RUAT Junior Glider Competition 2019
Critical Design Review (CDR)

PorCoPhine AERO

Presentation Outline

- **Systems Overview (Angelo)**
- **Structural Design (Jann)**
- **Aerodynamic Design (Oscar)**
- **Avionics Subsystem Design (Aqua)**
- **Distance Estimation (Angelo)**
- **Testing (Aqua)**
- **Costs (Angelo)**
- **Conclusions (Angelo)**

Team Organization

Team Lead
Angelo Ferreira

Avionics
Aqua Oca/Angelo Ferreira

Structural Design
Jann Cristobal

Aerodynamic Design
Oscar Rivera

Acronyms

- **CL** - Lift Coefficient
- **CDo** - Total Drag Coefficient
- **LE** - Leading Edge
- **TE** - Trailing Edge
- ***α*** - Angle of Attack
- **AR** - Aspect Ratio
- **LED** - Light Emitting Dial
- **H.W.** - Hot wire

Systems Overview

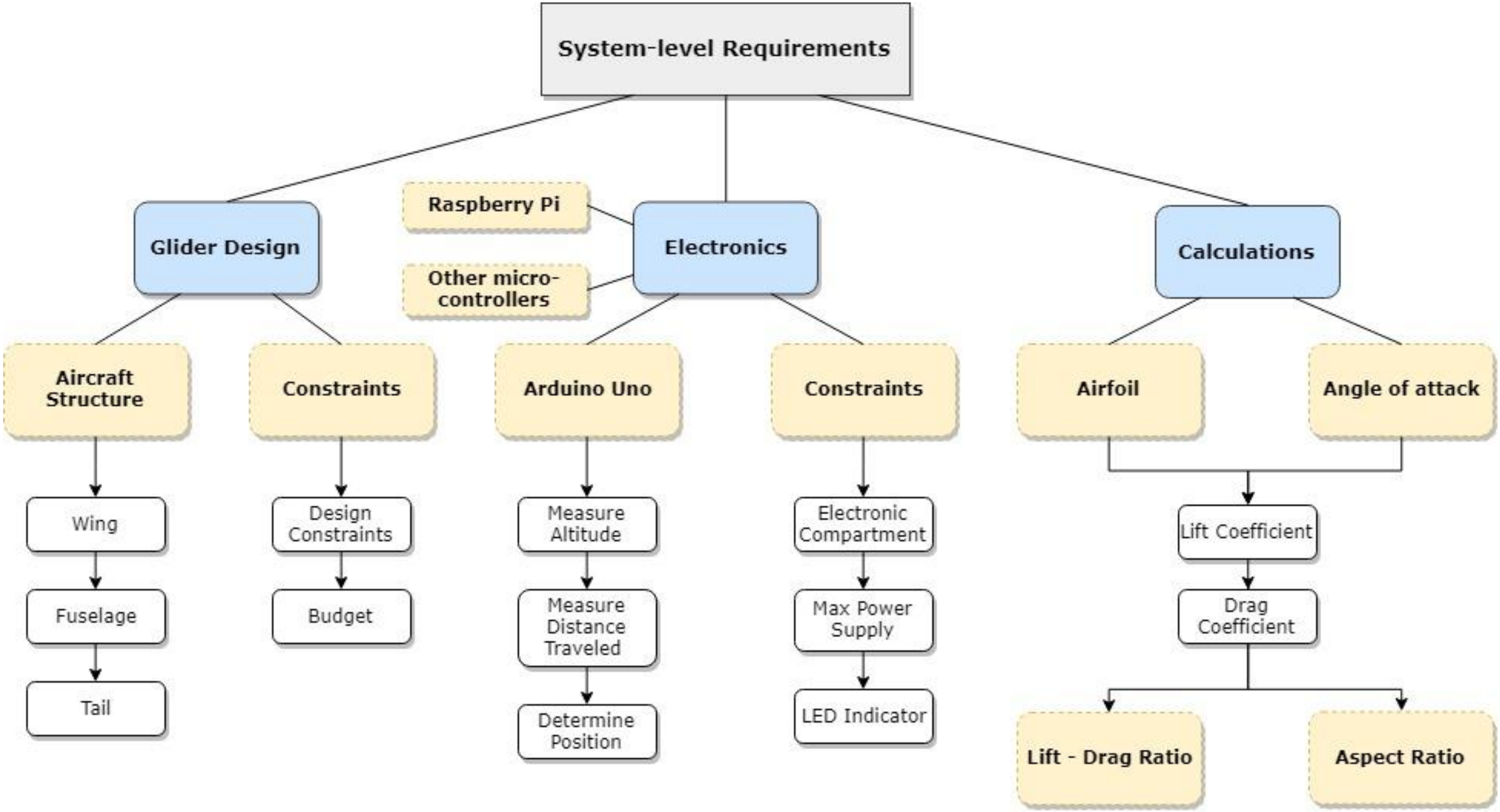
Angelo Ferreira

Mission Summary

- **Design and build an optimal glider for competition with the following characteristics:**
  - ✔ Strong built
  - ✔ Aerodynamic
  - ✔ Appropriate aspect and glide ratio
  - ✔ Easy to assemble
  - ✔ Travel/glide the farthest
  - ✔ Lift > Drag
  - ✔ Carry additional payload

- **Follow constraints outlined in competition rules.**
  - ✔ Design Constraints
  - ✔ Budget Constraints
  - ✔ Electronics Constraints

System Requirement Summary



Structures

Aircraft Structure

Wing: Cambered, appropriate airfoil (thin and does not stall at more or less 7 degrees), detachable (into three pieces to fit in the box), smooth surface, durable to support weight of the fuselage and other payloads.

Fuselage: lightweight, conical shaped nose (foam), rigid and have a huge compartment to accommodate electronics and support weight of any additional payloads.

Tail: Made from foam board - bevelled, be able to help in flight path of the glider.

Constraints

Design Constraints:

- Glider must fit within 30cm by 15cm by 10cm box.
- Wingspan must be no less than 30 cm.
- Easily assembled within 2 min time frame.
- Sharp/pointed components must be covered.
- No propulsion device must be used. Any surface control must be driven autonomously.

Budget Constraint: Total retail prices of all parts & components must be under 100 CAD.

More information in the Structural Design Section

System Requirement Summary Cont...

Avionics

Choice of Electronic: Arduino Uno

Why? Colleague have previous experience with the device.
The device must be programmed to be able to measure the following:

- Highest altitude the glider reached during flight.
- Ground distance glider has travelled during flight.
- Determine current position of the glider during flight.

Constraints:

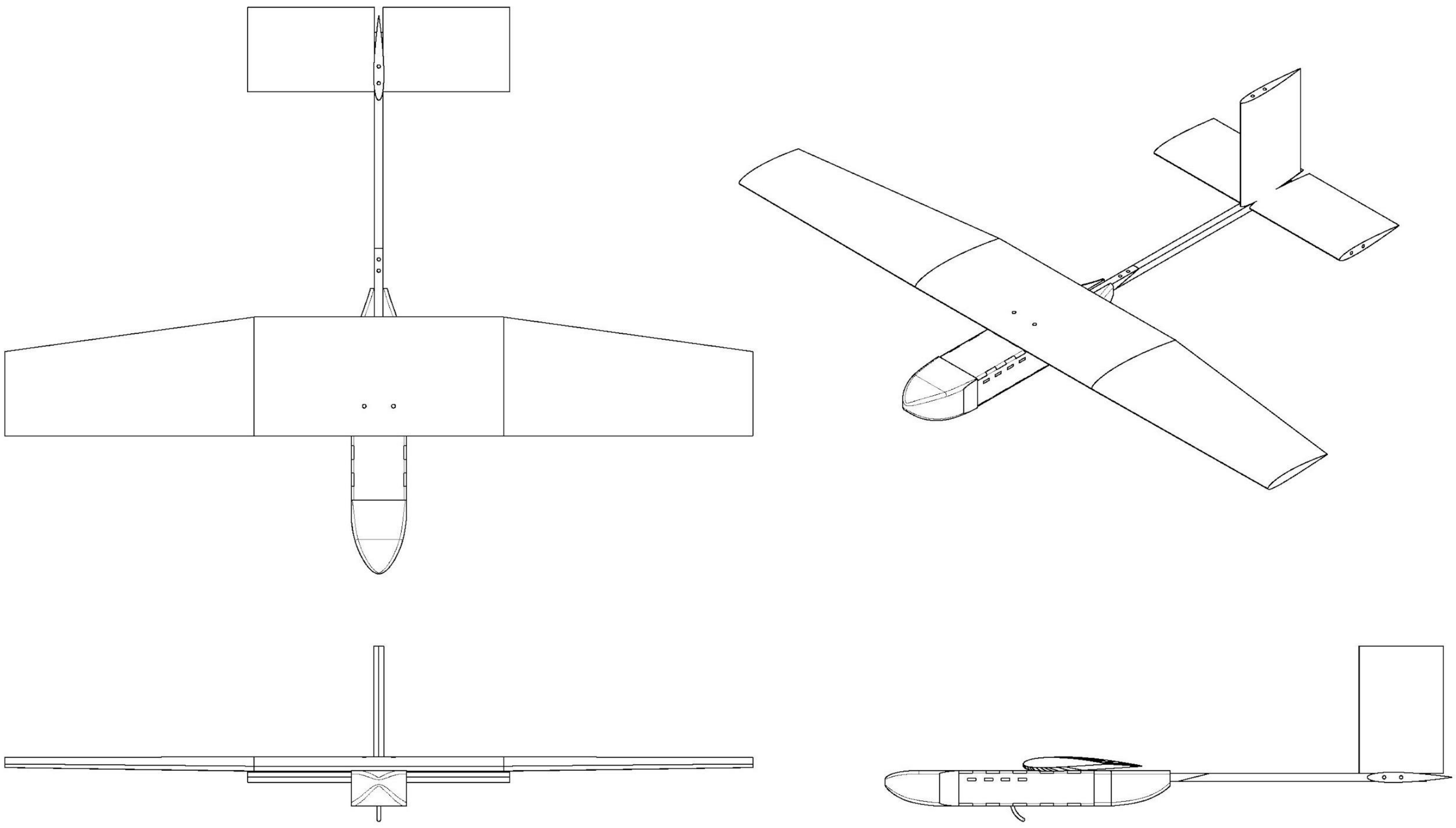
- All electronics must be stored in the fuselage and have a durable and safe compartment. Also have a physical switch that cuts of all power.
- Must have maximum power supply of 12V.
- There must be visible led indicator that shows when the electronics are turned on.

More information in the Avionics Section.

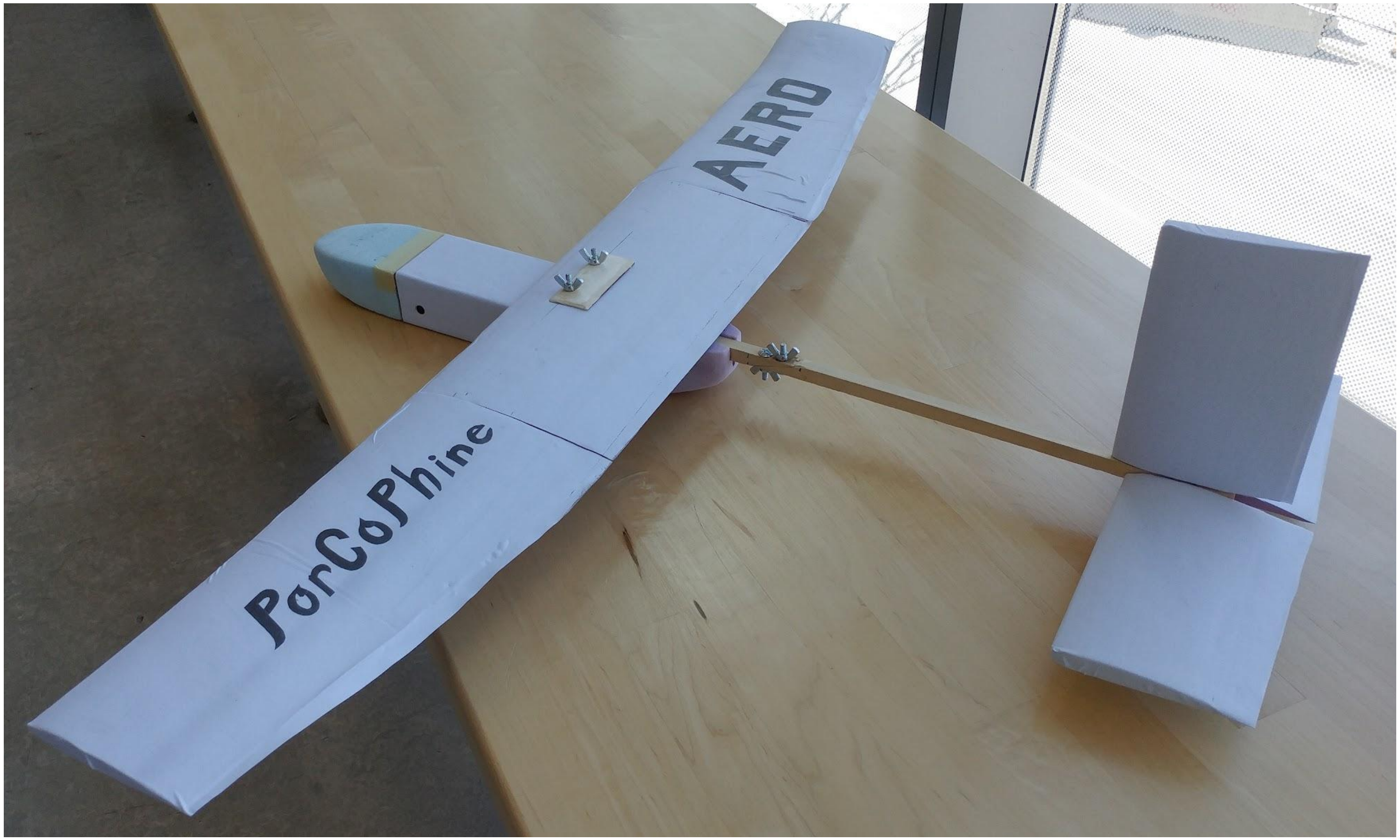
Summary of Changes

- **Wing chord length: 9cm to 14cm and 6.5cm to 10.3cm**
- **Vertical and horizontal stabilizers chord length: 6cm to 10cm**
- **Vertical and horizontal stabilizers span to 15 cm**
- **Wing/fuselage attachment: fit in fuselage with airfoil pocket, to screw attachment**
- **Arduino calculating distance to having arduino save data on sd card only, and analysing done on matlab**

Physical Layout



Physical Layout



System Concept of Operations

Before competition:

Check that all components are functioning properly

During competition

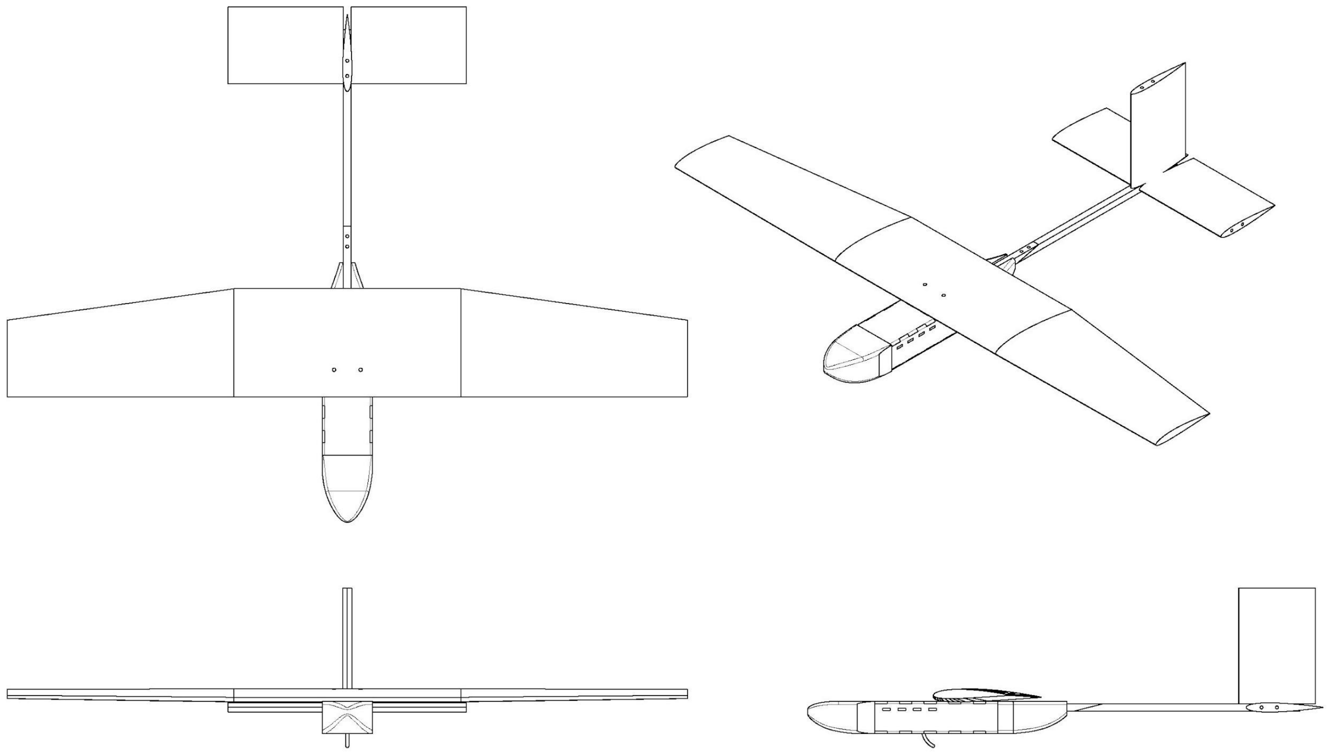
1. Remove components from box - Angelo
2. Assemble aircraft under 2 minutes - Angelo
3. Prepare launching positioning - all team members
4. Turn on avionics (flip switch) - Aqua
5. Reset Arduino (push-button) - Aqua
6. Start countdown
7. Launch
8. Turn off electronics after landing (Angelo)
9. Measurements by judges
10. Disassemble glider and place back in the box (Angelo)
11. Analyse data saved on SD card (Aqua)

Structural Design

Jann Cristobal

Structural Requirements

- Launch Interface
- Material Selection
- Attachment Methods
- Mass Distribution



Structural Requirements

Objectives	Constraints
• Lightweight • Stay Intact throughout the flight • CG in front of the Quarter Chord Line • Carry 125g of extra weight	• Exposed Metal must be covered with 2cm of foam around it • No Sharp/Pointy Design Elements • Minimum Wingspan of 30cm • Assembled and Disassembled within 2 mins each • All components must fit in a 30cm x 15cm x 10cm container • All electronics must be contained in the fuselage.

Main Structural Design Changes

Fuselage:

- Laser cut MDF parts assembled with epoxy instead of Balsa Wood and styrofoam
- Launch interface now under fuselage (around quarter cord) instead of on the rear of the fuselage

Wing:

- Attached to fuselage using screws
- Increased Chord length

Mass:

- PDR Predicted Mass: 316.8g
- CDR Actual: 464.5g

Structural Components

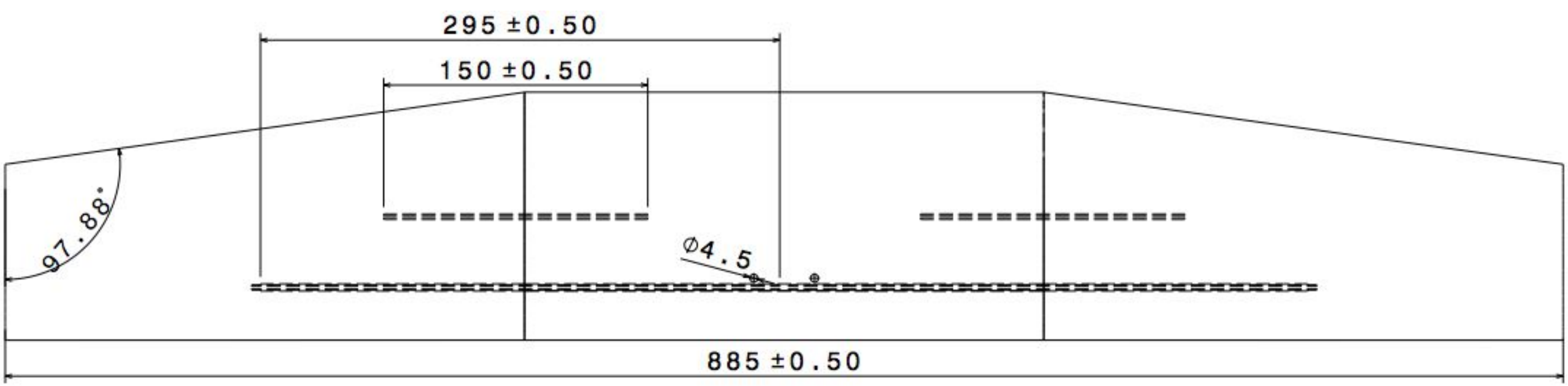
The following slides show the dimensions, materials and manufacturing processes in building the final glider.

Major Structural Components:

- **Wing Structure**
- **Fuselage Structure**
- **Tail Structure**
- **Launch Interface**
- **Avionics and Payload**

Wing Structure

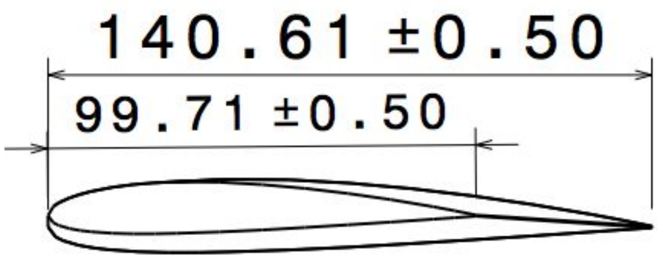
- Traditional monoplane; high wing configuration
- 3 pieces of foam, hot-wire cut into the NACA 2412 shape using laser-cut MDF jigs
- Tips connect to middle piece using 4 carbon fibre spars (friction fit)
- Dihedral after Heat Gun

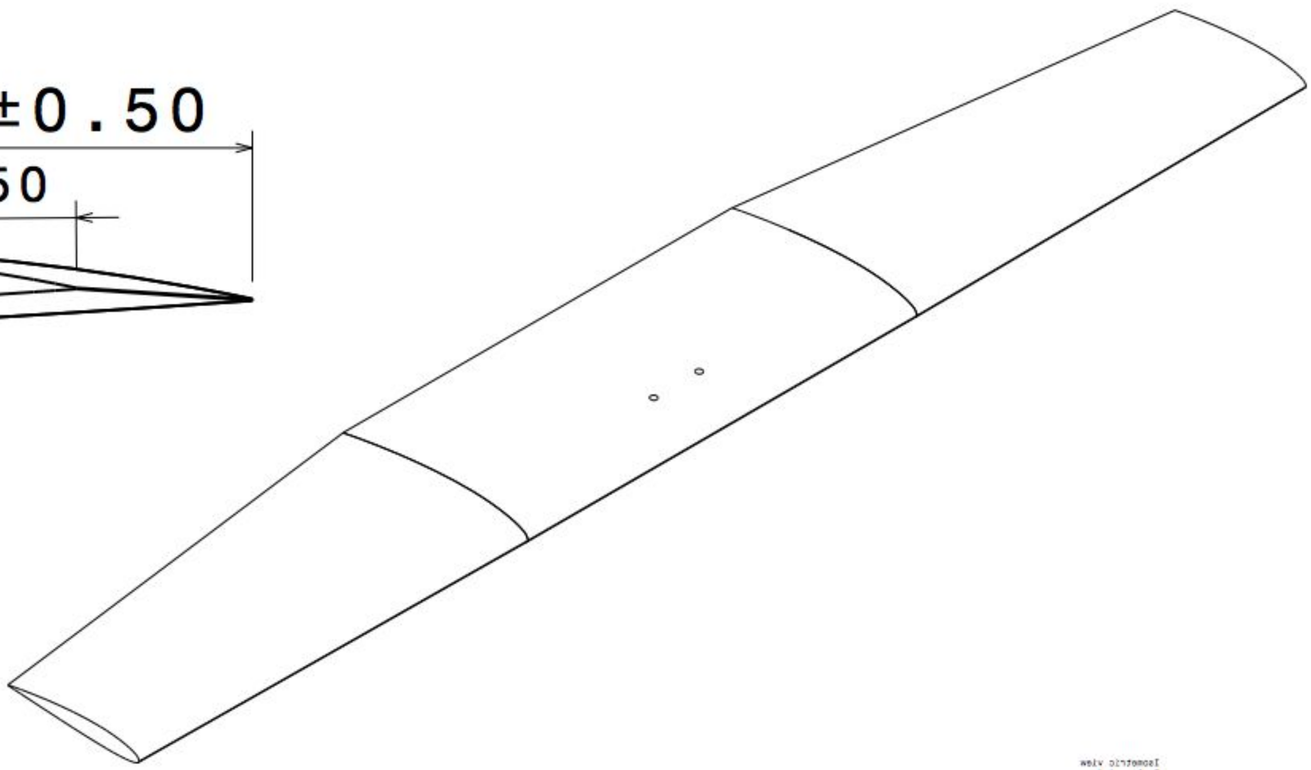


Top view

Wing Structure

- Covered in vinyl
- Attached to the fuselage using 2 screws

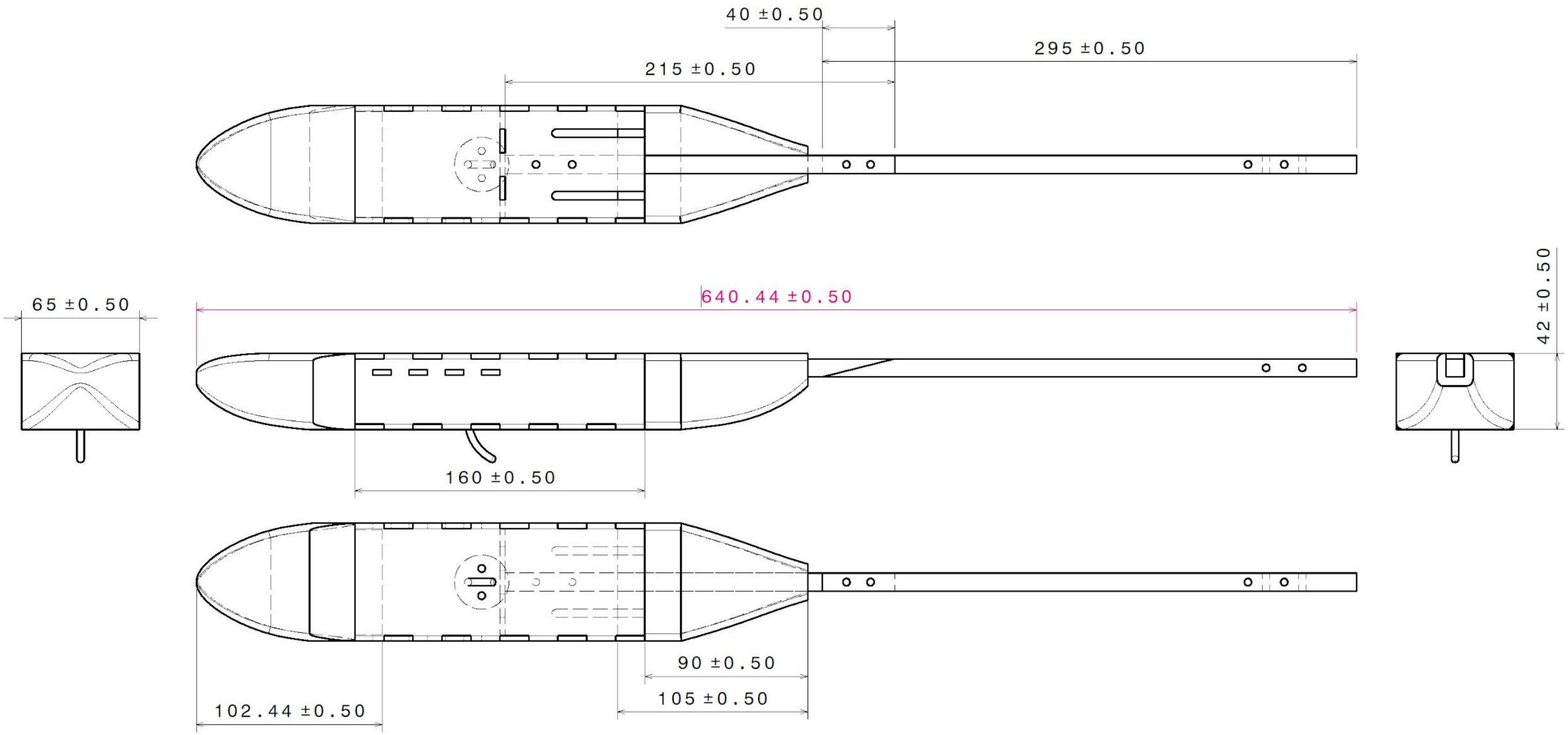




Components - Fuselage

Sub-Components	Materials	Structural Integrity	Method of Attachment	Manufacturing
Nose	Foamular	8/10	Friction fit	Hot Wire and sanded to aimed shaped
Main Body	MDF Board, and Vinyl	10/10	Epoxy	Laser Cut
Rear	Foamular	10/10	Friction fit	Hot Wire and sanded to aimed shaped
Boom	Wood	7/10	Butterfly screw	Wood Saw

Components - Fuselage CAD



Tail Structure

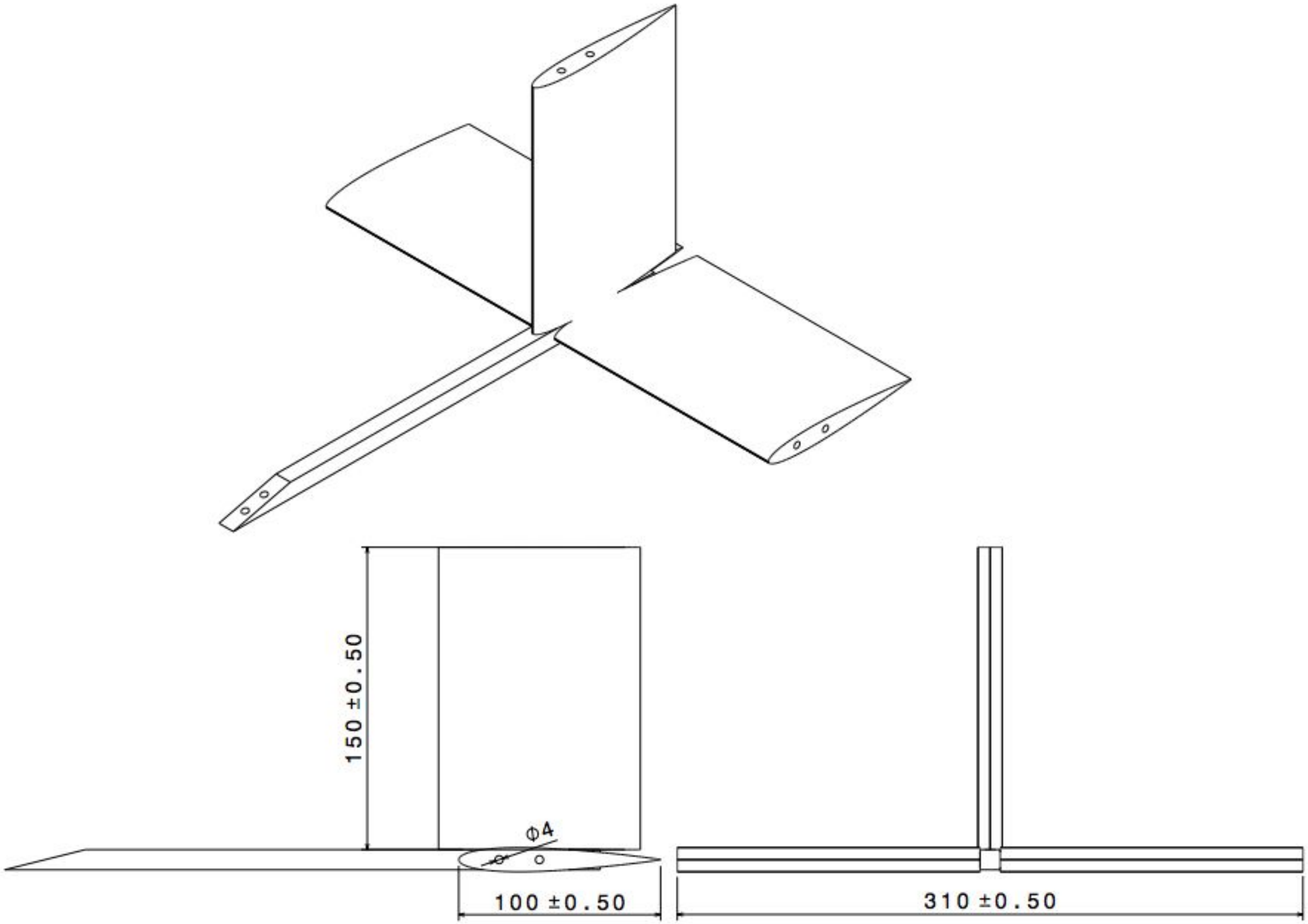
Horizontal Stabilizers

- 2 pieces of foam, hot-wire cut using laser-cut outlines
- Connect to each other through the boom using 2 carbon fibre spars (friction fit)
- Covered with vinyl

Vertical Stabilizer

- 1 piece of foam, hot-wire cut using laser-cut outlines
- Connect to the boom using 2 carbon fibre spars (friction fit and glue)
- Covered with vinyl

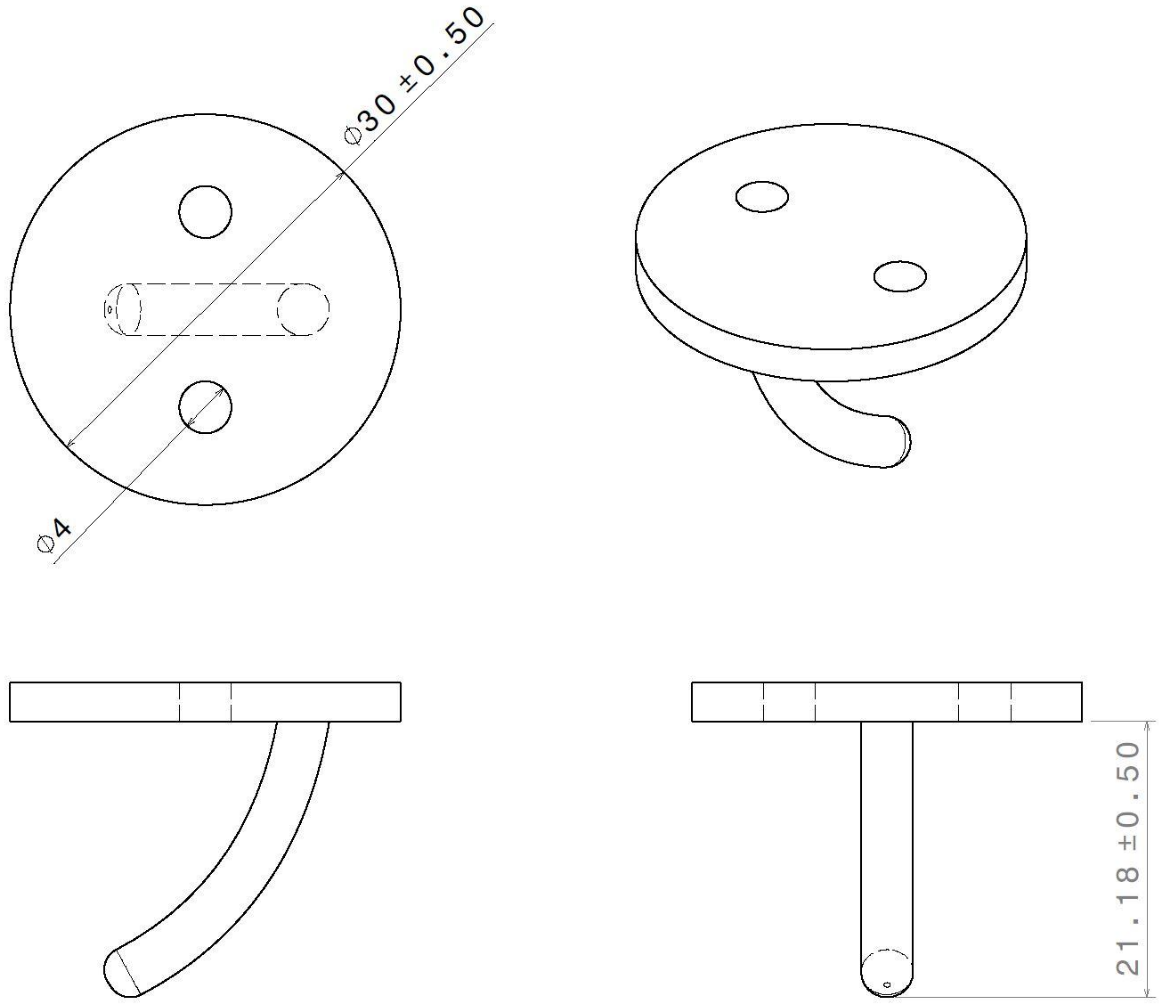
Components - Tail Cont...



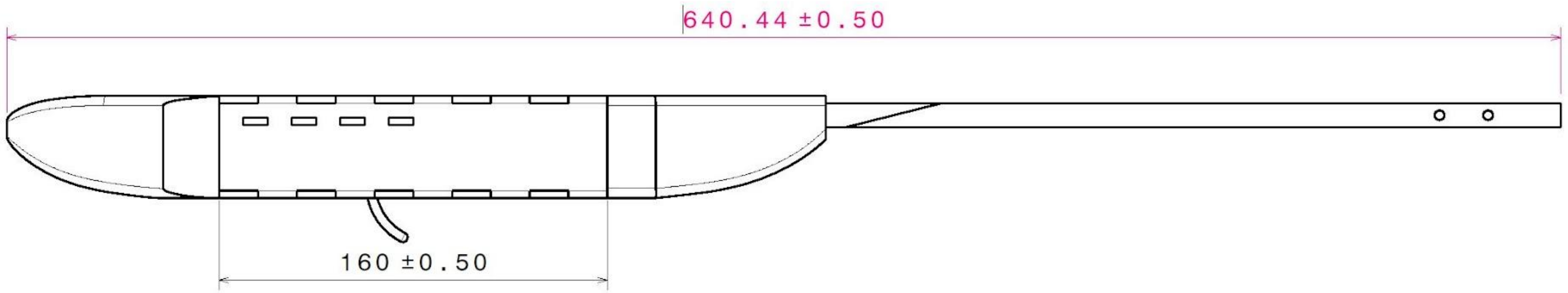
Components - Launch Interface

- **One piece component**
- **It will be attached at the bottom of the Fuselage**
- **Secure with two bolts and nuts.**
- **3D Printed out of PLA**
- **Structural Integrity: 8/10**
- **Pre-Attached to the Glider**

Components - Launch Interface CAD



Components - Launch Interface Cont...



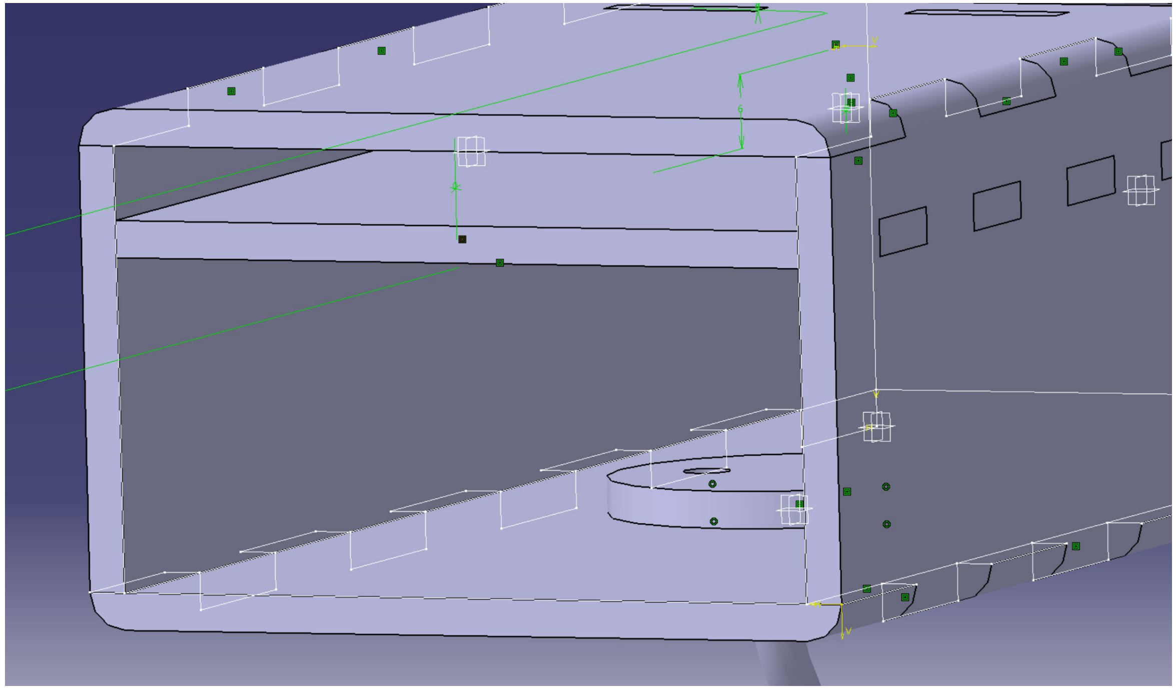
Components - Avionics/Payload

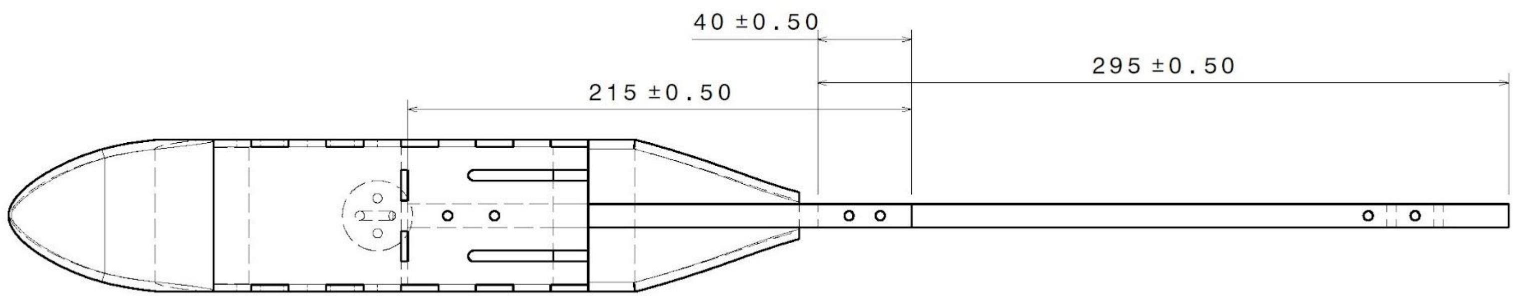
Components:

- Weights (Payload) = 127.7 g
- Battery = 33.2g
- Electronics = 50.7g

- The payload is made out of steel bars cut into certain lengths (approx. 6cm) using metal saw. Then, were taped together to produce total weight of 127.7 g.
- The payload has its own compartment in the fuselage (near the nose of the glider). Also, its location is convenient and accessible (great for 2min assembly timeframe!).
- The avionics is completely secure from external damages and safe from landing impact.

Components - Avionics/Payload CAD





Mass Budget

Table with component's weight

Component	Weight (g)	Component	Weight (g)
Wing*	88.0	Screws	10.7
Tail*	25.7	Battery	33.2
Foam (Fuselage)	11.8	Electronics Hardware	50.7
Carbon Fiber	12.7	Payload* (additional weight)	127.7
Fuselage* + Boom	104.0	-	-
Total	**242.2**	**Total**	**222.3**

*Weight of components with vinyl wrap

Total mass: 464.5g

Mass Budget

- **All the values shown where measured (digital scale with ± 1g uncertetainity)**

- **Total mass increased 147.72g (316.78 g)**

  Additional weight due to design changes/adjustments, are still considered to be beneficial for the glider performance.

- **For Center of Gravity adjustment, wings can be moved forward or backwards relative to the fuselage**

- **The quarter chord point is marked on the wings for in site balance check**

Aerodynamic Design

Oscar Rivera

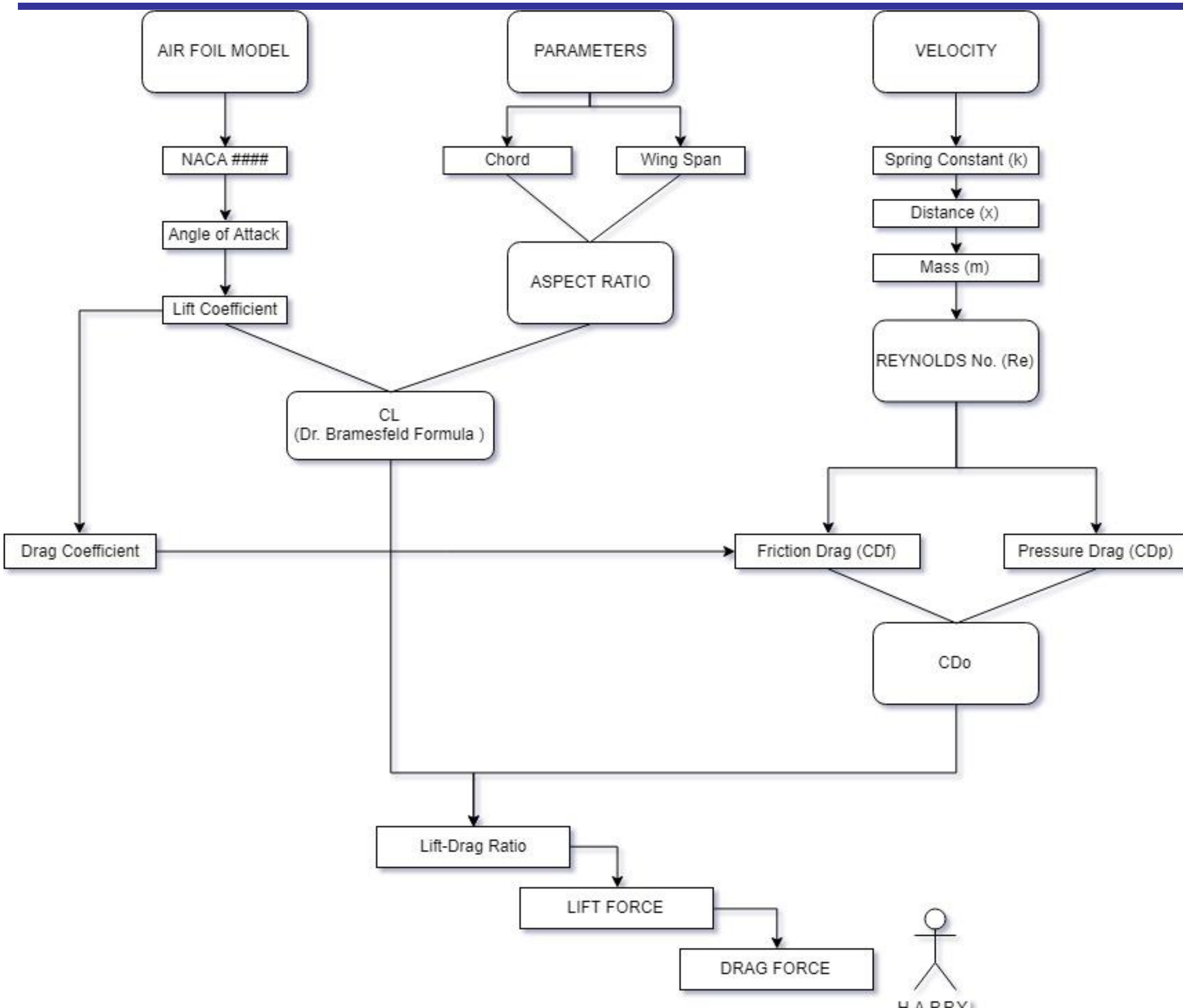
Aerodynamic Design Overview

Smooth design and surfaces are most aerodynamically effective

Section Outline:

- Wing dimensions and airfoil
- Tail dimensions
- Calculations
- Airfoil Manufacturing
- Stability Strategies
- Fuselage aerodynamic shape

Aerodynamic Requirements/Objectives



- **Airfoil:** select the most optimal airfoil design that will not stall at an initial angle of attack of 7 degrees. Can be manufactured easily in a thin airfoil (approx. 2 cm thickness) i.e. NACA 2412, and NACA 4412.
- **Parameters:** The chord and wing span of the glider primarily depend on the dimensional constraint outlined in the competition handbook (30cm by 15cm by 10cm box).

  Max chord: 14.0cm

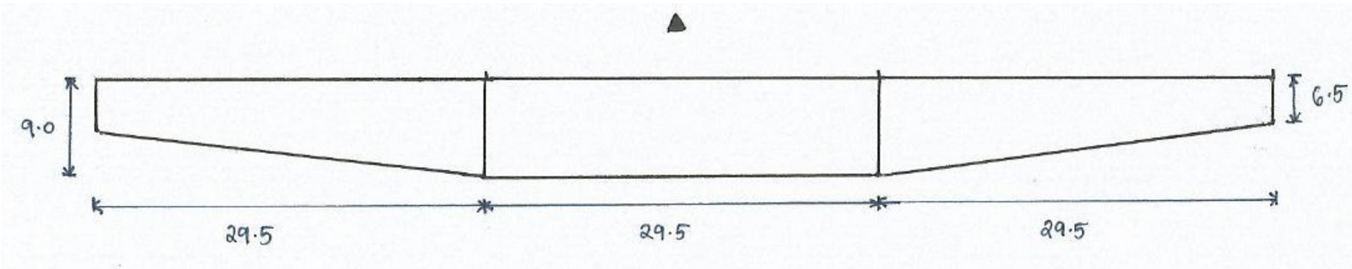
  Max Wingspan: 88.5cm
- **Velocity:** to find the max speed the glider can have, the spring constant (k) must be known first and the cumulative weight of the glider. From there, we can adjust distance (x) to find the most optimal speed the glider must launch.

From there, the following values for Re, AR, CL and CDo can de calculated.

Changes Since PDR

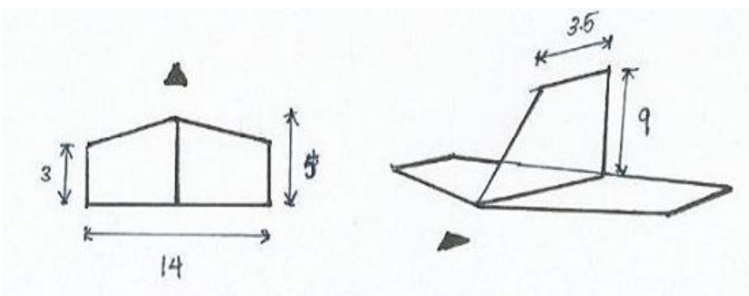
Wing:

- Increased both root and tip chord lengths



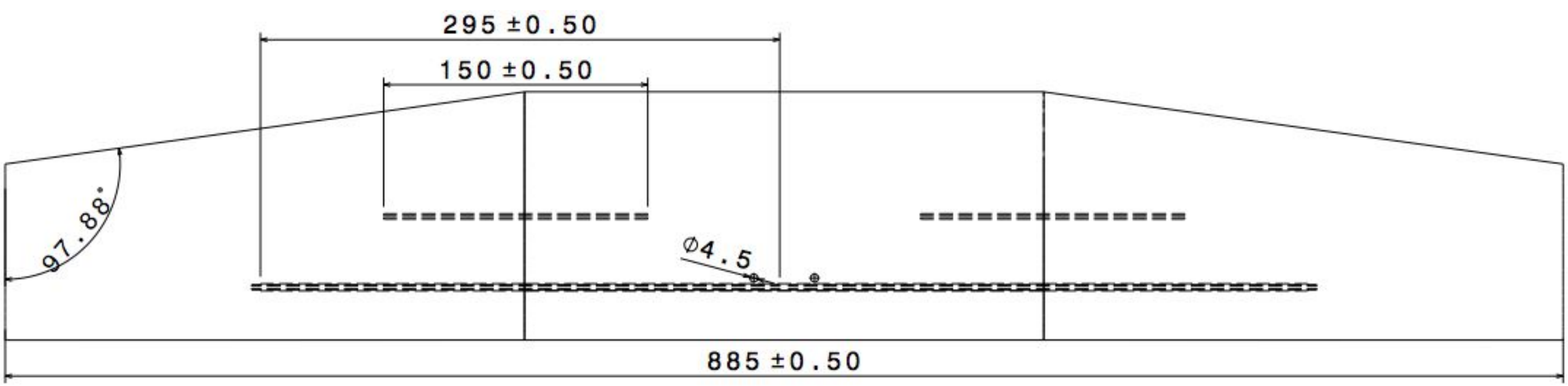
Horizontal and Vertical Stabilizers:

- Got rid of taper to simplify manufacturing
- Increased chord length to increase stability
- Symmetric airfoil instead of flat plate



Wing Design

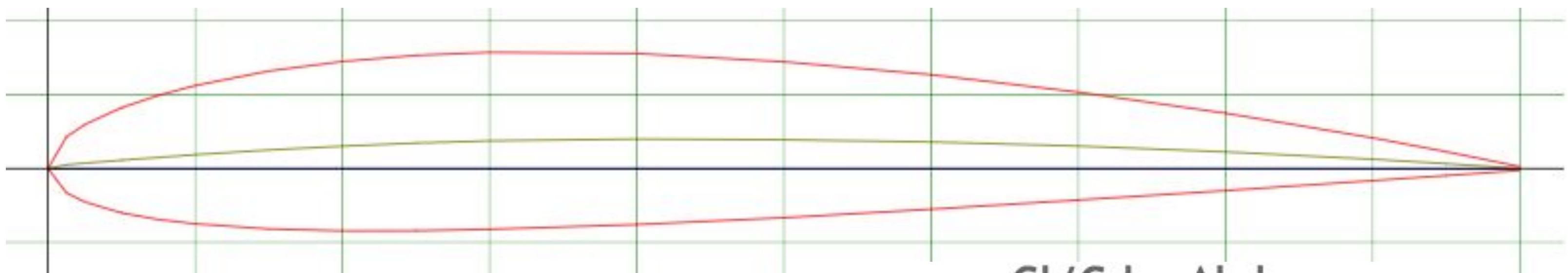
Shape: Tapered
Root Chord: 14 cm
Tip Chord: 10 cm
Span: 29.5*3 = 88.5 cm
Airfoil: NACA 2412
Preset Angle: ≈0 degrees

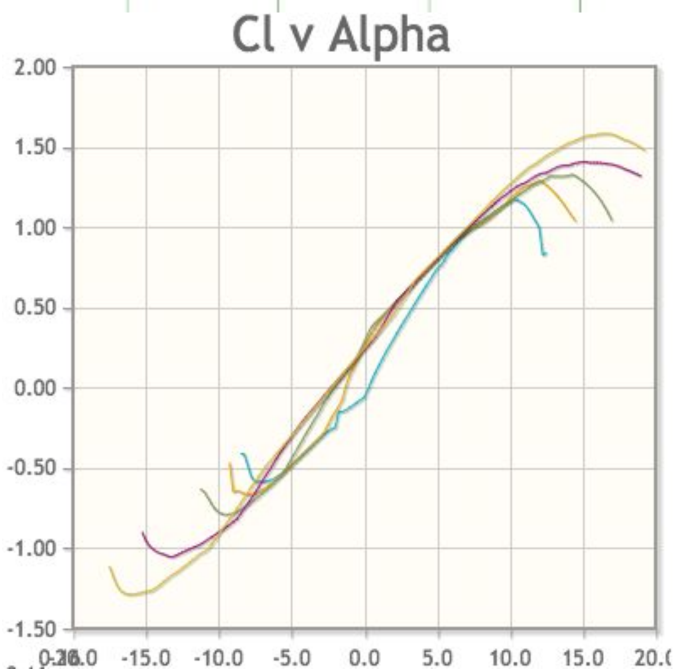


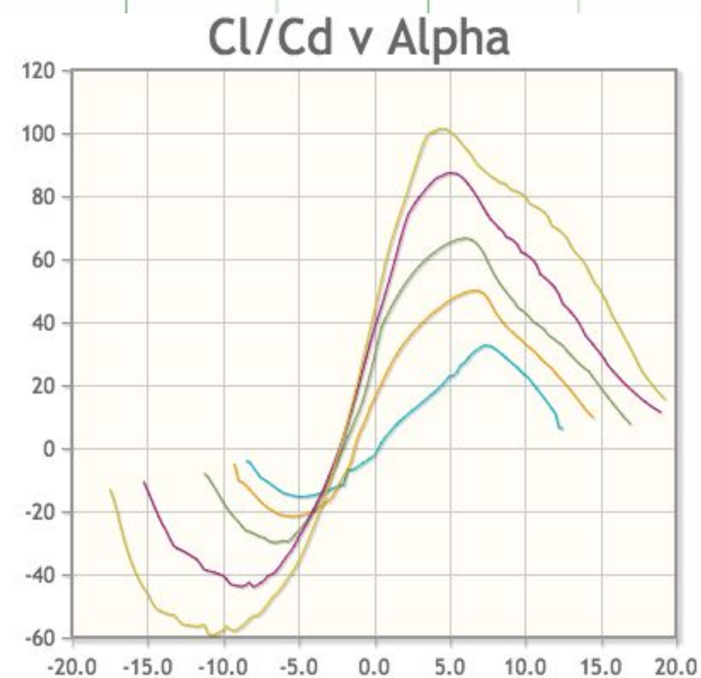
Top view

Wings

Airfoil: NACA 2412







Tail Design

Horizontal Stabilizers

Shape: Rectangular

Chord: 10 cm

Span: 30 cm (15 cm each)

Airfoil: Symmetric

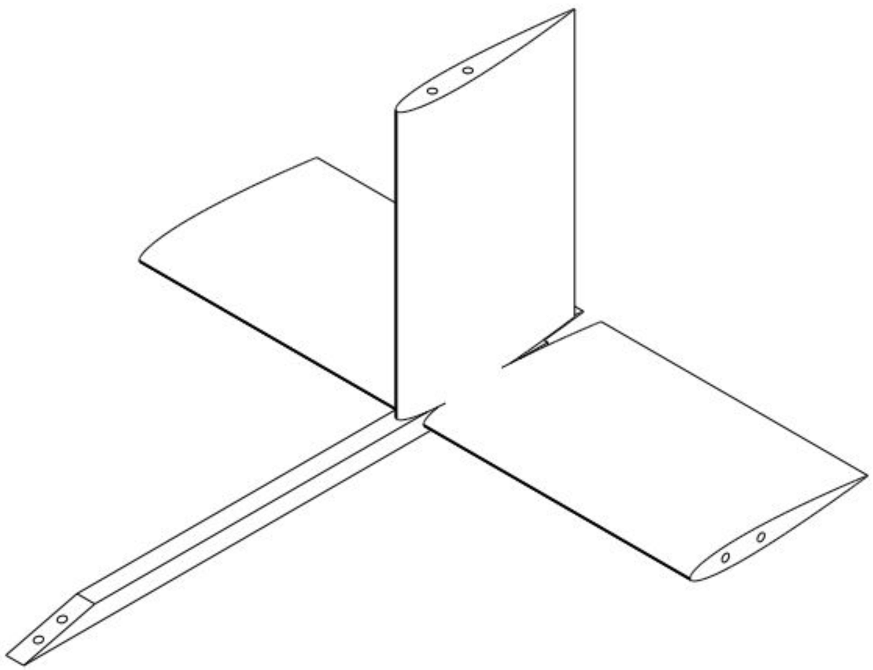
Vertical Stabilizers

Shape: Rectangular

Chord: 10 cm

Height: 15 cm

Airfoil: Symmetric



Aerodynamic Calculations

Air Foil Model	
NACA #####	2412
Angle of Attack	0
Lift Coefficient	0.2
Drag Coefficient	0.006

Parameters	Values
Chord	0.14
Wing Span	0.885
AR	6.321428571

Lift Coefficient (CL)	
LiftCoefficient	0.2
AR	6.321428571
C_L	0.15193133

Friction-Drag Coefficient (C_{Df})	
Laminar	4.1332E-03
Turbulent	2.16106E-14

Pressure-Drag Coefficient (C_{DP})	
C_{DP}	0.056

Total Drag	
C_{Df} *(L or T)*	4.1332E-03
C_{Dp}	0.056
C_{Do}	0.060133186

Lift - Drag Ratio	
Lift Coefficient	0.2
Drag Coefficient	0.006
Ratio	33.33333333

Velocity (v)	
k	30
κ	1.34
m	0.4645
v	10.76893

Reynold's No.	
Density	1.225
Velocity	10.76893
Chord	0.14
Viscosity	1.79E-05
Re	########

LIFT	
Density	1.225
Velocity	10.76893031
WingArea	0.1239
C_L	0.15193133
LIFT	1.337118426

DRAG	
Density	1.225
Velocity	10.76893031
WingArea	0.1239
C_{Do}	0.060133186
C_L	0.15193133
Chord	0.14
Wing Span	0.885
DRAG	0.539450058

Airfoil Manufacturing

For Wings, Horizontal and Vertical Stabilizers:

- Airfoil jigs were laser cut from (3mm thick) MDF
- Spar hole/fitting was drilled with 4mm circular rod into the foam
- Using airfoils as guides, wings were hot wired to the desired shape
- For initial prototypes, the foam was melting too quickly, leading to many imperfections (bumps). Adjusted the current passing through the wire.
- Sanded to achieve a smooth surface
- Wrapped foam in vinyl sheet

Stability & Control Analysis

- **Summary of Stability & Control Strategies:**
  - Wings can be moved forward and backward to adjust balance, depending on nose weight
  - Dihedral wings increase stability along longitudinal axis
  - Large tail to stabilize pitching moment

- **Test results:**
  - When thrown a distance of 3-4 meters, at a height of 1 meter, glider stayed fairly stable along all axes

- **Notable Drag Sources:**
  - Wing and boom attachment method (screws and wing nuts)
  - Creases and bubbles in vinyl
  - Power switch and LED porturde from fuselage

Fuselage Final Design

Aerodynamics of fuselage

– Components have precise dimensions to maintain streamlined structure
– Sanded down corners and covered in vinyl for smooth surface
– Aerodynamic nose and rear, also sanded

Payload Carrying Capabilities

– Compartment dimensions: 6mm*59mm*77mm
– Could fit ≈160g of extra weight

Manufacturing methods

– Laser cut pieces assembled with epoxy

Avionics Subsystem Design

Aquamarie Oca

Avionics Subsystem Requirements

Overview

- **Power Supply:** 9-V Battery
  Supply electrical power to all components.

- **MicroProcessor:** smraza UNO R3
  Microcontroller board

- **MicroSD card module & Micro SD card:** Arduino module to save information
  Stores all data collected from sensor(s).

- **Sensor:** Accelerometer/Gyroscope MPU6050
  Collect acceleration data (x,y,z axis).
  Use it to calculate for displacement.

- **Power Indicator:** LED
  ON set check

Avionics Subsystem Requirements Cont...

Additional Requirements:

- All electronics must be inside the fuselage.
- Secure and safe from external damages.
- Survive drop tests.

Avionics Subsystem Overview

- **Altitude and Distance Determination**
  - MPU6050 Accelerometer
- **Non Volatile Processor**
  - smraza UNO R3
- **Non Volatile Data Storage**
  - MicroSD card module & Micro SD card
- **Portable Power Source/Weight Limitation**
  - 9-volt carbon-zinc battery
- **Light for Turn-On check**
  - LED
- **Push Button**
- **Flip switch**
  - On/Off

Changes since PDR

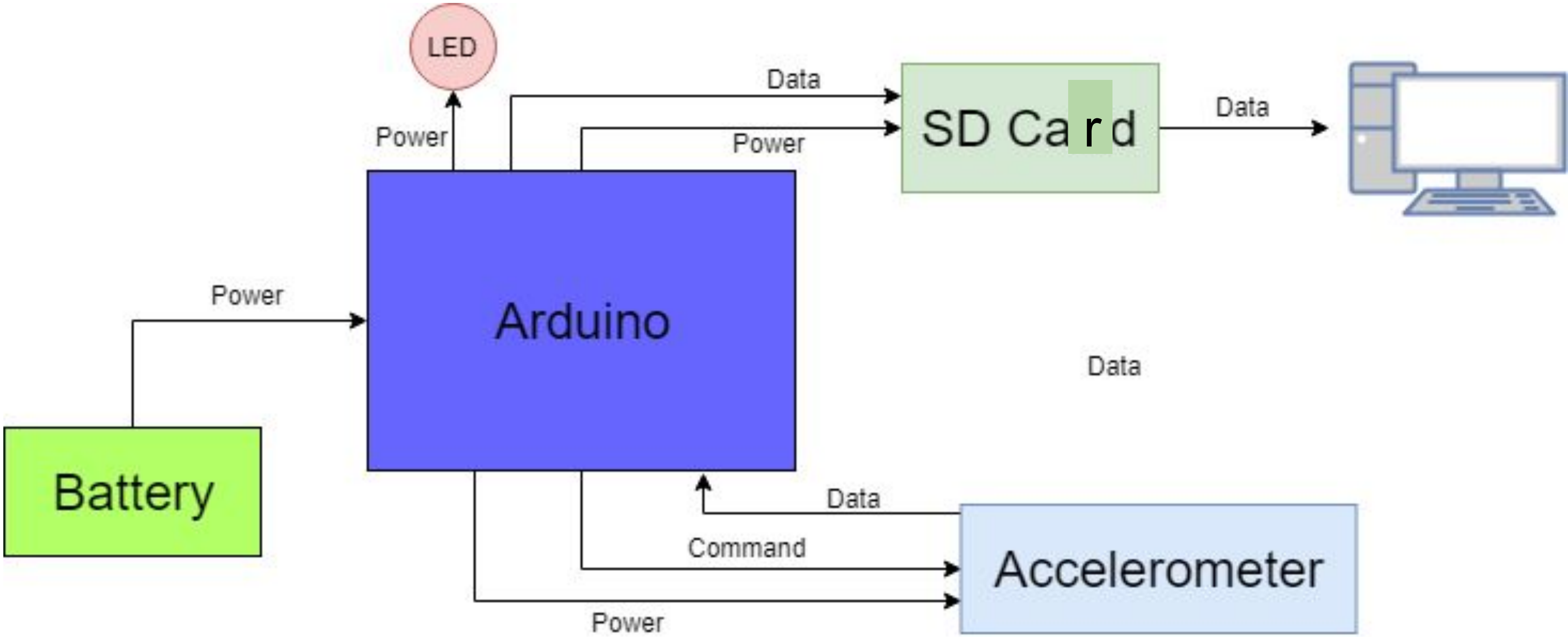
- **List of changes to the avionics since the PDR**

I. Addition of push button at the external surface of the fuselage for easy access.

II. Process data analyzation to obtain displacement of glider.

MPU6050 → SD Card → Evaluate Data in MATLAB

Avionics Subsystem Design



Avionics Subsystem Design Cont...

Processor speed

- Integrated 16-bit ADCs
- Programmable full scale range: ± 2 ± 4 ± 8 ± 16g

Full-Scale Range (g)	Sensitivity Scale Factor (LSB/g)
± 2	16384
± 4	8192
± 8	4096
± 16g	2048

Memory

- SD Card Capacity: 16GB
- Sketch(Code): 14880 bytes (46%) of program storage space
- Maximum of 32256 bytes

Avionics Subsystem Design Cont...

Power consumption

- Arduino: 7-12V
- MPU6050: 2.375V–3.46V
- SD Card Module: 5V
- LED: 1.8V

Power capacity

- 9-V from the Battery

Flight Software Overview

MPU6050 collects acceleration data → Send data to Arduino → Store data to SD Card → Process data in MATLAB → Obtain displacement through integration

Programming Language:

- MPU6050: C++
- Arduino Uno IDE: Version 1.8.9
- Integration of acceleration data to displacement: Matlab

Flight Software Task(s):

- Collect acceleration at a certain timeframe at scale range of +/- 2g.
- Must start collecting when push button is pressed and stop once pushed again.

Flight Software Overview Cont...

Difficulties encountered during development of software:

- The MPU6050 was not calibrated to read meaningful data.
- The MPU6050 was not storing the collected data to the SD card.
- Properly integrate the acceleration data to estimate displacement of the glider.
- The recorded acceleration keeps fluctuating.
- Propagation of inaccuracies builds up as sensitivity of accelerometer is increased.

Current difficulties:

- The sketch(code) does not collect new data when the push button is run again, nor does it overwrite the previous collected data.
- It continuously record the additional data and add it to the old data.
- The old data has to be manually deleted from the SD card.

Sensor Accuracy

- The accelerometer is accurate in recording accelerations however, it must be properly calibrated to generate meaningful results.
- As mentioned earlier, the recorded acceleration keeps fluctuating.
- Must filter acceleration signals and be able to use collected data to find displacement.

Data Acquisition Strategy

- Collect acceleration data at a certain sample rate using the MPU6050.
- Data is then stored to SD Card and evaluated at MATLAB.

-

Data Acquisition Strategy Cont...

ARDUINO

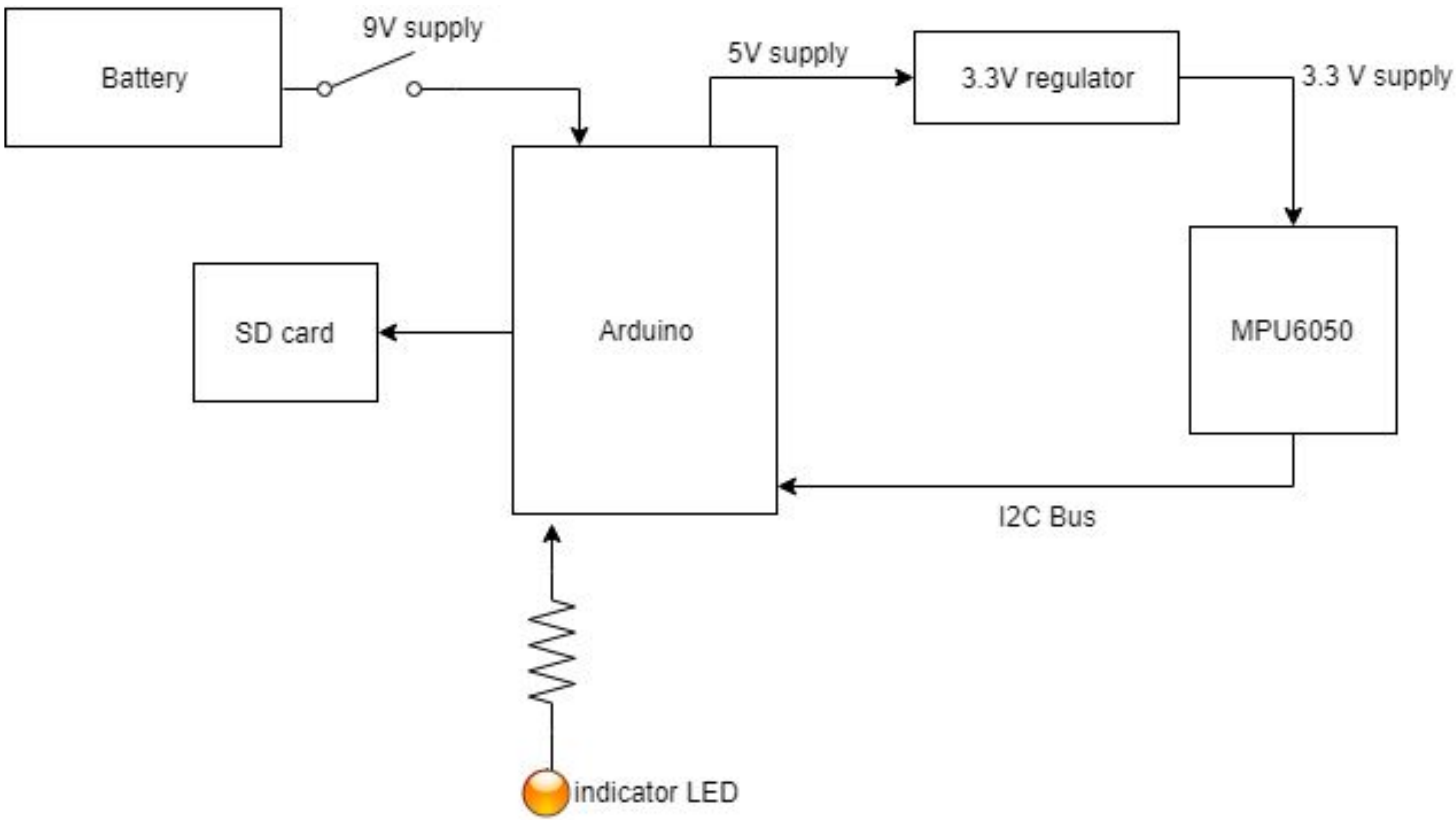
I. The IMU (MPU6050) reads raw acceleration data.
II. Divide the recorded data to its corresponding LBS/g.
III. Obtain acceleration in terms of ‘g’.
IV. Display results in serial monitor (when connected to computer).
V. Store collected data in SD Card as .xlsx file.

MATLAB

I. Read data from .xlsx file.
II. Filter acceleration signals.
III. That includes identifying sampling rate, cut off frequency, and order of filter.
IV. Integration can be performed (Acceleration → Velocity → Displacement).
V. Using cumtrapz (x,y) function where it computes an approximation of the cumulative integral of acceleration via the trapezoidal method.

Note: Results from integration is just an estimation and cannot be assumed to be reliable.

Electrical Power



Distance Estimation

Angelo Ferreira

Distance Estimation

- **$a = F/m$ → $a = 289.34 m/s^2$**
- **It is assumed bungee acts from 2m to 0.66m (1.34m):**
- $V_i = sqr(2*\Delta s*a)$ → $V_i = 27.847 m/s$
- **Using 10 degree angle for launcher:**
- $V_{ix} = 27.424 m/s$
- $V_{iy} = 4.836 m/s$
- **Finding climb interval:**
- $\Delta t = -V_{iy}/(g)$ → $\Delta t = 0.49 s$
- **Finding maximum height (adding launcher height):**
- $\Delta s_y = V_{iy}*\Delta t + 0.5*g*(\Delta t)^2 + 0.40$ → $\Delta s_y = 1.592 m$

Distance Estimation

- **Finding descent interval:**
- $\Delta t = sqr(2*(-\Delta s_y)/g)$ $\Delta t = 0.570s$
- **Total flight time: 1.06s**
- **Finding distance travelled:**
- $\Delta s_x = V_{ix} * \Delta t_{total}$ ***$\Delta s_x = 29.07m$***
- Notes (not included in the estimation):
- Any lift generator by the wings
- Drag felt by the glider

Distance Estimation - tests

- Small test was done by tossing straight 1m above ground

- Results:
- Flew approximately 4m to a height of 0.4m
- Climb was observed

- Results are taken as valid since small force was applied when tossing the glider

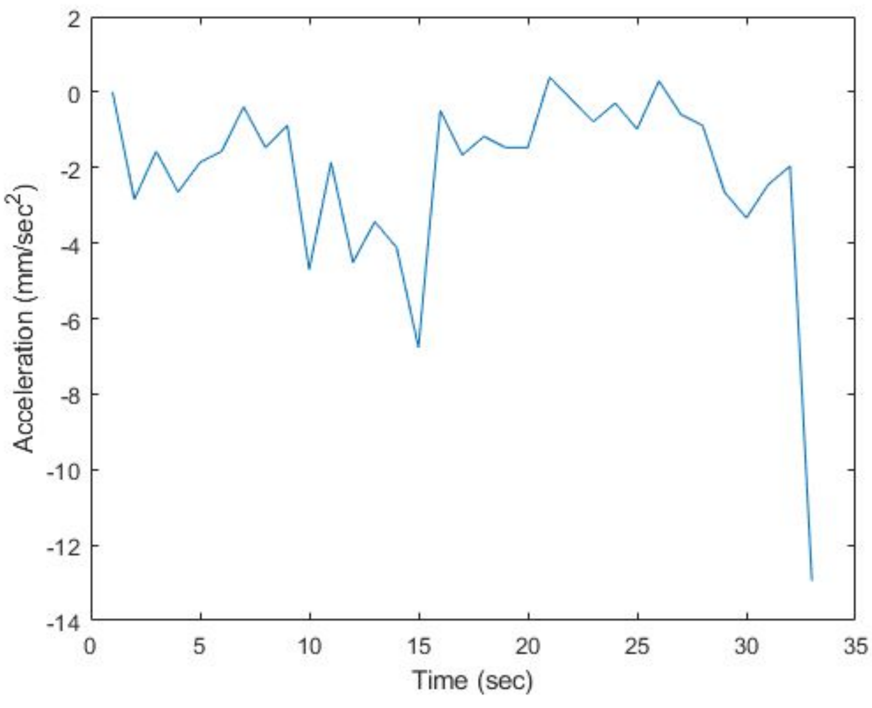
Testing

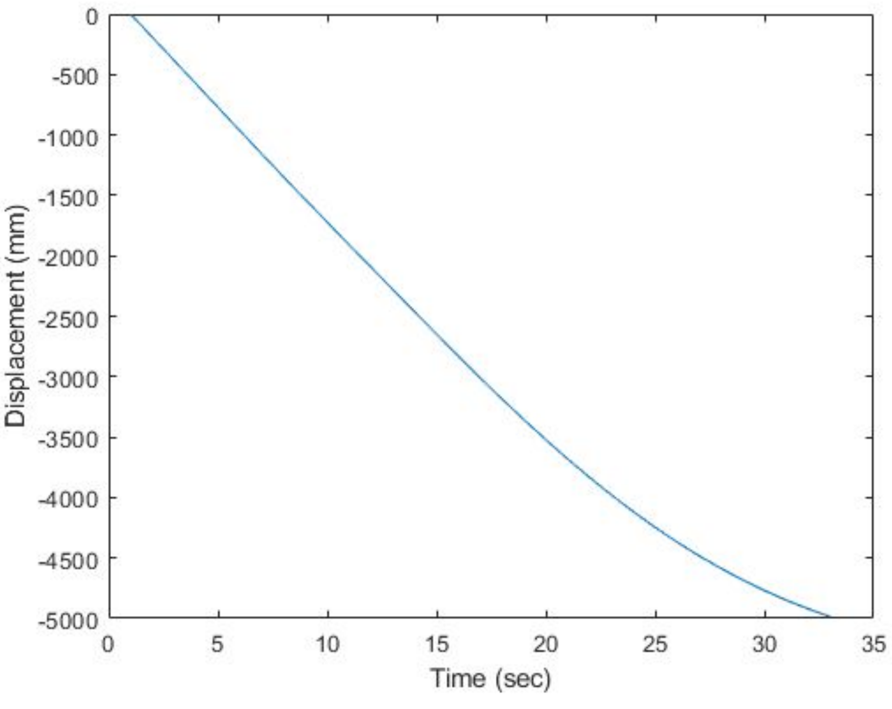
Aquamarie Oca

Test Overview

• Structural Test	Avionics Test
The glider was dropped to determine whether it can sustain impact at different heights. Success: - The glider remained intact during drop test. - It was able to hold the weights and avionics without any damage. Failures: - The wiring system in avionics came loose. - The nose of the glider loosens as soon as it impacts the ground.	The avionics system of the glider was tested to determine whether it is perfectly working(collecting data) and can approximate the displacement of the glider. Success: - The accelerometer was able to collect data. Failures: - The accelerometer was not calibrated properly to obtain meaningful data. - Accumulation of inaccuracies. - The acceleration data was not properly integrated to obtain displacement.

Media of Tests





Costs

Angelo Ferreira

Hardware Budget

Table of Costs for Component Materials and Hardware

Materials	Costs (CAD)	Hardware	Costs (CAD)
MDF	0.50	smraza UNO R3	12.99
Foam	approx. 4.50	Accelerometer	4.99
Carbon Fiber Rod	approx. 10.00	MicroSD card module	2.60
Solid Wooden Rod	2.00	MicroSD card	5.54
Screws, Bolts	3.00	Battery	2.85
Vinyl	approx. 4.00	Flip Switch	1.99
Extra weight	3.00	Resistor, Wires, LED	approx. 2.30
Epoxy (glue)	approx. 3.00	LED	0.21
Total	**30.00**	**Total**	**33.47**

Total cost: 63.47 CAD

Conclusions

- **Manufacturing 95% done (launch interface left to be manufactured)**
- **Weight of glider increased, but seen as beneficial for stability**
- **Simple flight test succeed since climb was observed from horizontal toss**
- **Avionics still requires a little more work on minimizing the errors from noise frequencies and integration**