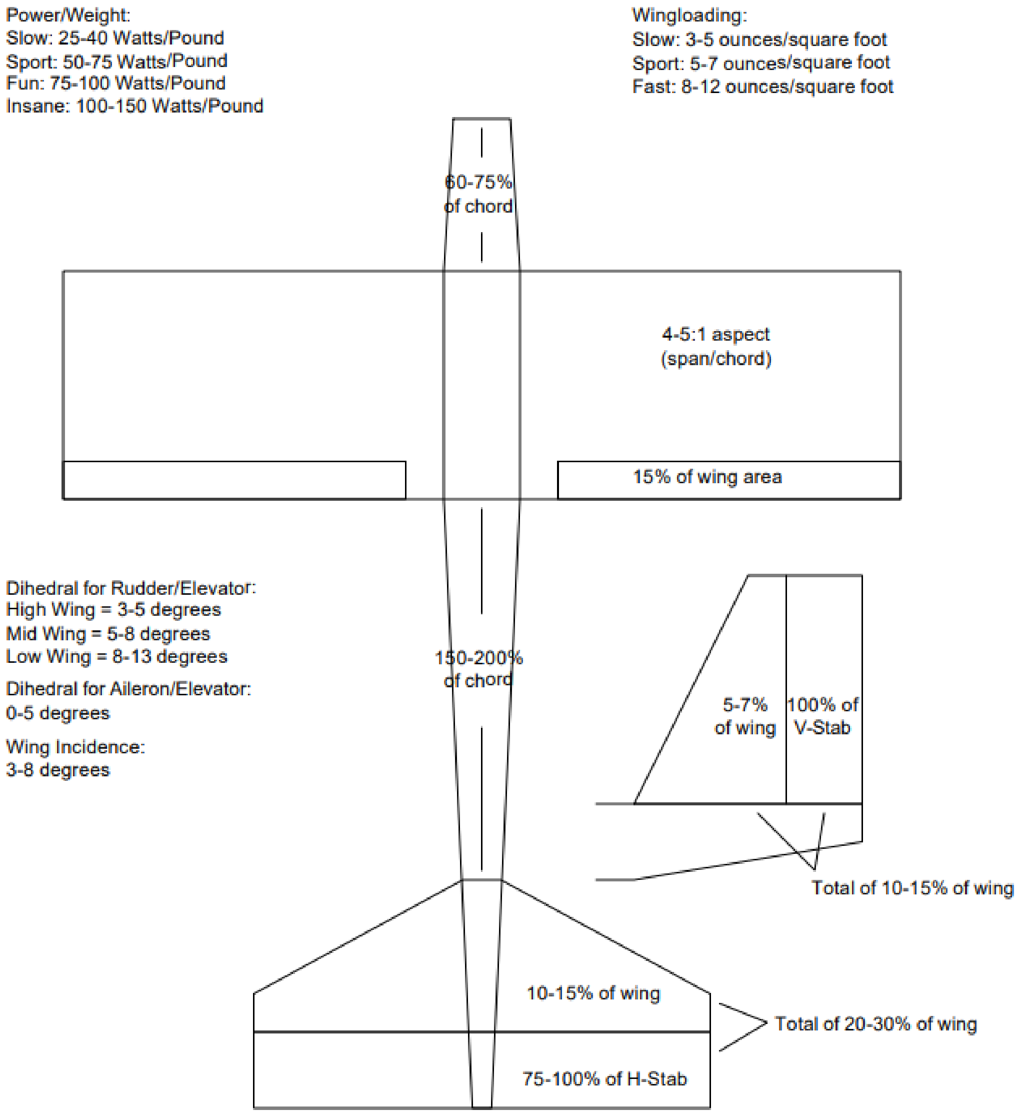
Aircraft design ratios

Fuselage to Wingspan Ratio Mid to low wing design

- Length of fuselage should be approximately 70%-75% of wingspan

Ratio of Wing Root Chord to Wingspan

- 5:6

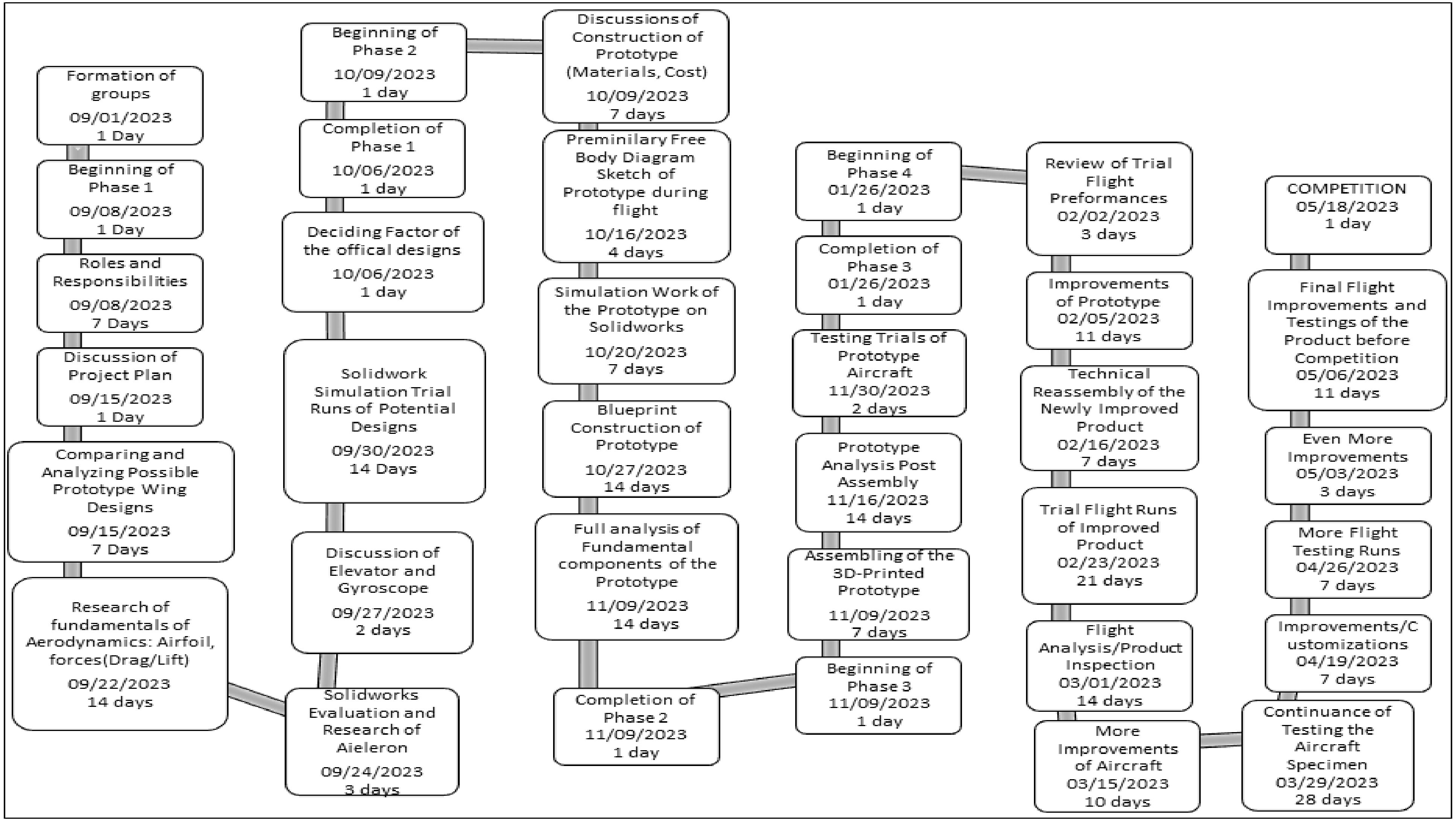


Gant Chart

TASK	ASSIGNED TO	PROGRESS	START	END
Phase #1				
Sketch Analysis/Rules and Requirements	Luis Rivera	100%	9/1/23	9/15/23
Drawing of Preliminary Design	Luis Rivera	100%	9/15/23	9/22/23
Air Foil Analysis and Research	Erik Ho	100%	9/22/23	9/30/23
Solidwork Application Research	Luis Gutierrez Jr	100%	9/30/23	10/6/23
Construction of Different Aircraft Designs	Lloyd Macauling	100%	10/6/23	10/9/23
Phase #2: Generatation of Ideas/Prototype				
Solidwork	Luis Rivera	100%	10/9/23	10/20/23
Cost of Parts	Luis Gutierrez Jr	100%	10/20/23	10/27/23
Aerodynamics/Coeff. Drag/Lift	Lloyd Macauling	100%	10/9/23	10/20/23
Aileron/Elevator/Gyroscope Development and Research	Erik Ho	100%	10/20/23	11/9/23

Phase #3: Evaluation of Concept				
Sauder Controls/Engine Technical Practices	Luis Gutierrez Jr	90%	11/9/23	11/16/23
Prototype Assembly	Erik Ho	90%	11/9/23	11/16/23
Analysis of the Prototype	Luis Rivera	85%	11/16/23	11/30/23
Flight Testing Runs of the Prototype	Lloyd Macauling	15%	11/9/23	11/30/23
Phase #4: Selection of Solutions/Managements				
Further Improvements/Reviews	Luis Rivera	55%	1/26/24	2/5/24
Technical Management	Erik Ho	42%	2/5/24	2/23/24
Flight Analysis/More Flight Testing Trials	Luis Gutierrez Jr	25%	2/23/24	4/26/24
Complete FAA trust	Erik Ho;Lloyd Macauling	100%	3/25/24	3/30/24
Complete team Registration	Luis Rivera	100%	3/25/24	3/30/24
Finish Aircraft Build	Luis Rivera;Luis Gutierrez Jr.;Erik Ho;Lloyd Macauling		4/1/24	4/7/24
Test Aileron Movement	Luis Rivera;Luis Gutierrez Jr.;Erik Ho;Lloyd Macauling		4/1/24	4/12/24
Fly our 3D Aircraft	Luis Rivera;Luis Gutierrez Jr.;Erik Ho;Lloyd Macauling		4/8/24	4/19/24
Final Improvements	Luis Rivera;Luis Gutierrez Jr.;Erik Ho;Lloyd Macauling		4/8/24	5/10/24
Competition				5/18/24

Pert Chart

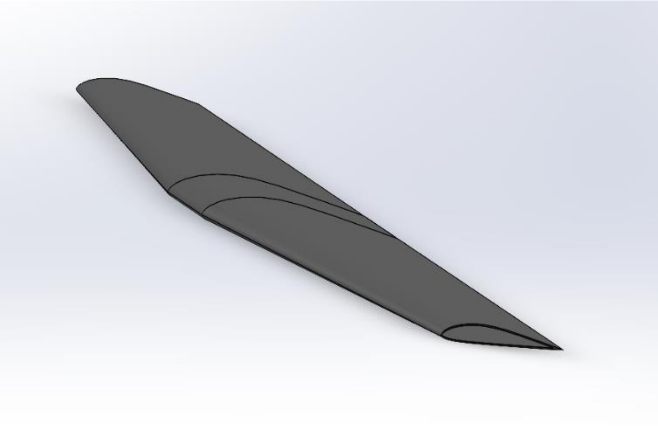


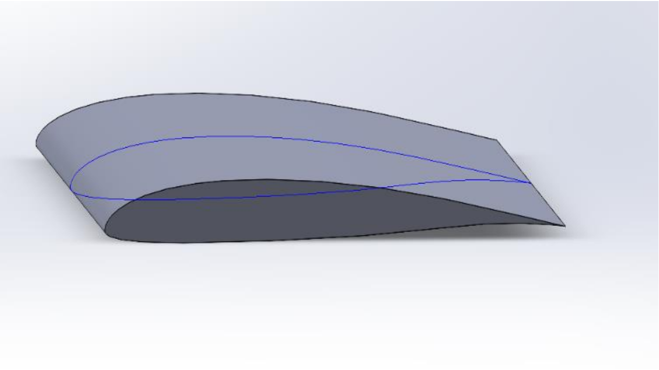
Formation of groups 09/01/2023 1 Day
Beginning of Phase 1 09/08/2023 1 Day
Roles and Responsibilities 09/08/2023 7 Days
Discussion of Project Plan 09/15/2023 1 Day
Comparing and Analyzing Possible Prototype Wing Designs 09/15/2023 7 Days
Research of fundamentals of Aerodynamics: Airfoil, forces(Drag/Lift) 09/22/2023 14 days
Solidworks Evaluation and Research of Aieleron 09/24/2023 3 days
Discussion of Elevator and Gyroscope 09/27/2023 2 days
Solidwork Simulation Trial Runs of Potential Designs 09/30/2023 14 Days
Deciding Factor of the offical designs 10/06/2023 1 day
Completion of Phase 1 10/06/2023 1 day
Beginning of Phase 2 10/09/2023 1 day
Discussions of Construction of Prototype (Materials, Cost) 10/09/2023 7 days
Preminilary Free Body Diagram Sketch of Prototype during flight 10/16/2023 4 days
Simulation Work of the Prototype on Solidworks 10/20/2023 7 days
Blueprint Construction of Prototype 10/27/2023 14 days
Full analysis of Fundamental components of the Prototype 11/09/2023 14 days
Completion of Phase 2 11/09/2023 1 day
Beginning of Phase 3 11/09/2023 1 day
Assembling of the 3D-Printed Prototype 11/09/2023 7 days
Prototype Analysis Post Assembly 11/16/2023 14 days
Testing Trials of Prototype Aircraft 11/30/2023 2 days
Completion of Phase 3 01/26/2023 1 day
Beginning of Phase 4 01/26/2023 1 day
Review of Trial Flight Preformances 02/02/2023 3 days
Improvements of Prototype 02/05/2023 11 days
Technical Reassembly of the Newly Improved Product 02/16/2023 7 days
Trial Flight Runs of Improved Product 02/23/2023 21 days
Flight Analysis/Product Inspection 03/01/2023 14 days
More Improvements of Aircraft 03/15/2023 10 days
Continuance of Testing the Aircraft Specimen 03/29/2023 28 days
Improvements/Customizations 04/19/2023 7 days
More Flight Testing Runs 04/26/2023 7 days
Even More Improvements 05/03/2023 3 days
Final Flight Improvements and Testings of the Product before Competition 05/06/2023 11 days
COMPETITION 05/18/2023 1 day

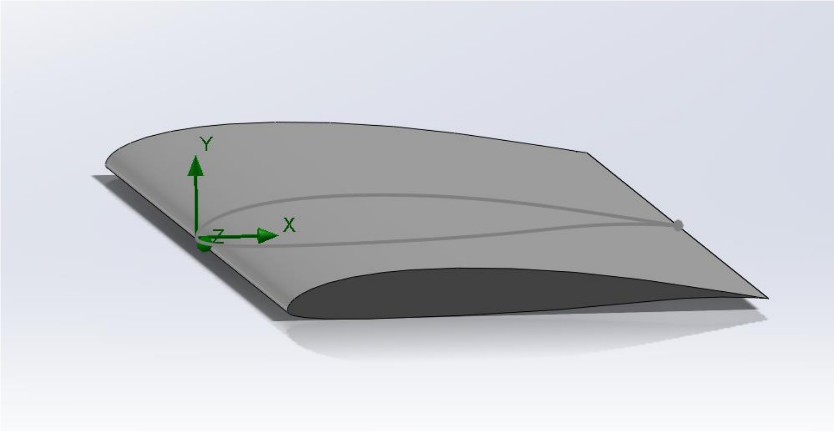
Design Overview

1 Concept, 3 designs

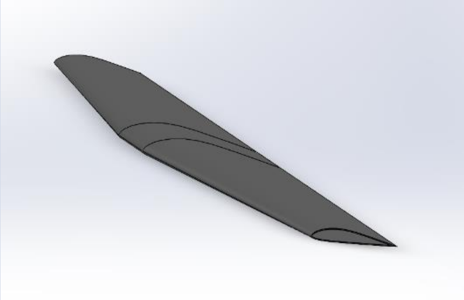
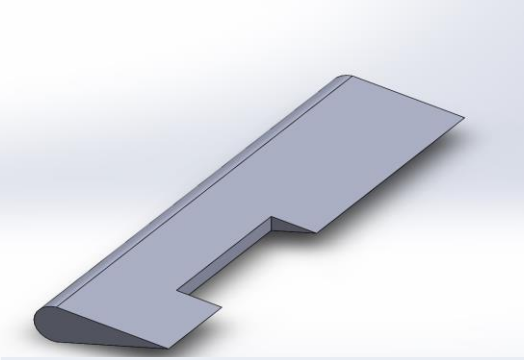
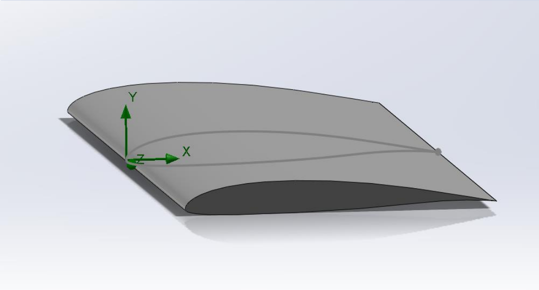
Airfoil: Eppler E205, NACA 0012, Selig S3021







Concept Design Selection

3 Different Airfoils	Pros	Cons
 EPPLER E205	• Simplistic Design • Cost efficient • Simplifies angle measurements of the propeller • Good lift at slow speeds	• Negative air pressure on the wing during flight • Structural weakness and internal weakness
 NACA 0012	• Symmetrical • Higher lift to drag ratio • Produces no lift at a zero-degree angle of attack • Easy design • High stalling speed	• Positive angle of attack produces very little lift and non-optimal efficiency • Must maintain high moving speeds to stay in flight
 SELIG S3021	• Provides more lateral stability when rolling • Less time spent on keeping your wings leveled	• Not optimized for low Angle of Attacks

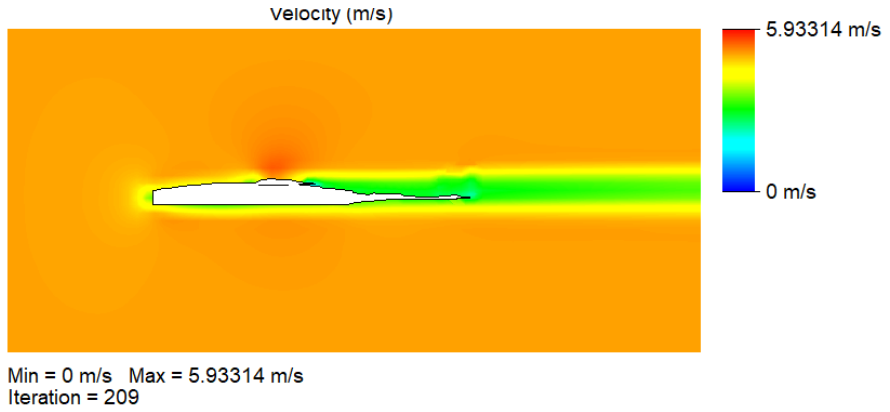
Weighted Decision Matrix

Weighted Decision Matrix				
Requirements	EPPLER E205	NACA 0012	SELIG S123	Weighted Scale
Costs	3	2	1	1
Maneuverability	4	3	2	4
Speed	3	2	3	3
Manufacturability	4	3	2	2
Total	87	62	50	100

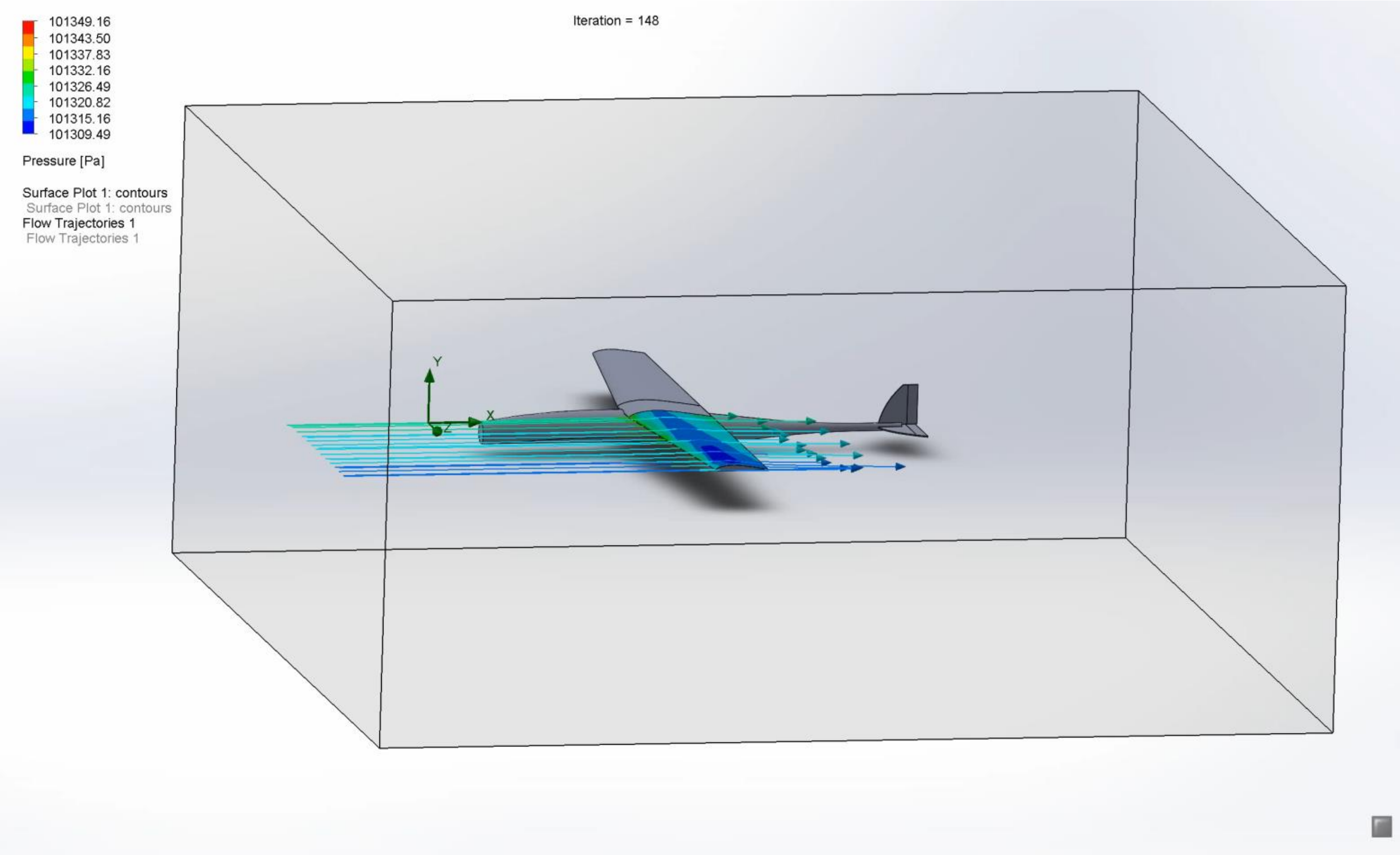
What is the main catalyst in choosing the final concept design?

Flow Simulation

- Allows simulation of scenarios for different engineering scenarios
- Provides information on flow of fluids that is critical to deciding the best working product
- Enables quick simulation around designs to calculate product performance and capabilities



Flow Simulation Video



Done for all three air foil designs.

This Flow Simulation video showcases the Eppler E205 airfoil Prototype Design in a virtual wind tunnel

Flow Simulation Results

Flow Simulation Results			
	Eppler E205	NACA 0012	Selig S3021
Lift to Drag Ratio	1.994	0.4976	1.2711
Lift Coefficient unitless	0.06722	0.00606	0.03112
Drag Coefficient Unitless	0.03370	0.01218	0.02448
Density (kg/m^3)	1.184	1.184	1.184
Area (m^2)	0.10568	0.04210	0.00367
Velocity^2	24.5255	23.7241	24.852
Area/2	0.05284	0.02105	0.001835
Reynolds Number	15595.69	58510.92	27602.893

Flow Simulation results tables for all three airfoils

Reynolds Number, Turbulent or Laminar Flow

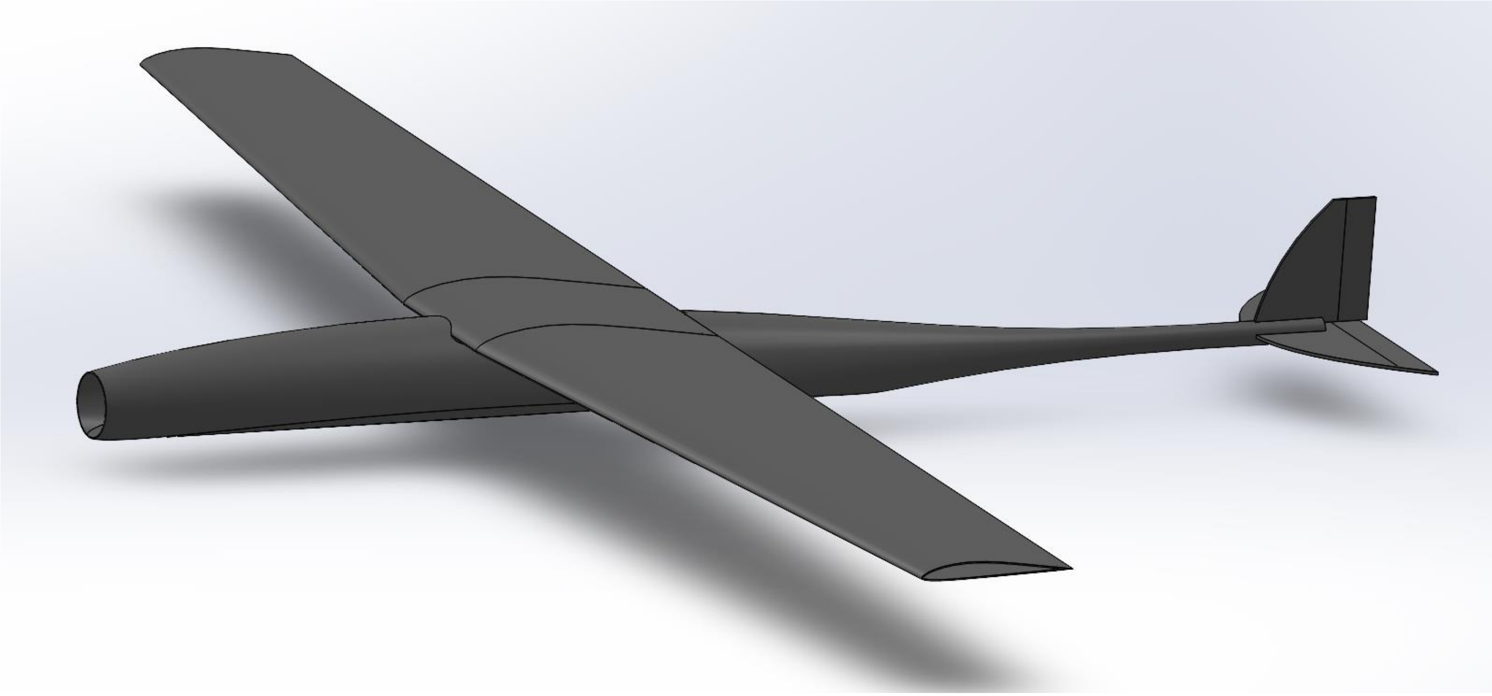
- Re<2100, Laminar
- Re>4000, Turbulent

Drag to lift Ratio, Higher ratio = good

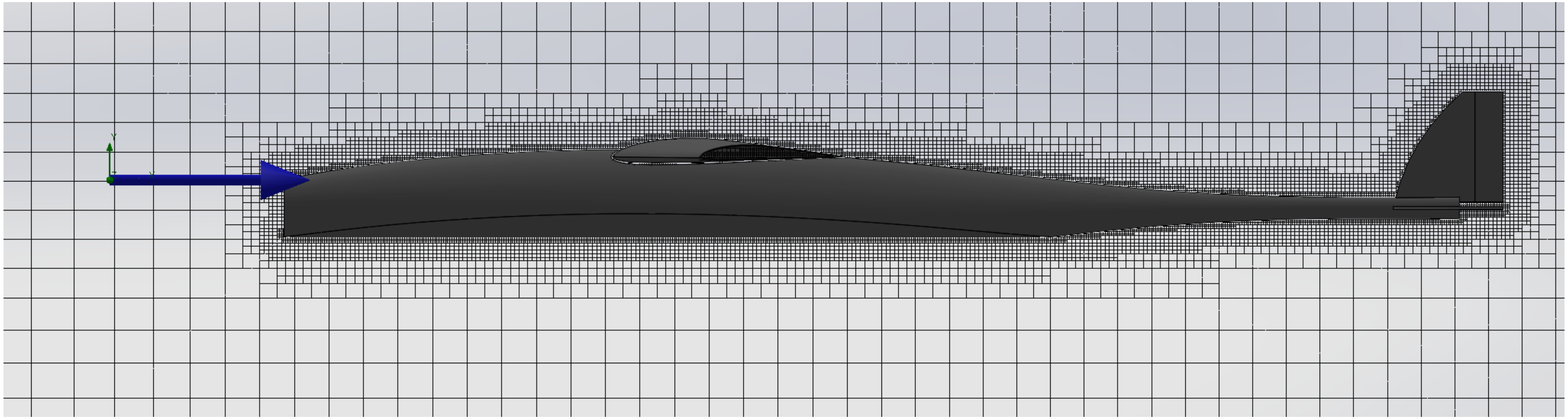
Drag Coefficient, smaller drag coefficient = good

Design Selection

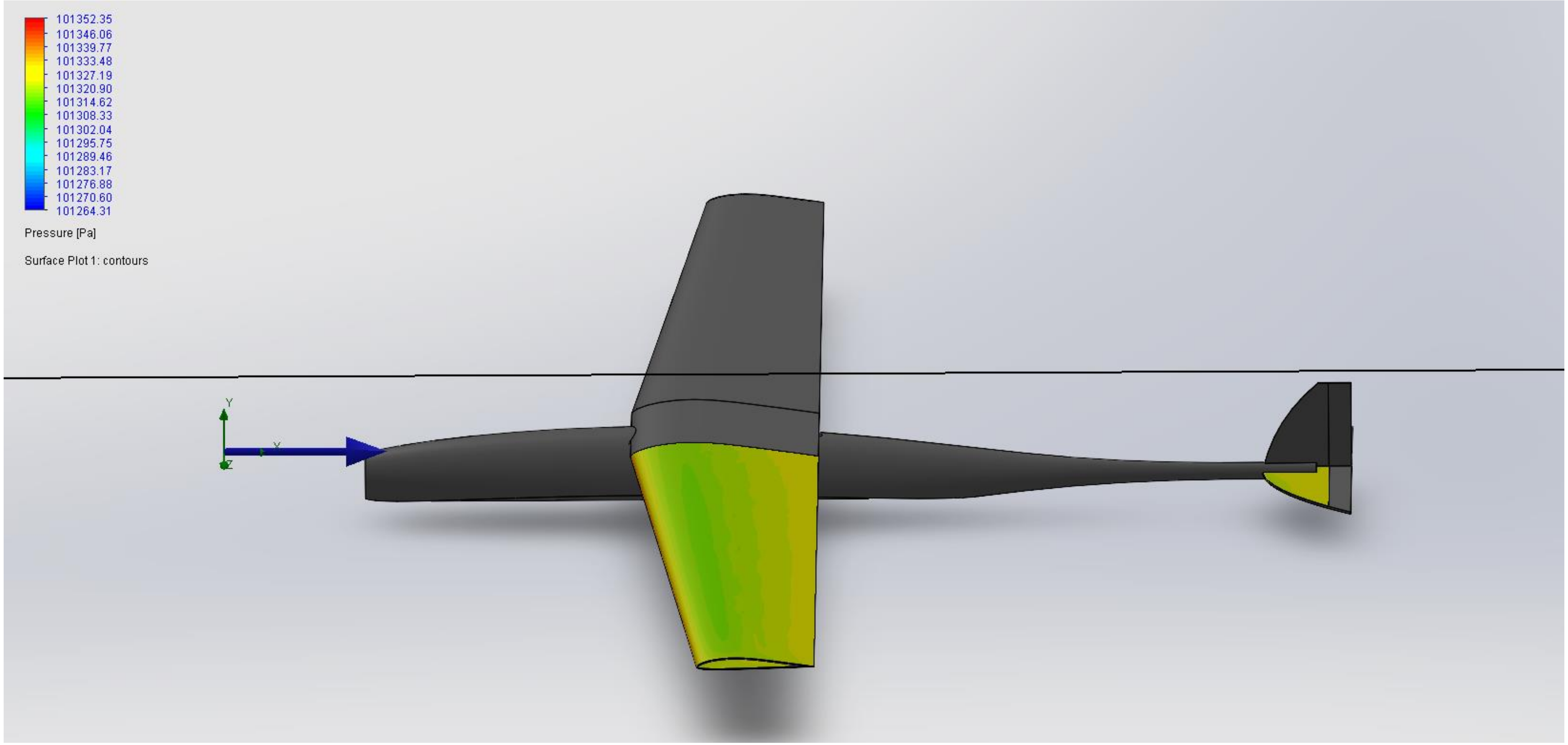
Eppler E205



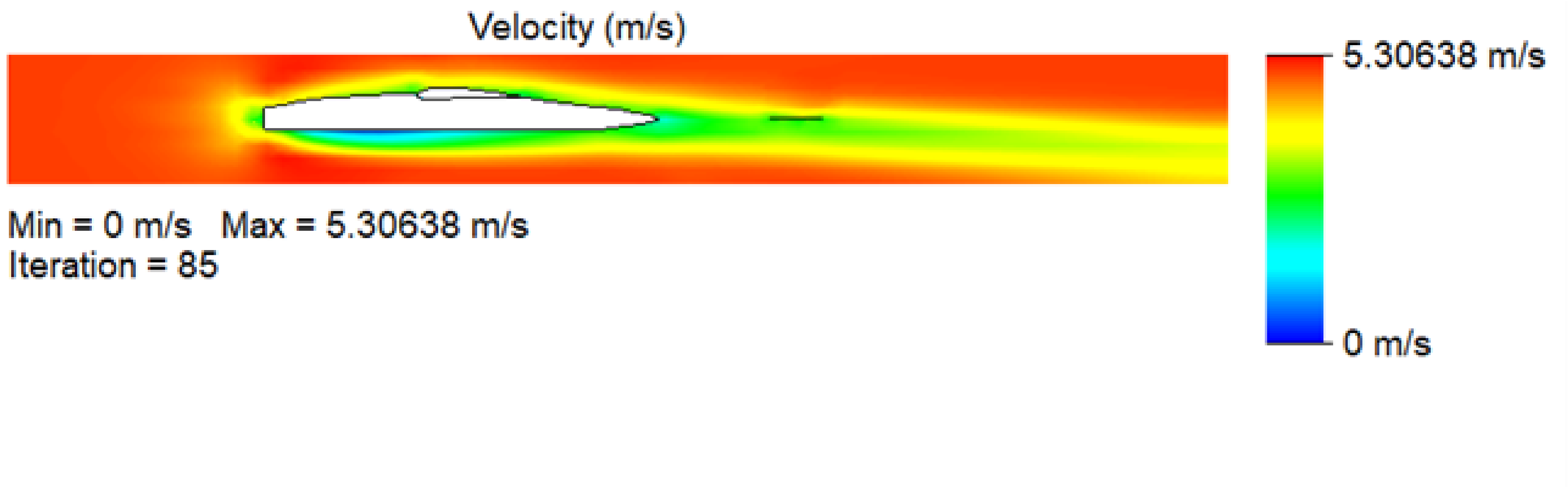
Equidistant Refinement Mesh @ Level 4



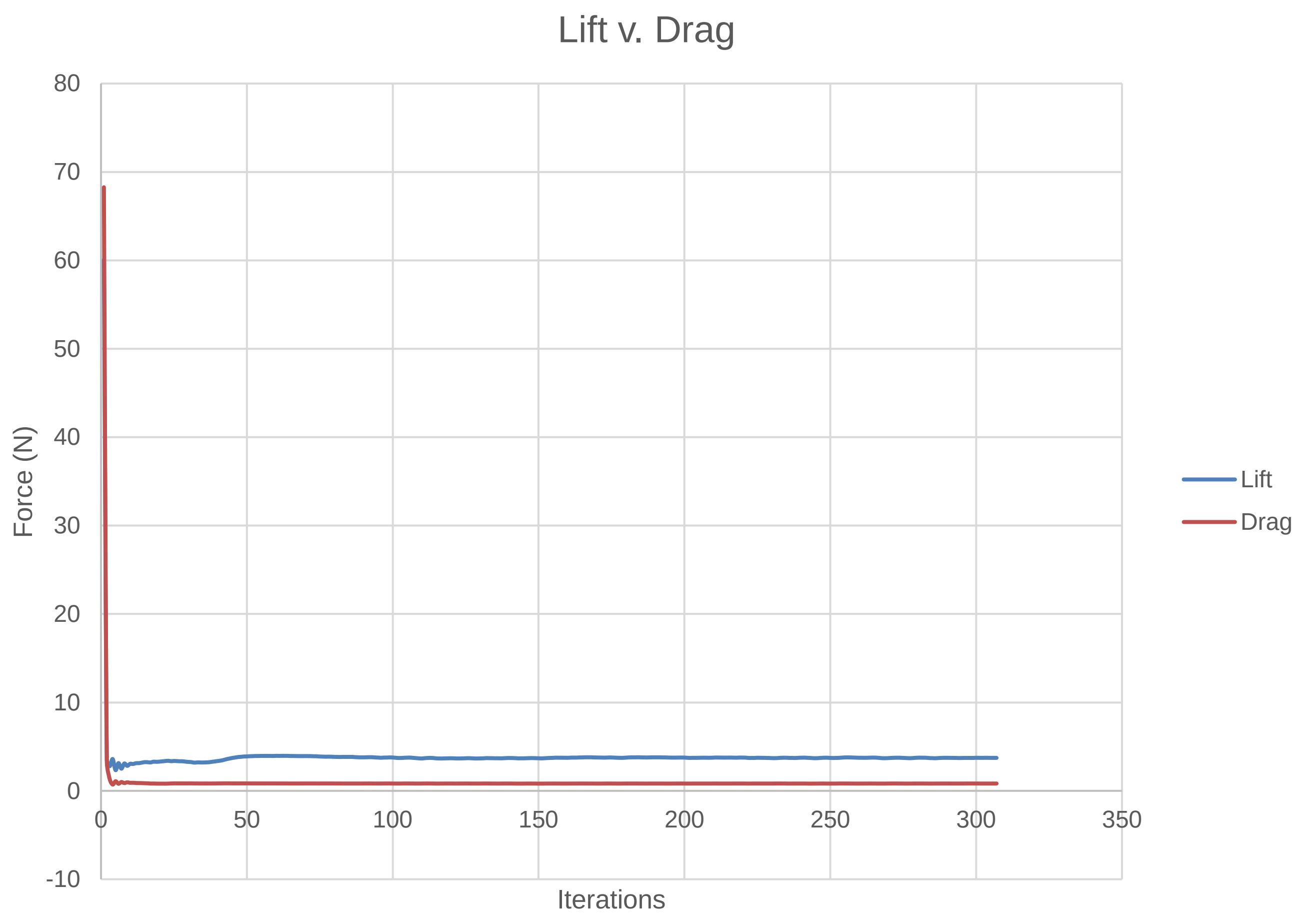
Pressure Surface Plot



Flow Simulation Complete Body



Complete Body Simulation



Lift to Drag Ratio	4.56374135
Lift Coefficient unitless	0.26939748
Drag Coefficient Unitless	0.05902996
Density kg/m^3	1.184
Area m^2	0.10568327
Velocity ^2	225
Area/2	0.05284163
q	14.0770113
Re	159324.02
Velocity	15
Dynamic Viscosity	1.8404E-05

Motor

Our wingspan to be is 1.3m with the fuselage length to be 1m

Ideally a motor should generate 50-80 W/lb.

Outrunner Brushless Motor

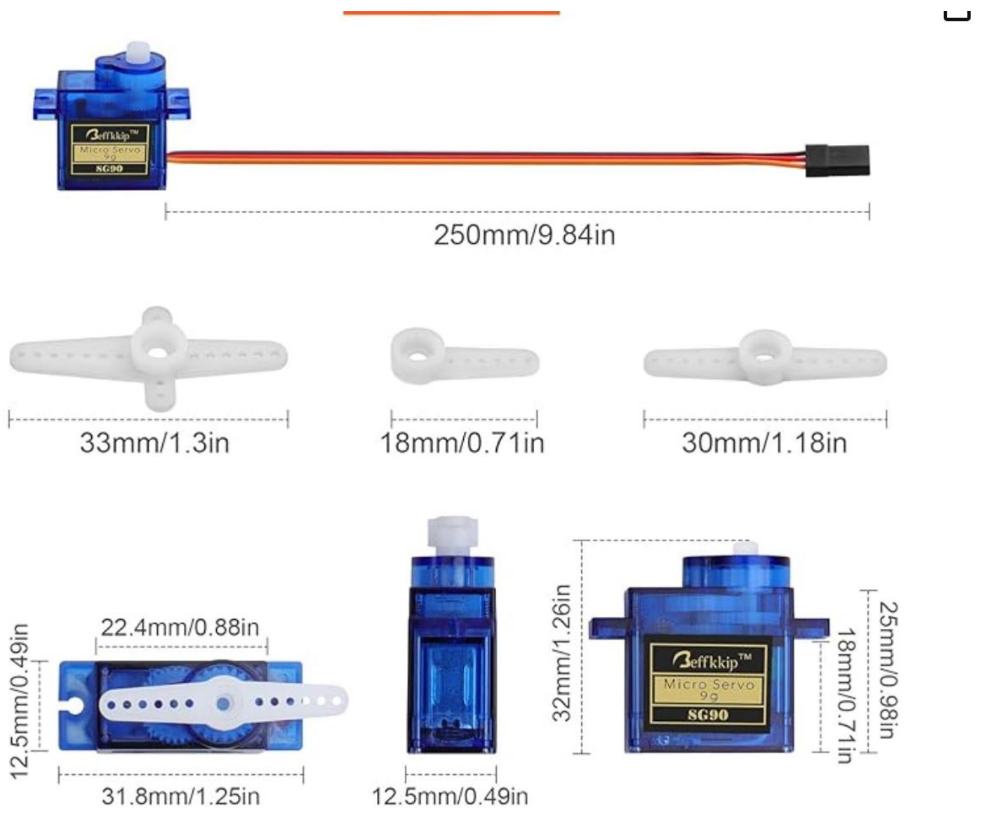
- Dimensions: 1.4 x 1.4 x 2.6 inches
- Weight
  - 5.5 ounces
- Material
  - Copper
- Horsepower
  - 911 Watts
- Speed
  - 1100 RPM
- Cost
  - $21.99

Propellers

- Dimensions
  - 12.17 x 4.37 x 0.67 inches
  - Weight
  - .087 ounces
- Costs
  - $15.29

Metal Gear Analog Servo

- Dimensions
  - 3.86 x 3.46 x 1.34 inches
- Weight
  - 2.89 ounces
- Voltage
  - 4.8V ~ 6.0V
- Cost
  - $31.96



Radio Transmitter (Controller) and 6-channel RC Receiver

Receiver
- Dimensions
  4.8 x 2.6 x 0.59 inches
- Weight
  - .317 ounces
- Cost
  - $55.75

LiPo Battery Pack

- Dimensions
  - 5.8 x 2.5 x 2.3 inches
- Weight
  - 197 g
- Voltage
  - 14.8 V
- Material
  - Lithium Polymer
- Cost
  - $19.99

Electric Speed Controller

- Weight
  - 1.44 ounces
- Dimensions
  - 2.09 x 0.43 x 0.98 inches
- Cost
  - $21.99

Gyro (Stabilizer)

- Weight
  - 2.11 ounces
- Dimensions
  - 5.08 x 4.8 x 1.22 inches
- Cost
  - $42.99

Bill of Materials

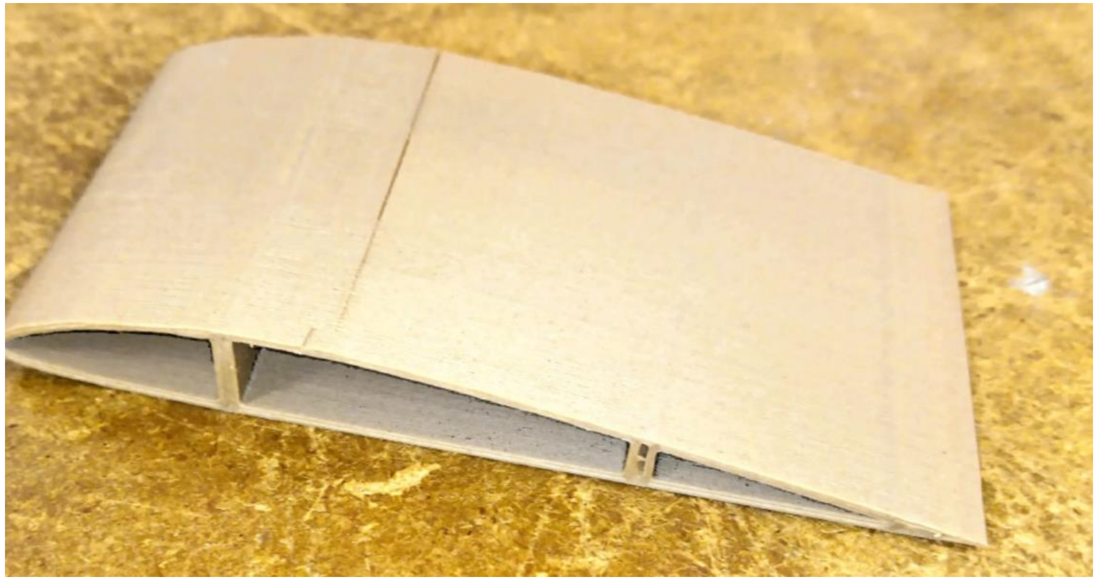
Material	Number of Parts	Cost	Weight Lb	Dimensions
Outrunner Brushless Motor	1	$22		0.341.06 x 1.06 x 0.71 inches
Propeller	2	$14.99		0.087 x 2 x 0.6 inches
Metal Gear Analog Servo	4	$31.96		0.05996.86 x 3.46 x 1.34 inches
Folding Electric Prop Hub	8	$40		45 mm x 10 mm
Radio Transmitter (Controller)	1	$55.75		12.1 x 9.4 x 5.6 inches
6-Channel RC Sport Receiver	1			0.031.78 x 0.79 x 0.55 inches
Electric Speed Controller	1	$21.99		0.092.09 x 0.43 x 0.98 inches
Lipo Battery Pack	1	$19.99		0.45.8 x 2.5 x 2.3 inches
Gyro Stabilizer	1	$42.99		0.135.08 x 4.8 x 1.22 inches
		$250	1.12996574	

3D-Printing Process

- Using P1S Bambu Lab 3D printer
- Material used is PLA 1.75 mm
- 5% infill on our prototype, final design is 15% infill
- Followed mechanical testing standard, D638 due to PLA material, to test yield stress, yield strain, tensile strength and strain at break.

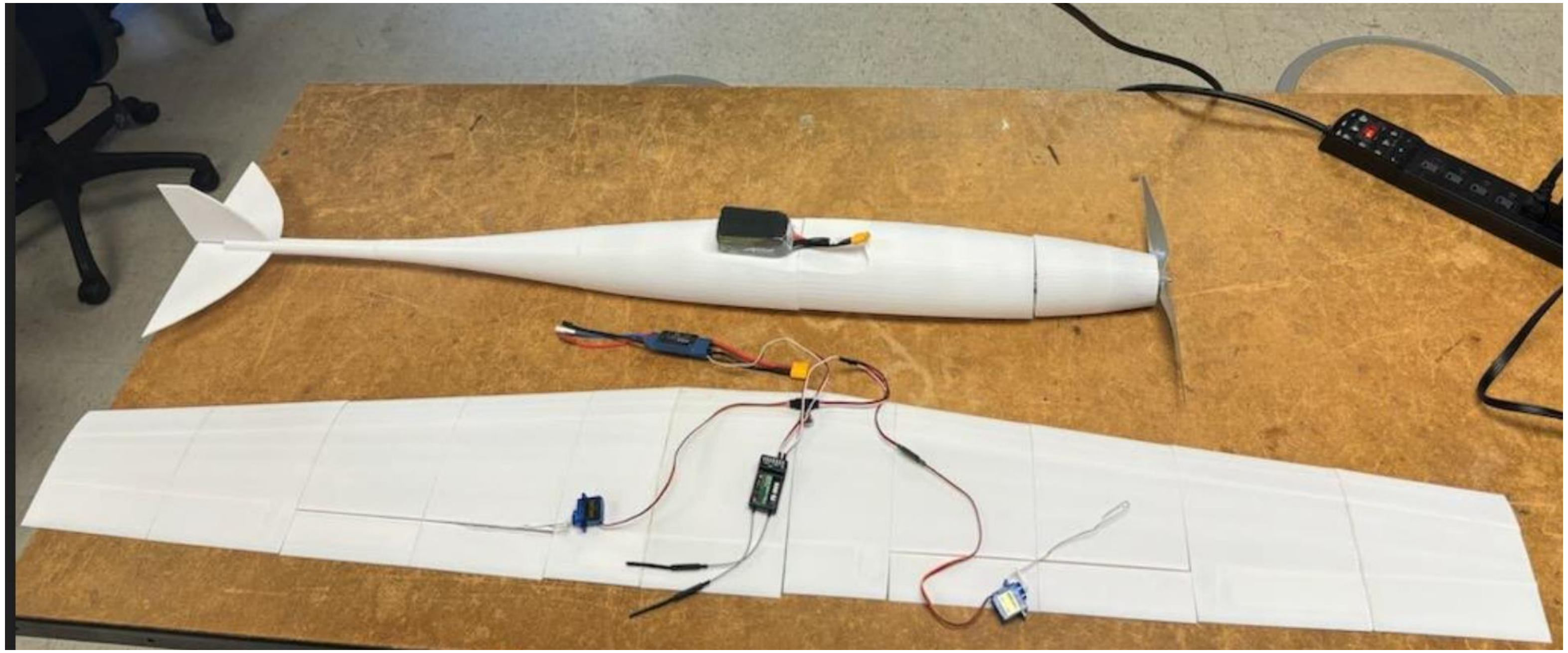
Obstacles Tackled

- Section each part of the glider 10x10 due to the 3D printer area availability.
- Creating inserts to connect each sectional wing.
- Finding an adequate size for our aileron rod inserts on Solid Works.
- Evaluating the center of mass so it is correctly onto the gyro/stabilizer.



First Prototype

Weight of Material
1.95 Lb's
Weight of Glider
1.1.549 Lb's
Total Weight of Glider
3.49 Lb's



Final Print

Conclusion

Completed:

- Preliminary Design
- Prototype Design Selection
- Flow simulation
- Bill of Materials
- Prototyping
- Assembly
- 3D-printing

Planned

- Improvements
- Analysis of concept
- Improve our Pilots Test Fly