Joint Project-Based Learning Experience

IMT-POLI-UIUC

INSTITUTO MAUÁ DE TECNOLOGIA

MAUÁ

Escola Politécnica da Universidade de São Paulo

ILLINOIS

The Glider Challenge

MAY, 2019

SÃO PAULO, BRAZIL

1. Objectives

The main goals of the GLIDER CHALLENGE are to (i) design, (ii) put together and (iii) fly a small balsa-wood model glider, achieving the highest combined score for the three phases of the challenge in the process.

The challenge must be met by teams of 4 students (± 1 student), preferably comprising of two UIUC students, one IMT student and one POLI-USP student (task 1: form teams of 4 ± 1 students).

WARNING: During this challenge the students will be handling sanding, filing, cutting and gluing operations. The use of safety goggles is mandatory at all times and care should be exercised at all time while handling sharp hobby knife and tooling. While sanding balsa wood, it is also recommended the use of a dust mask. The use of portable electrical tools or machine shop tools are not necessary and will only be allowed if justified by the team and authorized by the activity coordinator, who will supervise the whole operation. The use of equipment inside a shop or Fab Lab (Poli´s or IMT´s) will be subjected to local safety instructions and availability of personal safety equipment as requested (task 2 for all teams: observe safety precautions at all times).

2. Rules and task sequence.

(task 3: read ALL the rules prior to engage any action!).

1) A set of pre-cut parts and blanks will be delivered to each team.

2) Check the kit received (task 4) in order to make sure it includes:
   a) One safety goggle for each member of your team.
   b) Dust masks.
   c) A blank for cutting the fuselage forward section.
   d) Two blanks for conforming the wings.
   e) A long square-section stick to be cut in proper length and used as a tail boom.
   f) A balsa sheet from which the horizontal and vertical stabilizers will be cut, after proper sizing.
   g) Some minor weights and towing hook (piano wire sections), for CG adjustment and catapult launch, respectively.
   h) CA Glue, sandpaper, sand block, ruler, hobby knife.

3) Give your project a name (team name, task 5).
4) Design your glider (task 6).
5) Build your glider (task 7).
6) Balance the CG of your glider (task 8).
7) Test your glider dynamically in an open-discharge wind tunnel for verifying the longitudinal stability (task 8a - optional).
8) Prepare a few slides for a PPT presentation based on your team´s project and sizing notes (task 9).
9) Present your project (task 10).
10) Make up to 3 adjusting/rigging launches (preparation) (task 11).
11) Participate in the competition (task 12).
12) Your design will be evaluated by one of the appointed judges using the following grading criteria:

TEAM NAME: ________________________________ Date: May _______, 2019.

1- Design Competition			
Phase	Requirement	Grading range	Assigned Grade
Design	Criteria for tail sizing and tail boom sizing and technical design	0-3	
	Criteria for sizing the dihedral angle	0-3	
	Criteria for airfoil choosing and shaping.	0-5	
	CG position estimation	0-3	
	Creativity	0-3	
	Decoration and number markings	0-2	
		Sub-total->	
Construction	Overall appearance and cleanliness	0-3	
	General alignment of angles and symmetry	0-3	
	Lateral balance	0-3	
	Position of CG as per design (before any testing)	0-3	
	Airworthiness condition (will hold together under a high G catapult launch?) *	0-3	
		Sub-total->	
Flight	Velocity measured at take-off.	See Section 5	
	Straight line distance	See Section 5	
	Lateral Deviation	See Section 5	
	Overall Launch Quality	See Section 5	
	CG position on longer flight x Predicted CG position	See Section 5	
		Sub-total->	
1-Design Competition Team Total →			
2-Flight Competition Team Total (from section 5) →			
Joint PBL Team Grand Total →			

Table 1 – Grading criteria

(*) Average launch acceleration: 10 N / 0.02 kg = 500 m/s^2 = 51 gs !!!

3. Designing.

This is part (i) of the competition and comprises:

Step	Description	Task	References
1	Calculate the Mean Aerodynamic Chord (MAC) of your wing	Research on how to calculate the MAC and perform the calculation. You may use the graphical approach as well (recommende).	• Nasa Online Mean Aerodynamic Chord Calculator (Site 2) • Airfield Models Site (Site 3)
2	Define the length of the tail boom	Research on "Tail Volume and Tail Volume Coefficient" for the horizontal and vertical tails and understand its meaning. Research values for the Horizontal and vertical tail volume coefficient and choose values that you consider suitable for your design.	• MIT-OCW – Basic Aircraft Design Rules (site 1). • Nasa Online Mean Aerodynamic Chord Calculator (Site 2)
3	Define the area of the horizontal stabilizer		
4	Define the arm of the horizontal stabilizer		
5	Define the area of the vertical		
6	Define the arm of the vertical stabilizer		
7	Define the dihedral angle of the wings. Assume $C_L \approx 0.3$	Research on spiral stability.	• MIT-OCW – Basic Aircraft Design Rules (site 1).
8	Choose how you would like to shape your wing cross sections (airfoil, leading-edge and trailing-edge) geometry.	Research on airfoil camber and thickness over chord (t/c) parameter.	• Journal of Aircraft Paper: Basic Understanding of Airfoil Characteristics at Low Reynolds Numbers, Figures 11 and 12, only (site 4)
9	Define the position of the Center of Gravity (CG or CoG) of your glider.	Research on the meaning of "Static Margin".	• MIT-OCW – Basic Aircraft Design Rules (site 1). Use Equation 1 and Figure 2 of the paper and assume for this calculation that the $x_{np} = 23\ mm$ from the MAC Leading Edge. Consider that the catapult will launch your glider with a slight "pitch-up nose setup".
10	Weight your balanced model and calculate W/S (weight over wing area), known as	Measure and calculate in grams/sqcm.	

	wing loading parameter.		

Take note of all your calculations and decisions as you make progress, in order to make a complete report and presentation of your design, later in the challenge.

Step	Description	Results
1	MAC	
2	Define the length of the tail boom.	
3	Define the area of the horizontal stabilizer and declare the Horizontal Volume Coefficient chosen.	
4	Define the arm of the horizontal stabilizer	
5	Define the area of the vertical stabilizer and declare the Vertical Volume Coefficient chosen.	
6	Define the arm of the vertical stabilizer.	
7	Define the dihedral angle of the wings (ϒ) and declare the Spiral Parameter B, chosen.	
8	Choose how you would like to sand (shape) the Leading-Edge and the Trailing-Edge of your wing.	
9	Define the position of your CG and declare the Static Margin Chosen.	
10	Weight of the finished model.	
11	Wing loading of the finished model.	

3.1 Suggested Research References for the design competition:

Site 1: https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-01-unified-engineering-i-ii-iii-iv-fall-2005-spring-2006/systems-labs-06/spl8.pdf

Site 2: http://www.nasascale.org/p2/wp-content/uploads/mac-calculator.htm

Site 3:
https://www.airfieldmodels.com/information_source/math_and_science_of_model_aircraft/formulas/mean_aerodynamic_chord.htm

Site 4: https://arc.aiaa.org/doi/pdf/10.2514/1.C034415

Figures 11 and 12 are excerpts from the Journal of Aircraft PDF (site 4) and are reproduced below for identification purposes only. For larger resolution and better reading, please open the original PDF document by following the link provided:

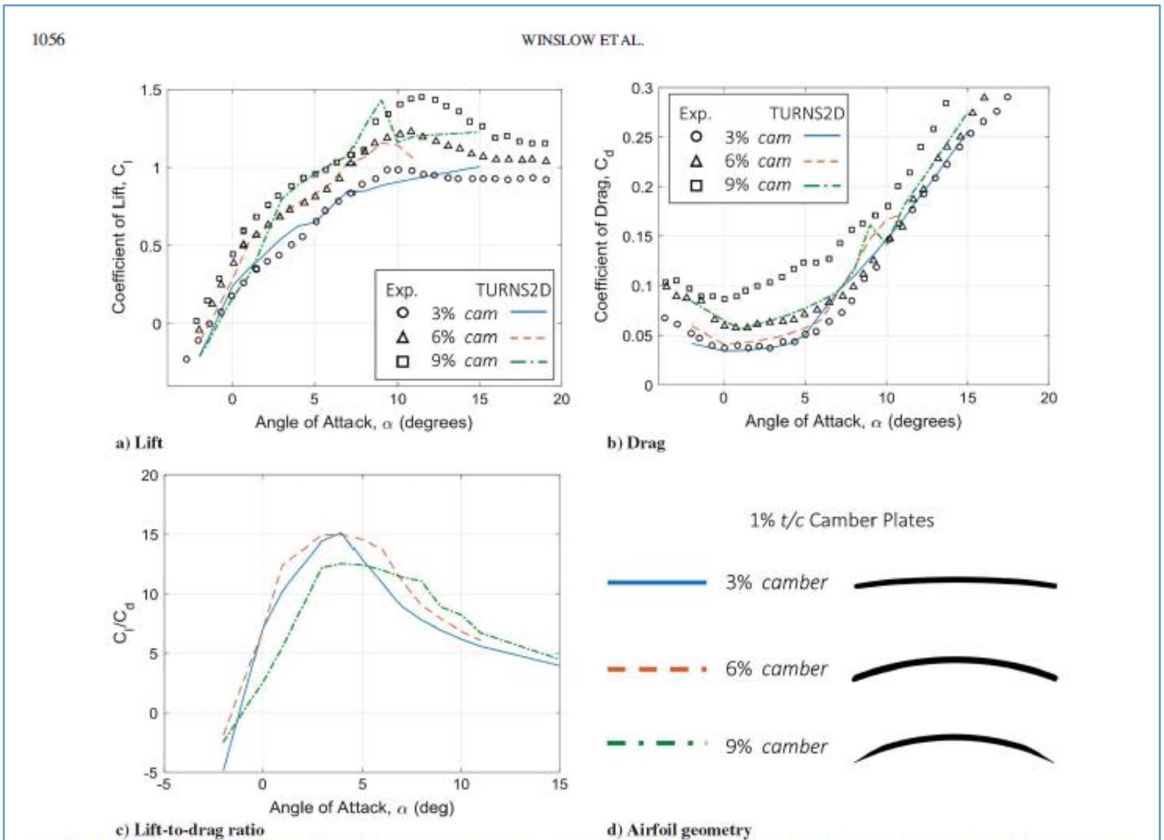

Fig. 11 Effect of thin plate (t/c1%) camber on lift, drag, and lift-to-drag at a Reynolds number of 10^4. (Experimental data from Okamoto et al. [21].)

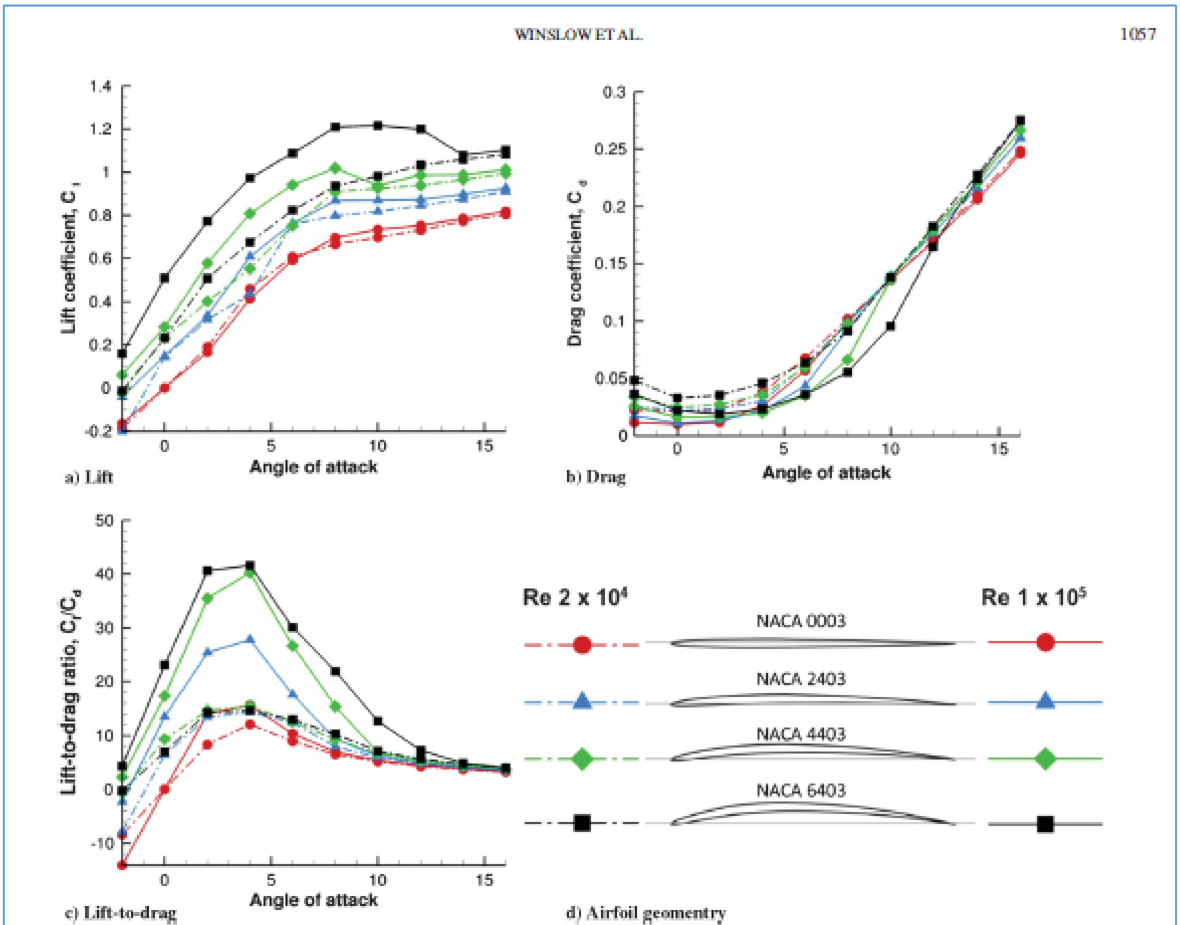

Fig. 12 Effect of camber on lift, drag, and lift-to-drag ratio for NACA airfoils of 3% t/c ratio at Reynolds numbers of 2×10^4 and 1×10^5.

Notice: all sources referenced here are documents seemingly at public domain over the Internet.

4. Constructing

Use the space, materials, directions and personal protection material provided for construction. A supervisor will be on-site for construction tips. The supervisor will define the maximum building time available for the activity, based on the daily schedule.

All aircraft will be graded in accordance with design and building criteria before the flight sessions.

5. Flight Competition

- The flight competition is planned to occur at IMT´s soccer field.
- 30 minutes will be allocated in the competition morning for all teams to warm up and trim the gliders, with up to 3 catapult launches per team in the period. The launch order will be defined by a line formed behind the launch line. During this time the marking for the competition boundaries will be drawn in the lawn.

- The teams may accomplish as many hand launches as they want during the 30 minutes warm up in order to trim their gliders for attempting the longest and straightest flights possible.
- Three official catapult launches will be made by each glider. The catapult releases every glider at the same angle and with the same launching force.

The judges will provide the following information for each flight:

TEAM NAME: ___________________________________ Date: May ________, 2019.

Flight	Velocity at take off (m/s)	Straight Line Distance from launch line to touchdown place (m).	Lateral deviation from the midfield line (m). <u>This grade is attributed only for flights of 10 m or more</u>	Overall Launch quality (based on longitudinal and lateral stability)	CG position on longer flight x Predicted CG position
Grading Criteria	• 0 to 10 m/s: 0 pt • 11 to 15 m/s: 1 pt • 16 to 20 m/s: 2 pt • >21 m/s: 3 pt	• 0 to 5 m: 3 pts • 5.1 to 10 m: 6 p • 10.1 to 15 m: pts • 15.1 to 20 m: 1 pts • >20 m: 25 pts.	• 0 to 3 m: 9 pts • 5.1 to 10 m: 6 pts • 10.1 to 15 m: 3 pts • >15 m: 0 pts.	Use figures below to judge the flight trajectory quality. For each correct volume coefficient (horizontal and vertical) and (dihedral) angle, add 3 points (máx of 9 points).	• No difference: 9 pts • Difference less than 5 mm: 3pts • Difference more than 5 mm: 0 pts.
FLT 1					
FLT 2					
FLT 3					
Sub-Totals→					
				2- Flight Competition Team Total→	

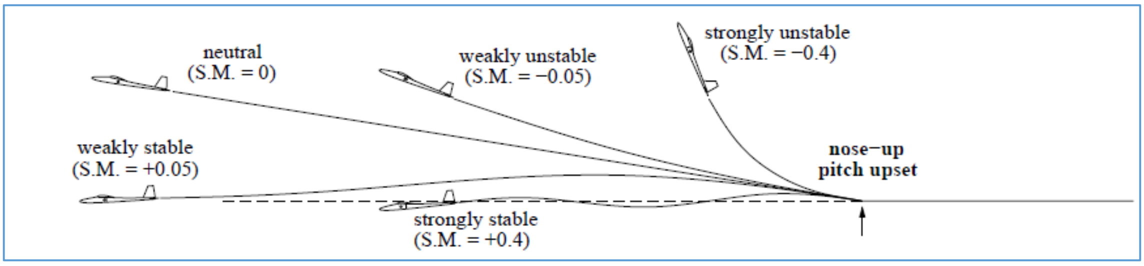

Figure 1 – Figure from MIT-OCW to be used as a benchmark for overall flight quality in longitudinal stability (Horizontal Stabilizer Volume).

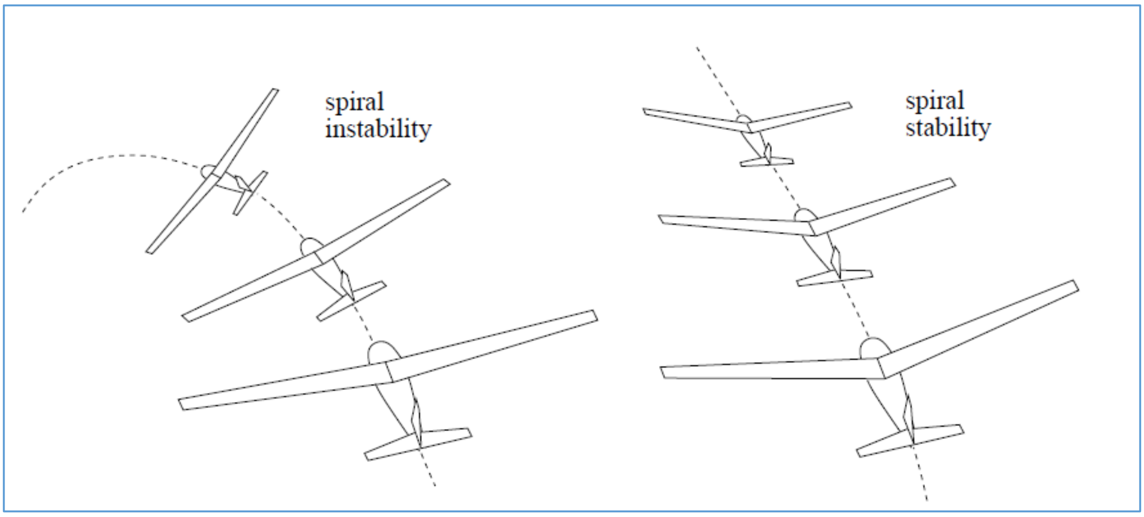

Figure 2 - Figure from MIT-OCW to be used as a benchmark for spiral stability (amount of dihedral angle).

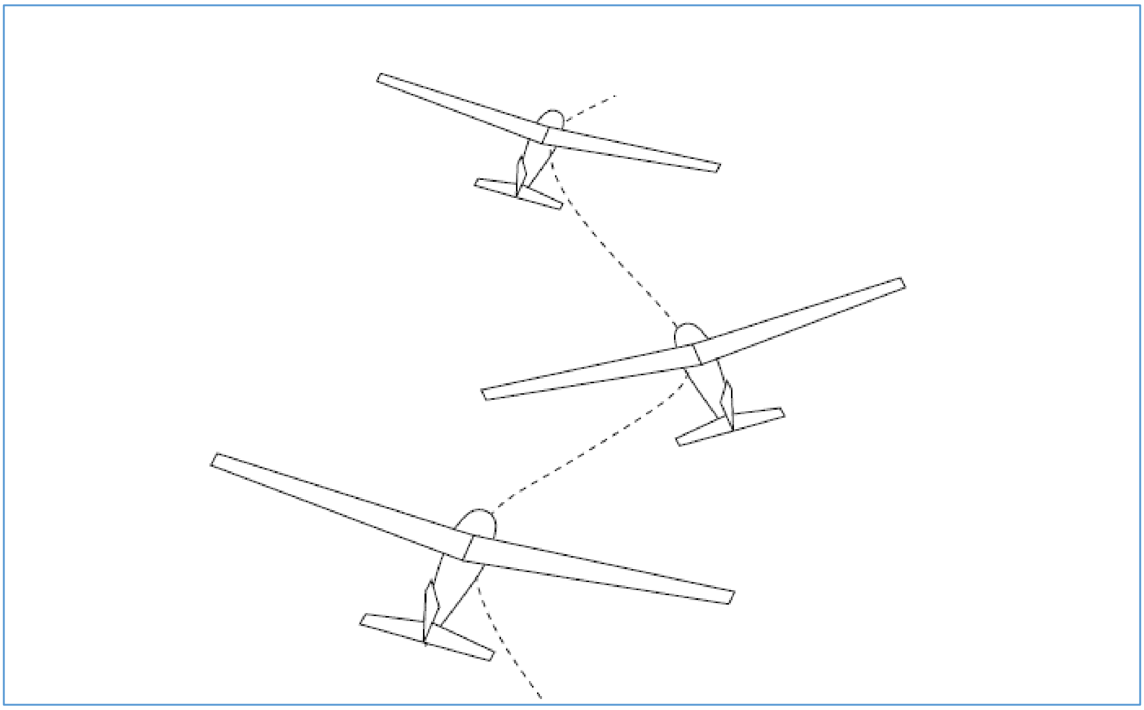

Figure 3 - Figure from MIT-OCW indicating insufficient Vertical Tail volume (dutch-roll oscillation).

Final grade for each team: transport above grades from the flight competition to Table 1 and sum up all grades.

Good challenge!

Joseph Y. Saab Jr - Instituto Mauá de Tecnologia, IMT, Brazil – saab@maua.br

Antonio Luis Campos Mariani – POLI-USP, SP, Brazil - camposmariani@gmail.com

Brian S. Woodard – UIUC, University of Illinois, IL, USA- bswoodrd@illinois.edu

Annex 1 – Basic Glider Reference Diagrams

In

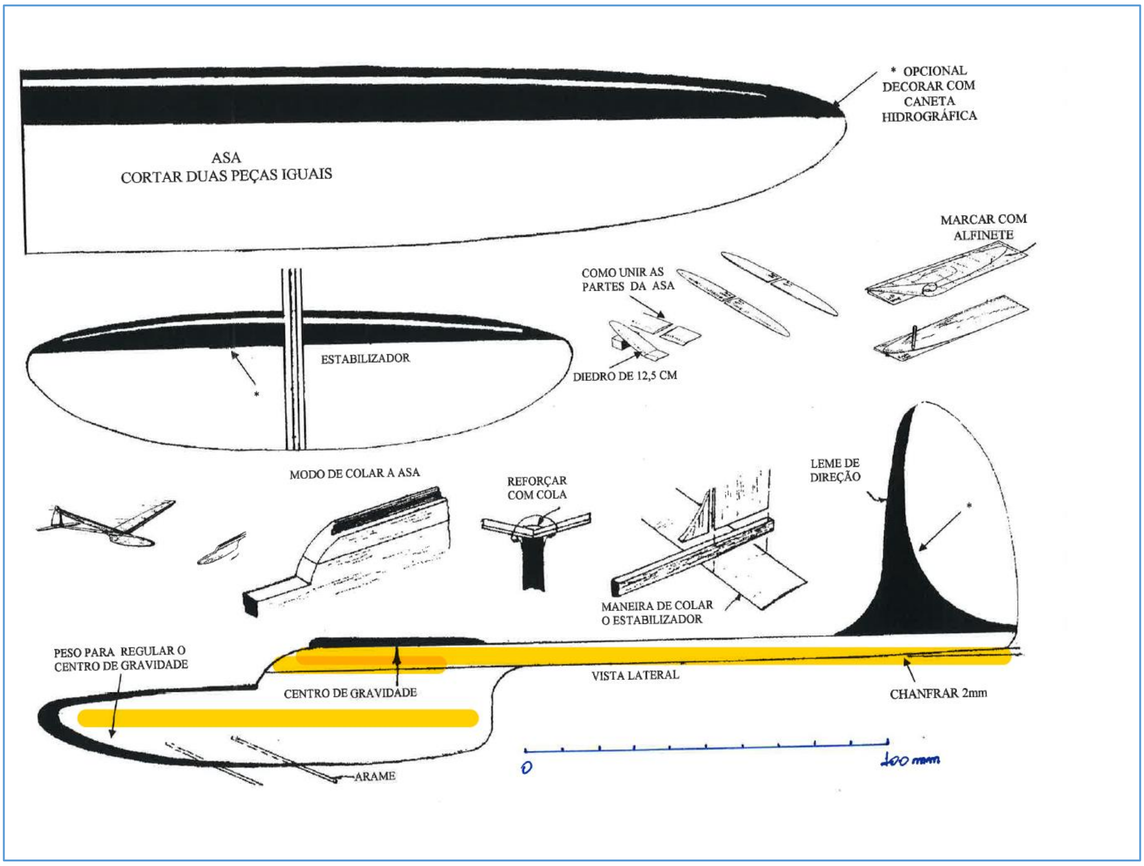

Figure 4 a general glider layout is shown. The wing of your glider will be a simple, tapered trapezoidal wing, not the elliptical one displayed in the figure. Also the horizontal and vertical stabilizers should be shaped in a simple, tapered, trapezoidal or rectangular shape for easy manufacturing.

The fuselage forward section and the tail boom, however, will be as indicated in Fig. 4. Both parts are marked with yellow highlight in the drawing. For a more detailed fuselage profile please refer to

Some suggestions on how to construct the dihedral angle are also shown. Also, notice: (i) the insertion of the skids, made out of piano wire; (ii) the 2 mm chamfer in the lower tailboom, in order to give the horizontal stabilizer some negative incidence. The wire-skids can double as hooks for the catapult-launch, provided they are kept ahead of the Center of Gravity.

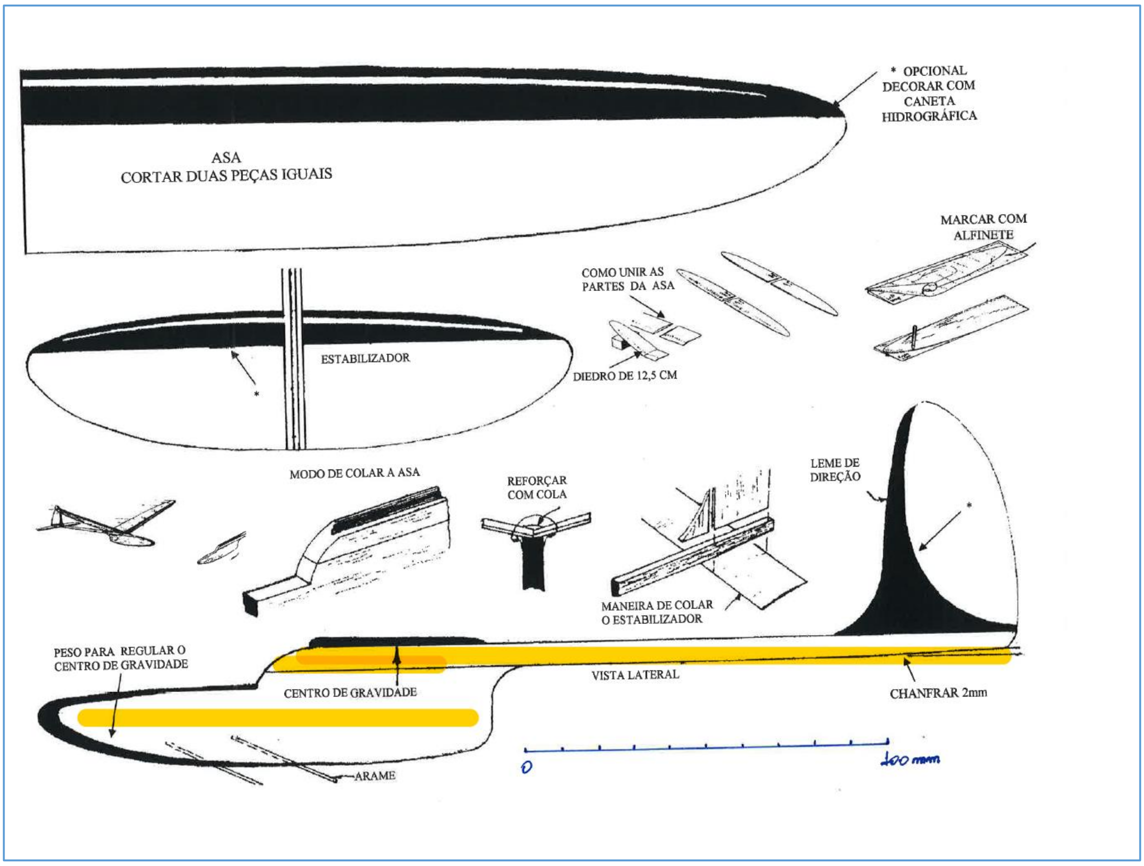

Figure 4 – General glider layout.

A more detailed drawing of the fuselage and of the wood blank, from which the wing will be produced by each team are shown in Figure 5 and Figure 6, respectively.

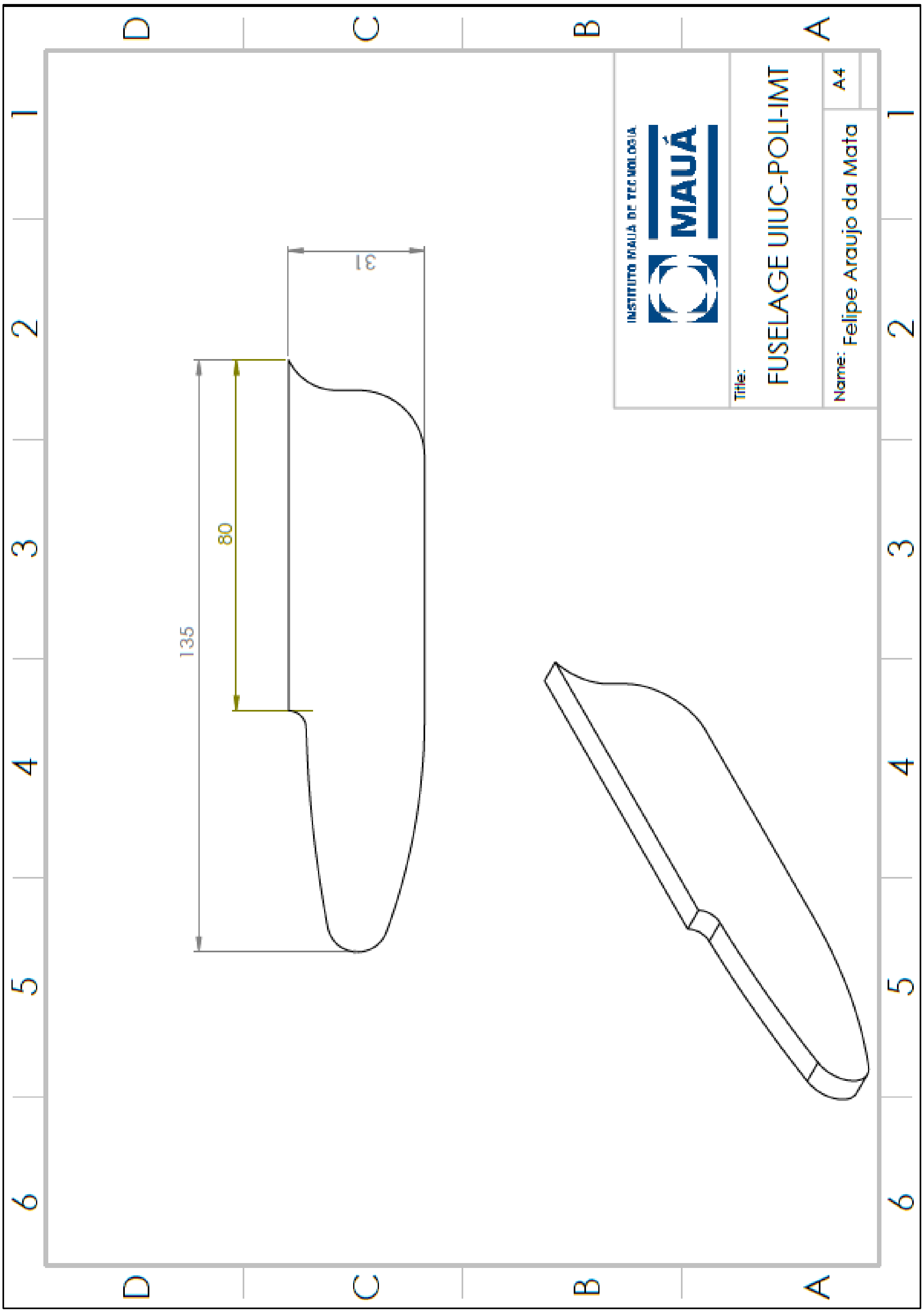

Figure 5 – Fuselage Drawing with dimensions.

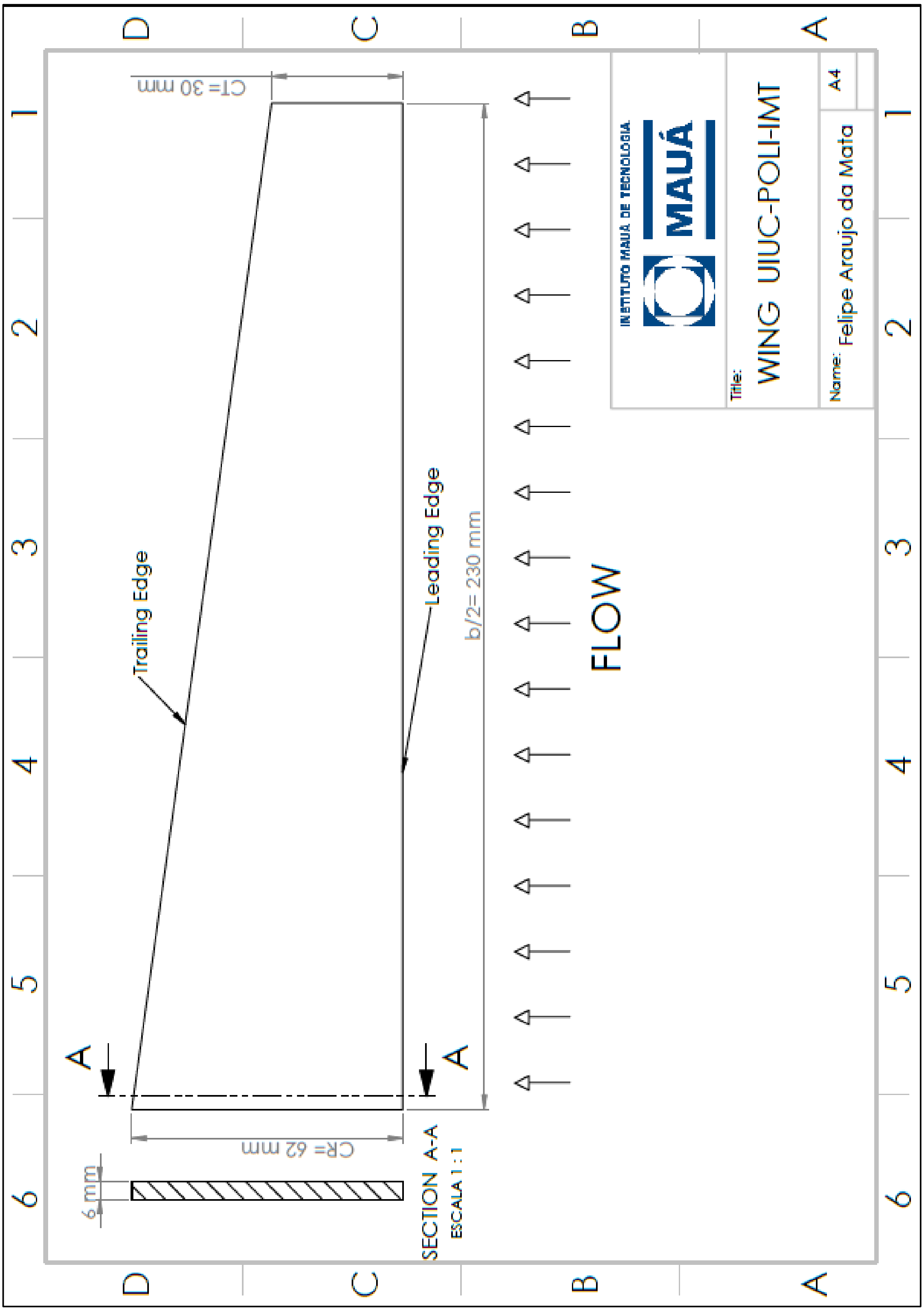

Figure 6 – Semi-wing blank.

Annex 2 – Bill of Material (Parts List)

Item	Description	Quantity (with spares)	Dimensions	Aplication
1	Safety Goggles	32 (max)	One size fits most	For all manufacturing operations.
2	Dust masks	10	One size fits most	For wood sanding and gluing.
2	Balsa blank for cutting the forward fuselage section	10	140 x 33 x 6 mm AAA balsa	Fuselage construction
3	Wing Blanks (trapeizodal)	20	230 (lenght) x 62 (root-chord) x 30 (tip-chord) x 6 (thickness) mm AAA balsa	Wing construction
4	Square-section stick	10	250 x 6 x 6 mm hard balsa	Tail boom
5	Balsa Sheet	10	200 x 100 x 2 mm	For empennage construction
6	Towing hook	10	1/32" piano wire	Catapult launch
7	Wind-Tunnel testing attaching point	5	Thin wire or rope.	Dynamic Longitudinal Stability testing.
8	Hobby Knives	10		Glider Construction
9	Glue	10	CA (cyanoacrylate), medium viscosity	For wood, quick setting.
10	Sandpaper	10 + 10	180 grit and 400 grit	For airfoil shaping.
11	SandBlocks	10	Suitable for the sandpaper size	For airfoil shaping.
12	Pencils	10	Soft point	Glider construction
13	Rulers	10	mm and inches	Glider construction
14	Notebook	10	Any	For taking notes and and later making a report.
15	Minor weight set	10	As necessary to balance.	Balancing the Glider CG.
16	Glider catapult	1	Made of PVC tubing	Glider launching.
17	Competition Manual and Rules	10		
18	Transporting box	10		For protection.
19	Access to the internet	10		Necessary

Notice: gloves will be provided as an optional accessory for the teams.