

Aircraft Design

Module #6

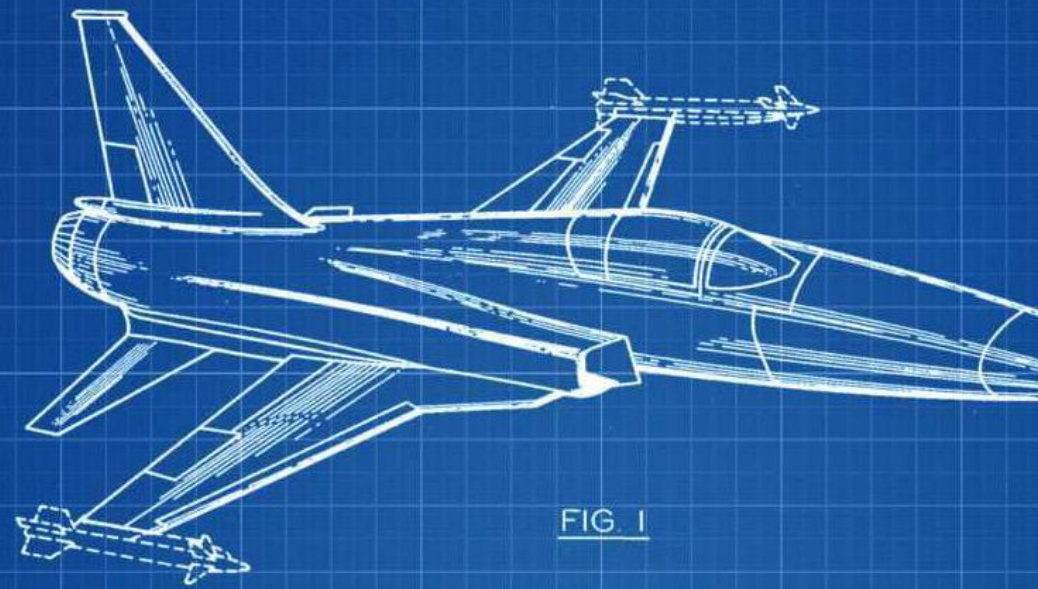


FIG. 1

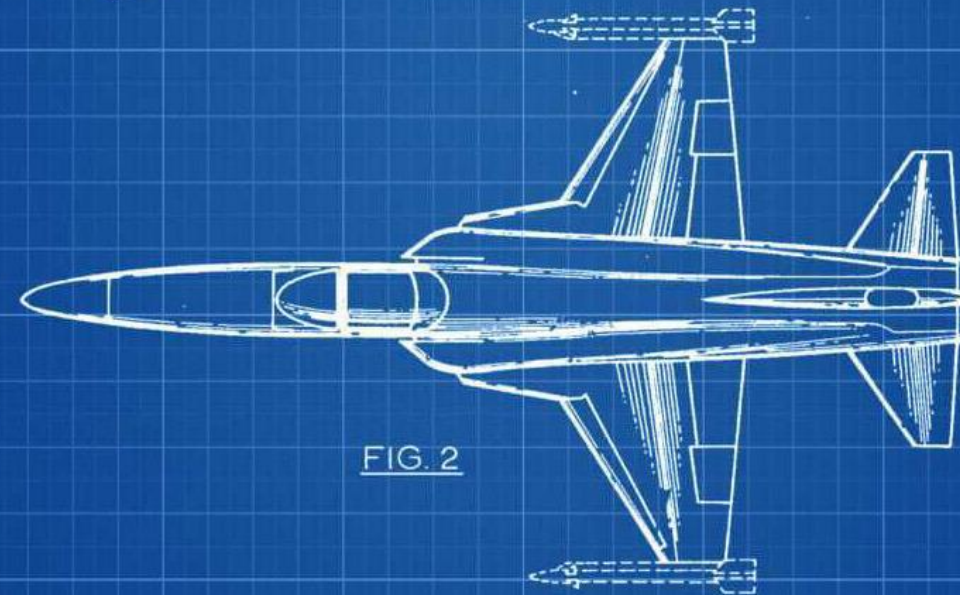
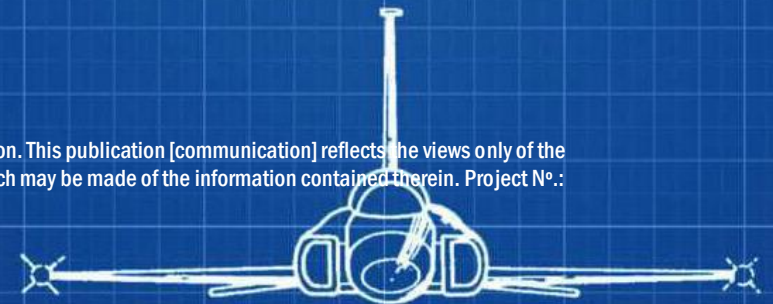


FIG. 2



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6. Aircraft Design

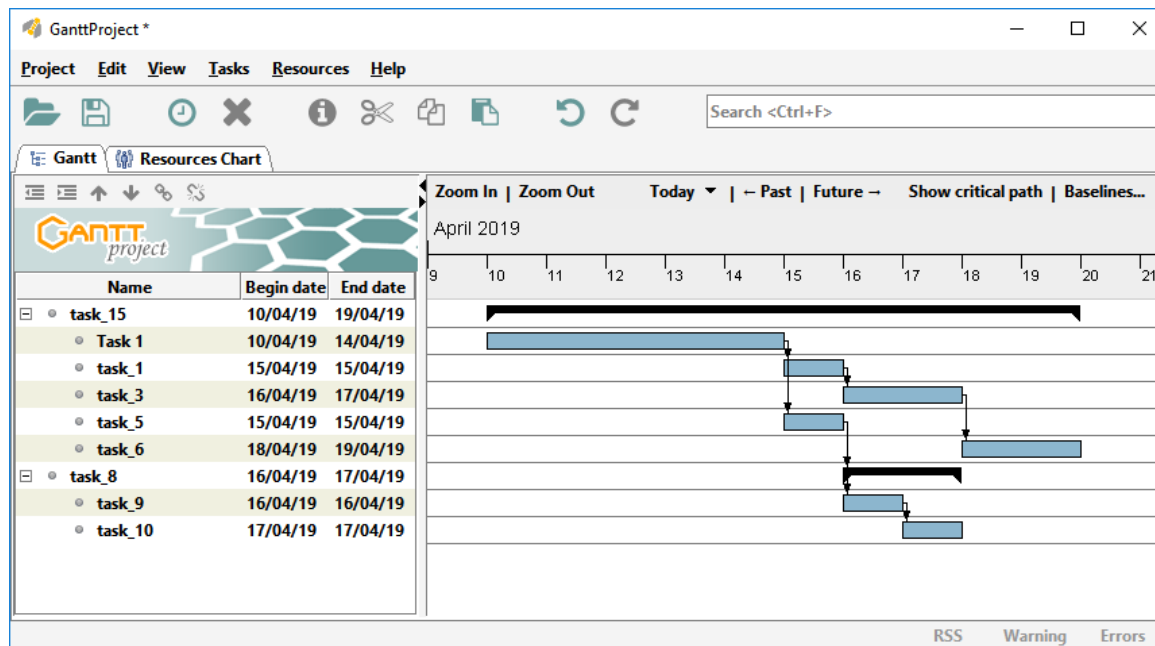
6. 1. Project Management

Before starting product development it's quite important that you plan the workload of the team, considering other activities such like your studies

You do not need sophisticated tools to do this. A spreadsheet is enough for this kind of project

In the “Learn&Fly Challenge” report you must include your planning

[illegible]



In more complex projects, and when a lot of activities depend on others, is generally used a Gantt chart to manage the project.

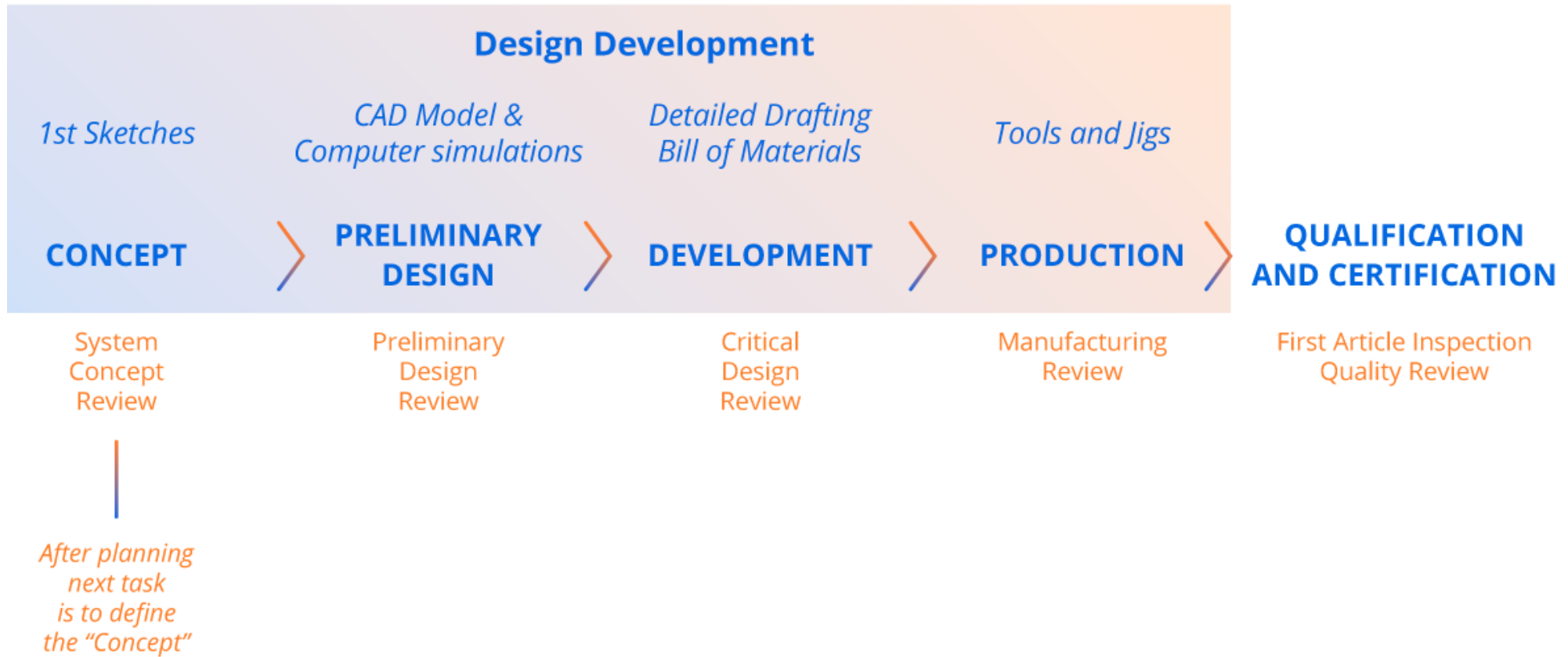
A Gantt chart is a visual presentation used in project management to show overview of timeline for project activities and their inter-dependence. This includes the management of resources, costs, issues and risks.

- Easy to understand
- Clarity of dates
- Brings efficiency and time management
- Allows coordination among stakeholders



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6. 2. Product Development



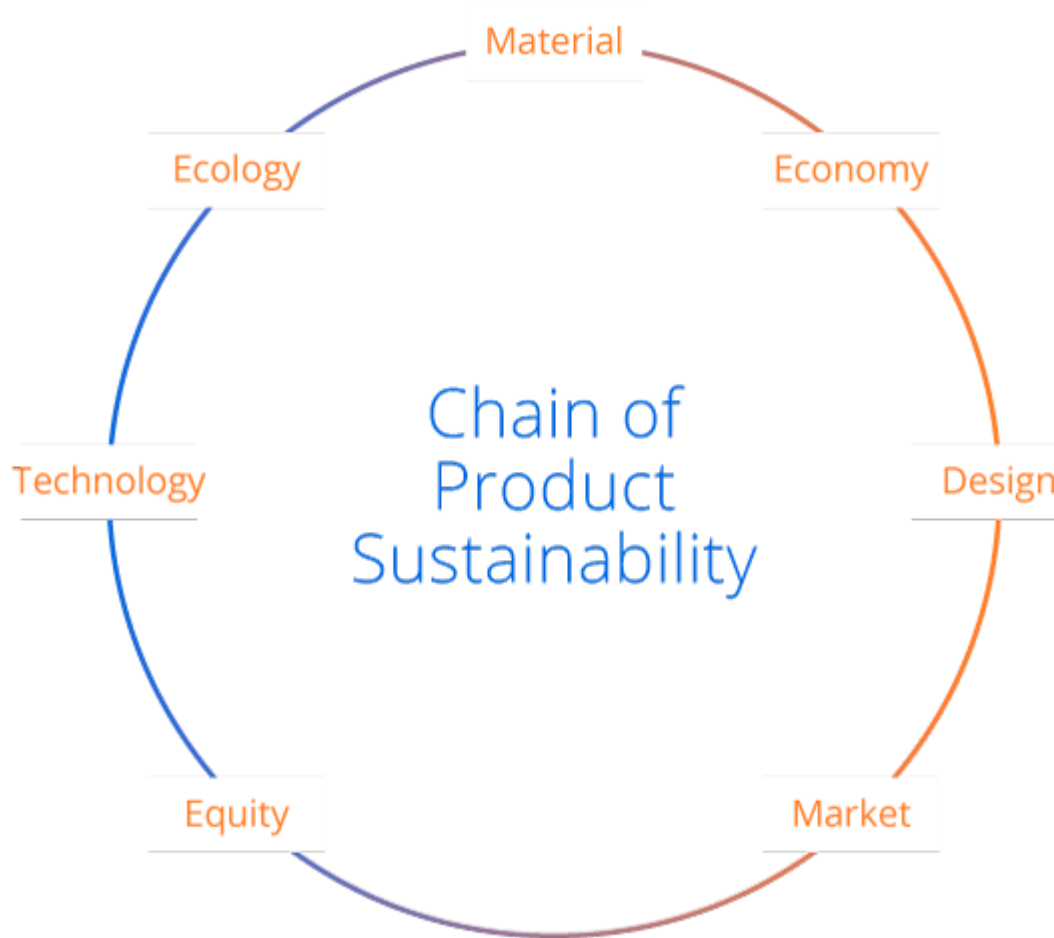
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6.3. Product Sustainability

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Material

- Minimize the material to use and try to reuse or recycle materials

Economy

- Consider the total cost during the life cycle, including recycling

Design

- Design for the environment and the product user as well as for recycling

Market

- Develop products according to the needs

Equity

- Reduce the impact on the local and global community

Technology

- Optimize raw materials and production process

Ecology

- Minimize the environmental impact

Materials and Design 28 (2007) 466–479

6. Aircraft Design

6. 4. Technical Requirements



www.learn-fly.eu

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Developed by Noriaki Kano in the 1980s, Kano Model Diagram helps to identify the requirements for your project

Must-be

These are the basic features that your product must have.

Examples: must fly; wing area $< 10 \text{ dm}^2$; payload 100g

One-dimensional

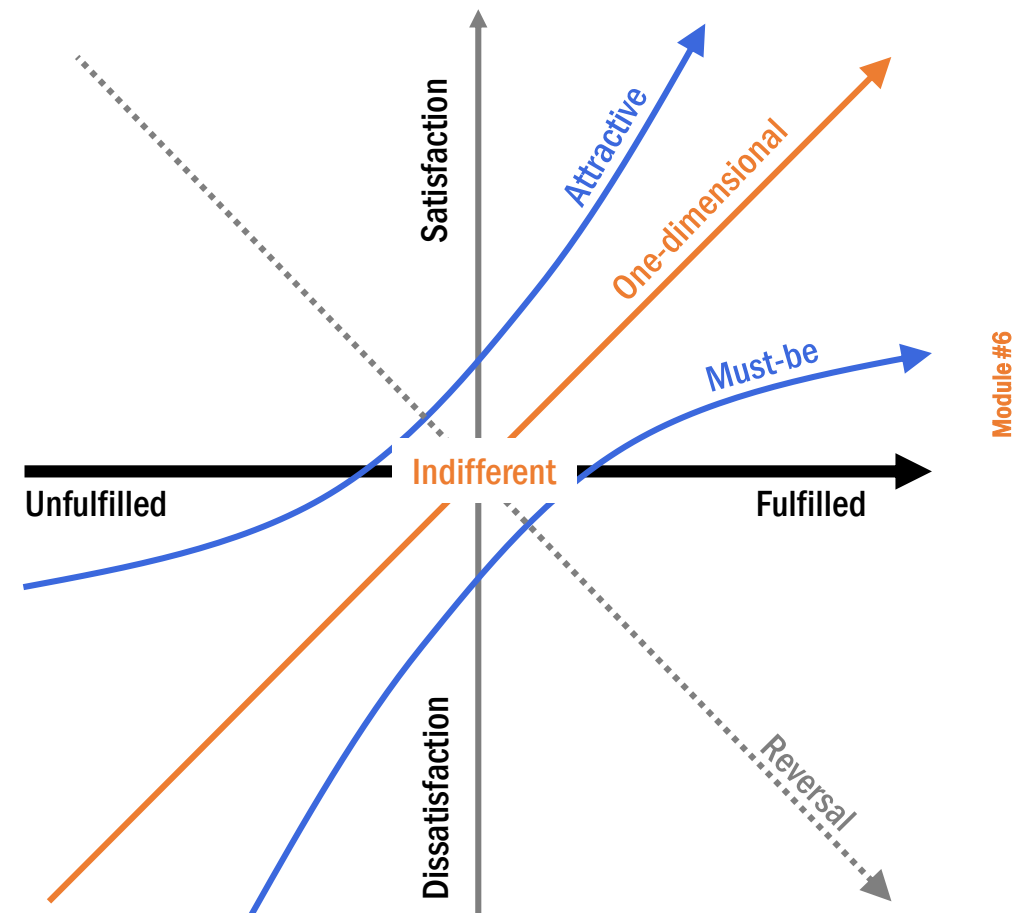
Also called performance features. The better you execute these better it will be your product

Examples: light construction; small drag, mass and balance well done

Attractive

These are the innovations that you bring to your product. Are in general unexpected pleasant surprises or delights.

Examples: new wing shape, different stabilizer shape, solution for wing disassembly



Indifferent

Requirements that are not important for the challenge

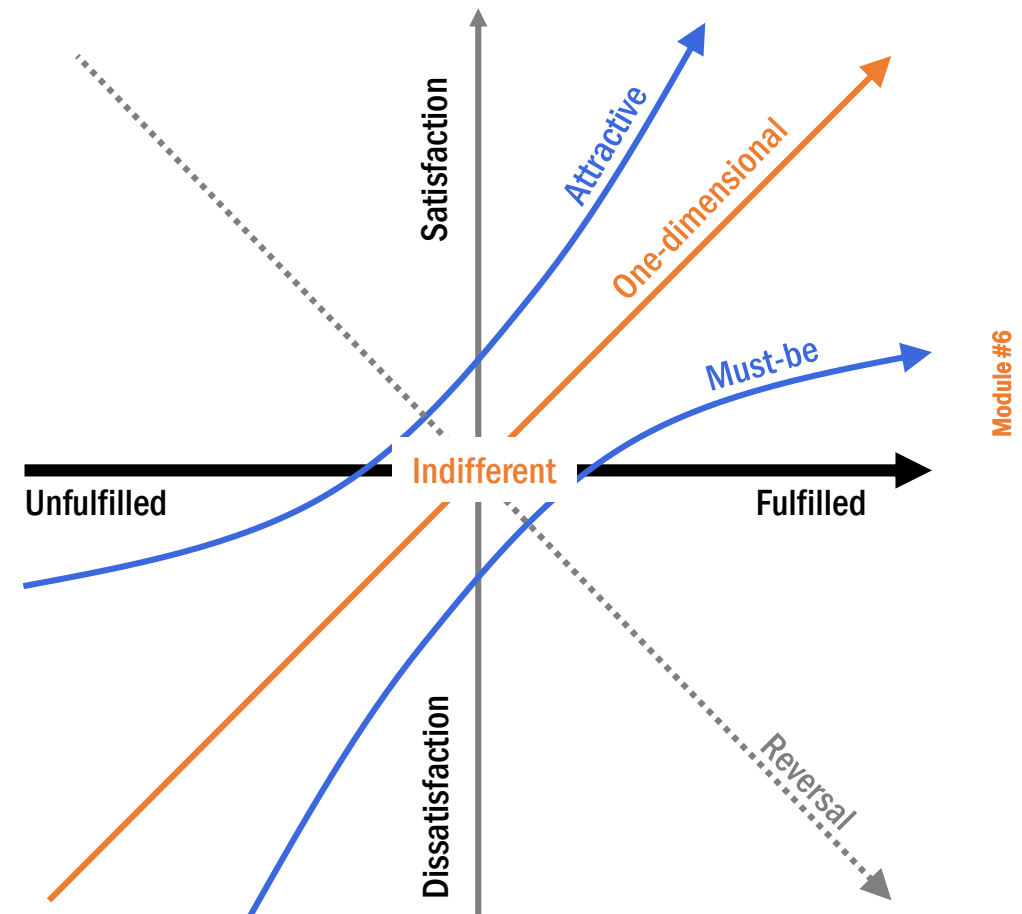
Examples: nice painting, all made from carbon fiber

Reversal

Causes dissatisfaction. Must be excluded from your product

Examples: standing support attached to the aircraft

To have customer satisfaction very high we need to include some one-dimensional and attractive requirements.

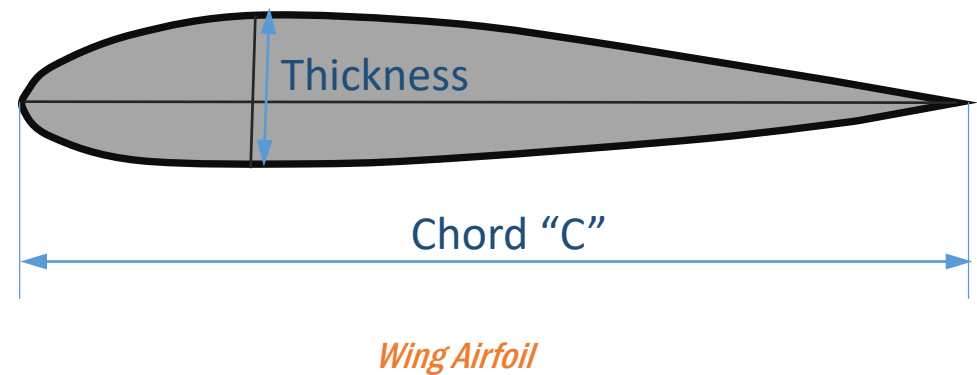


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6. 5. Tool to concept a glider model

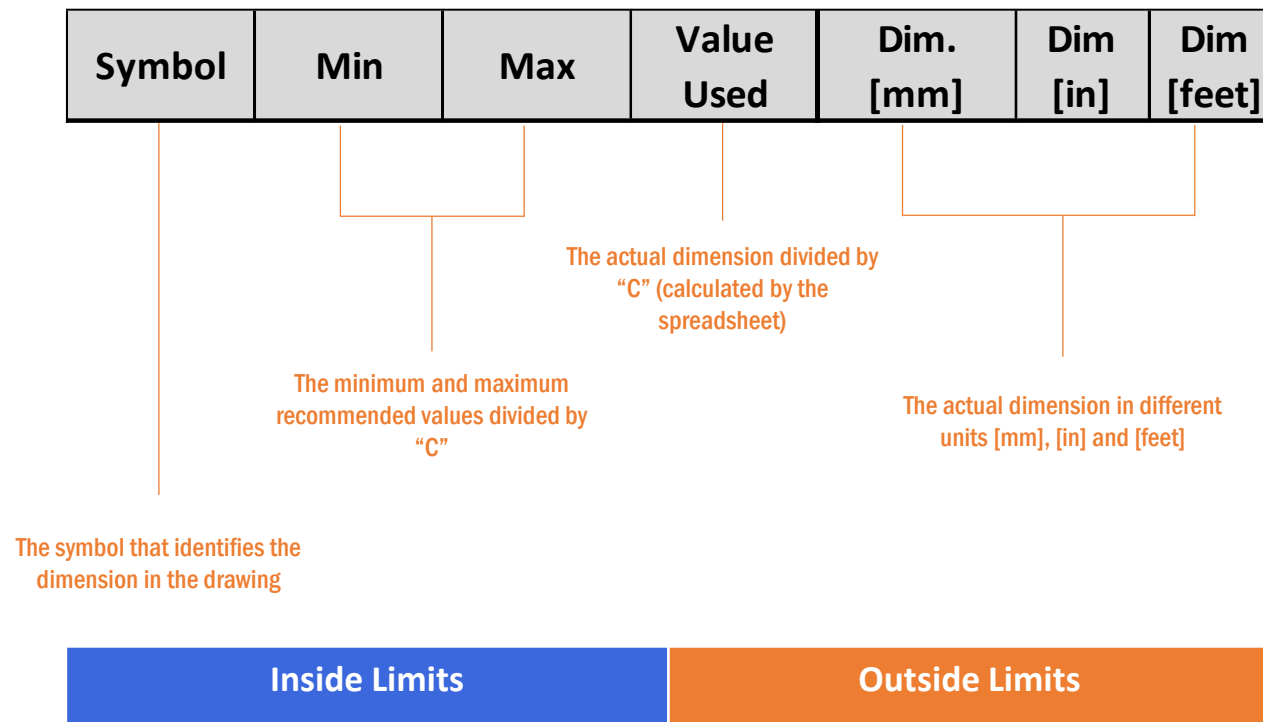
A spreadsheet tool is provided to concept your glider model

- This tool gives you the first approach about the dimensions and the most important parameters for your aircraft to fly
 - You can find this tool in moodle classes together with the slides
- All dimensions are related to the wing chord “C”. This means that if you define the wing chord all the other dimensions become defined, between certain limits
- Even if certain limits are passed, it can be a good solution, but more care must be taken

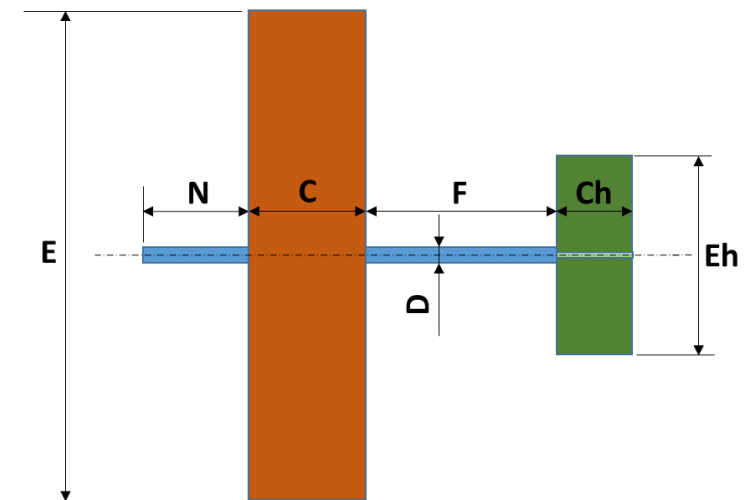
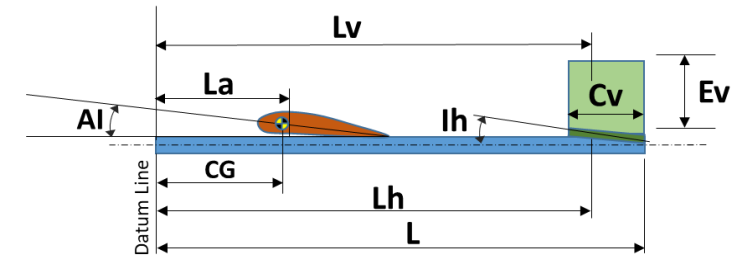


Header of the spreadsheet explained

1. Define the Chord “C” of the glider, filling in the white cell (F6).
Keep in mind that the projected area (in the case of a rectangular shape wing is the (Chord “C”) x (Wing Span “E”)) must be below 10 dm² and that the recommended wing span must be 8 to 10 times the chord
2. Define the Wing Span “E” considering that the area must be below 10 dm², that is 100000 mm²
3. Define the remain parameters of column (F). Cell “Value Used” becomes green if inside limits and orange if outside



	Symbol	Min	Max	Value Used	Dim. [mm]	Dim [in]	Dim [feet]
Wings							
Root Chord (C)	C	1	1	1,00	110	4,331	0,361
Wingspan (if glider 8 to 10C or more)	E	8	10	8,26	909	35,79	2,982
Incidence angle of wing [°]	AI	0	4	2,00	2		
Longitudinal position of wing (N + 1/4 C)	La	1,25	2,25	1,25	138	5,425	0,452
Area of wing (C x E) [unit] ²	A	0	100000	99990	99990	3937	328,1
Fuselage							
From wing leading edge to nose (1C)	N	1	2	1,00	110	4,331	0,361
From wing tail to leading edge of stabilizer (1,5 to 2C)	F	1,5	2	2,00	220	8,661	0,722
Fuselage total length (N+C+F+Ch)	L	4,17	5,75	4,75	523	20,57	1,714
Fuselage diameter	D				20	0,787	0,066
Horizontal stabilizer							
Chord of horizontal stabilizer (2/3 to 3/4 of C)	Ch	0,67	0,75	0,75	83	3,248	0,271
Length of horizontal stabilizer (2 to 2,5C)	Eh	2	2,5	2,50	275	10,83	0,902
Incidence angle of horizontal stabilizer (0° to 5°) [°]	Ih	-5	0	-1,00	-1		
Longitudinal position of horizontal stabilizer (of C)	Lh	3,67	5,19	4,18	460	18,11	1,509
Vertical stabilizer							
Chord of vertical stabilizer (3/4 to 1C)	Cv	0,75	1	0,75	83	3,268	0,272
Height of vertical stabilizer (1C)	Ev	1	1	1,00	110	4,331	0,361
Longitudinal position of vertical stabilizer	Lv	3,6875	5,25	4,23	465	18,31	1,526
Control Surfaces (optional)							
Chord of horizontal stabilizer (1/3 of stabilizer chord)	Clp	0,33	0,33	0,33	36	1,429	0,119
Chord of vertical stabilizer (1/2 of stabilizer chord)	Cld	0,5	0,5	0,50	55	2,165	0,18
Aileron chord (1/3 of C)	Cla	0,33	0,33	0,33	36	1,429	0,119
Aileron length (2C)	Ela	2	2	2,00	220	8,661	0,722
Centre of gravity position (CG) (N + 1/4 C)	CG	1,1	1,3	1,23	135	5,315	0,443



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6. 6. Glide ratio

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Glide ratio is the relation of total distance travelled horizontally in still air by the altitude lost.

Glide ratio of 20:1 mean that the glider will lose 1 meter in altitude for each 20 meters travelled in horizontal

To increase this you must be careful with the design and construction:

- Appropriated airfoil, wing geometry and right angles
- Light weight construction
- Appropriate dimensions
- Well balanced aircraft





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6. 7. Airfoil Design

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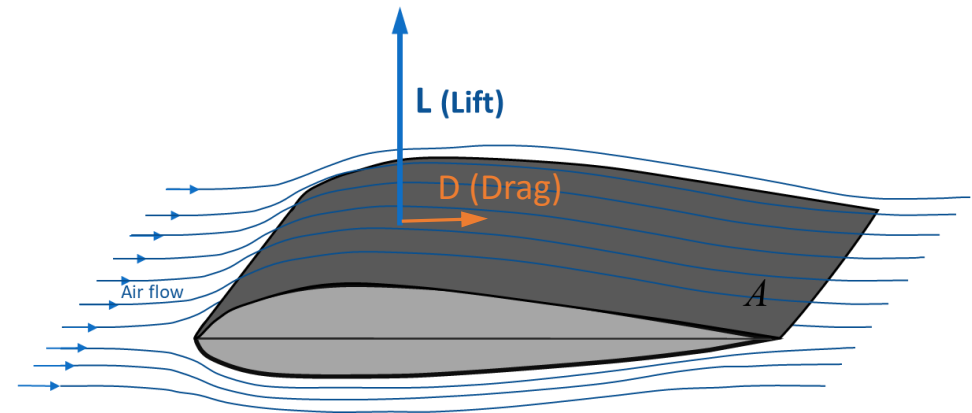
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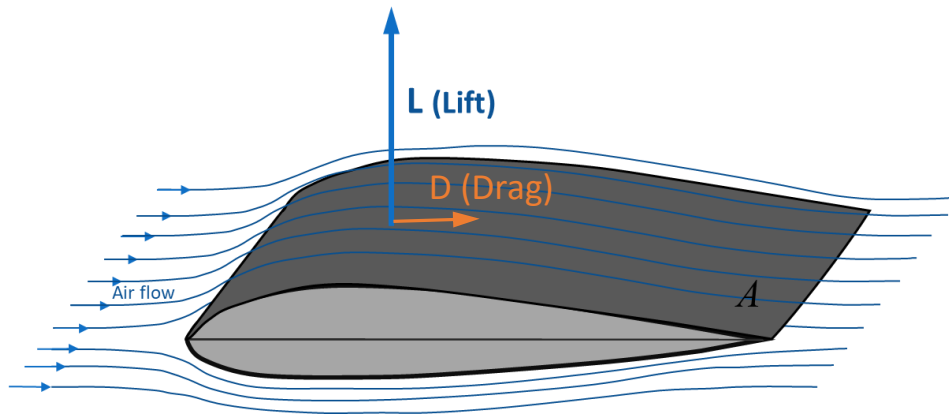
The aerodynamic behaviour of the aircraft is very important to archive the maximum possible glide ratio (in case of “Learn&Fly Challenge” the maximum travelled distance).

The wing has a strong influence in the aerodynamics, creating the Lift force to sustain the weight. However the wing also creates a Drag force that must be minimized. The values of Lift and Drag force can be calculated knowing the C_L and C_D coefficients

- There are thousands of airfoil profiles available. Depending on the kind of aircraft the right airfoil must be chosen.
- For the aircraft you are designing, that flies like a glider, it is very important to achieve the highest possible relation of C_L/C_D with a certain angle between the chord and the airflow (alpha angle, of next slides).

Next slides will provide you tools to obtain Lift and Drag forces of an airfoil.





$$L = \frac{1}{2} \rho v^2 A c_L$$

$$D = \frac{1}{2} \rho v^2 A c_D$$

- C_L and C_D depends of the type of airfoil and the angle of attack of the flow.
- For each airfoil it is possible to obtain the graphics of C_L and C_D
- As an example, can be used the link of Airfoil Tools - <http://airfoiltools.com> to choose an airfoil.
- For example the airfoil NACA2412 has the following graphics

L – Lift force (N - Newton)

ρ – Air density (1.225 kg/m^3 at 15°C and 1013hPa)

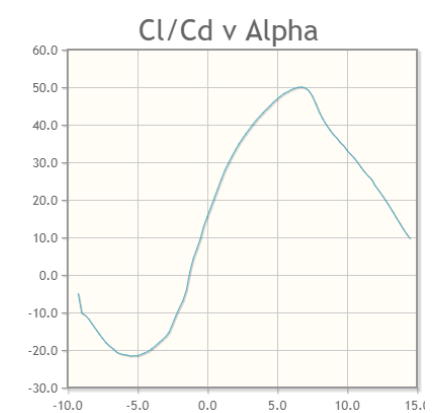
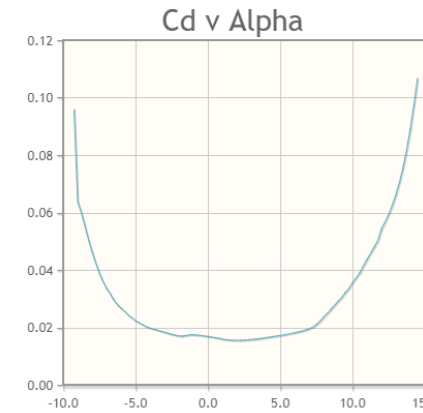
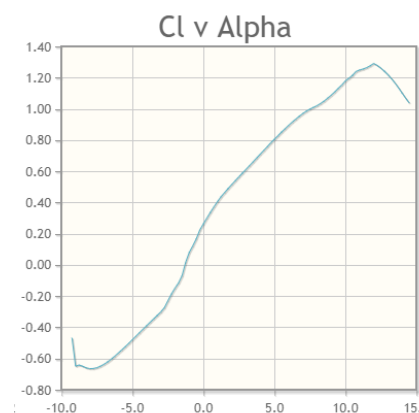
v – velocity or airspeed (m/s)

A – Wing area surface (m^2)

C_L – Lift coefficient (dimensionless)

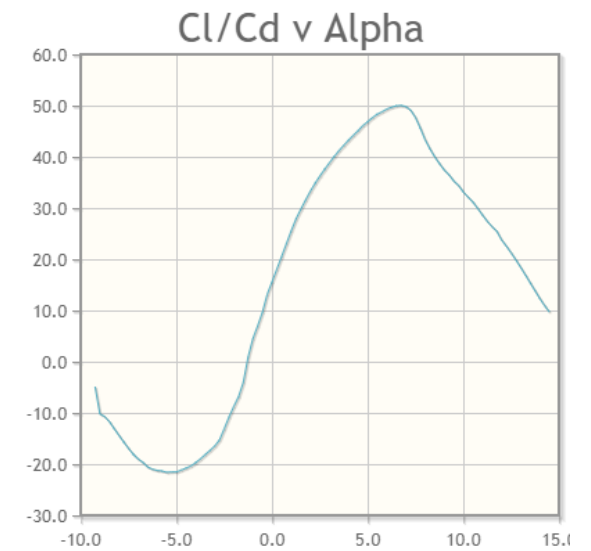
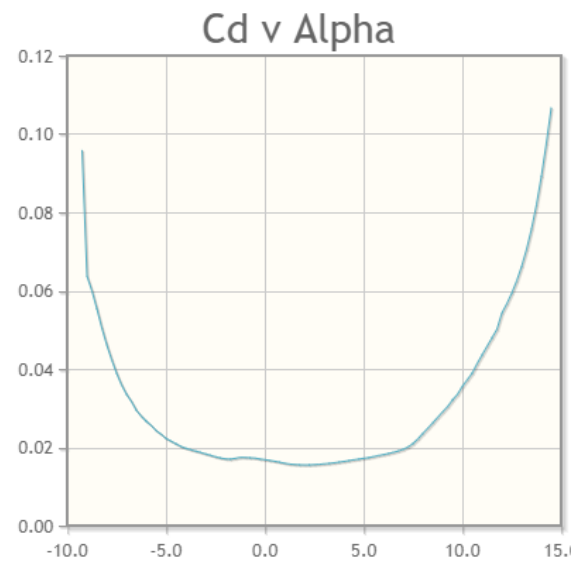
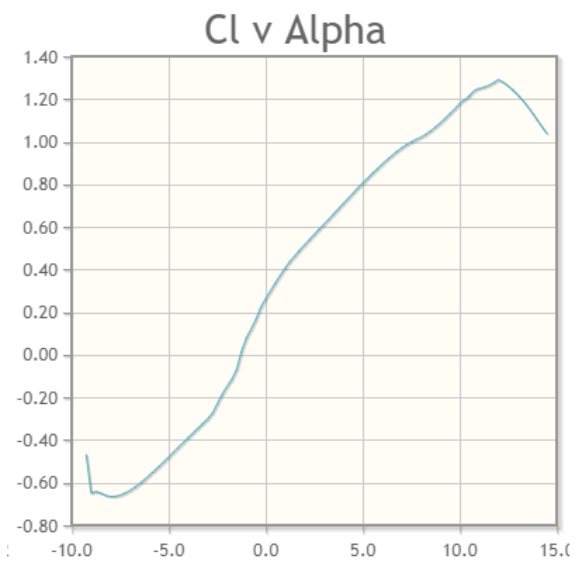
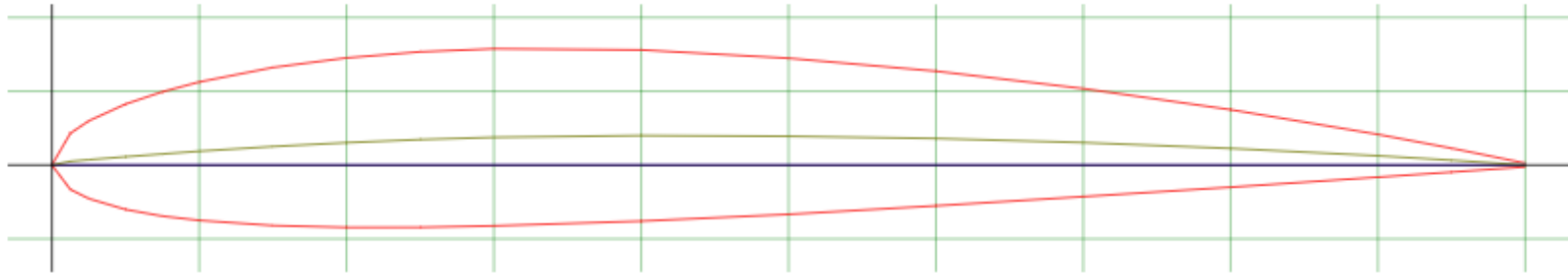
C_D – Drag coefficient (dimensionless)

Alpha – Angle between the chord and the air flow



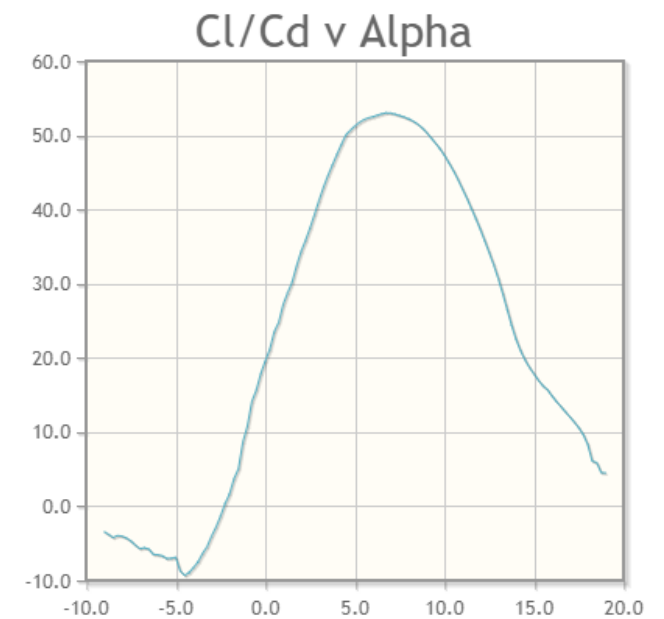
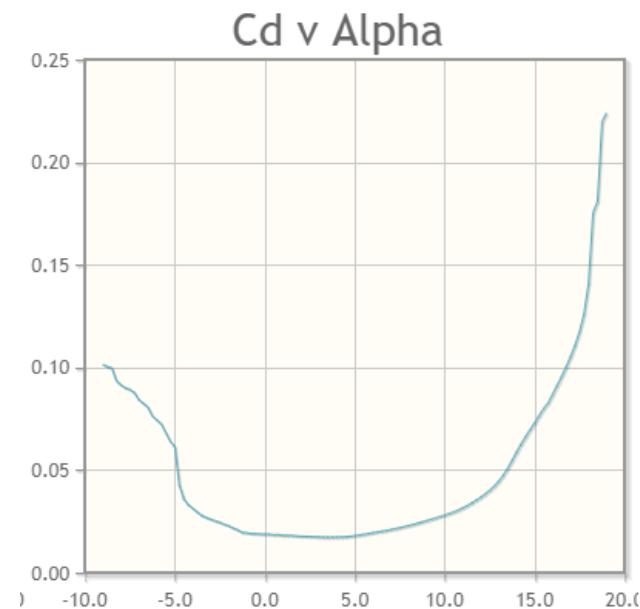
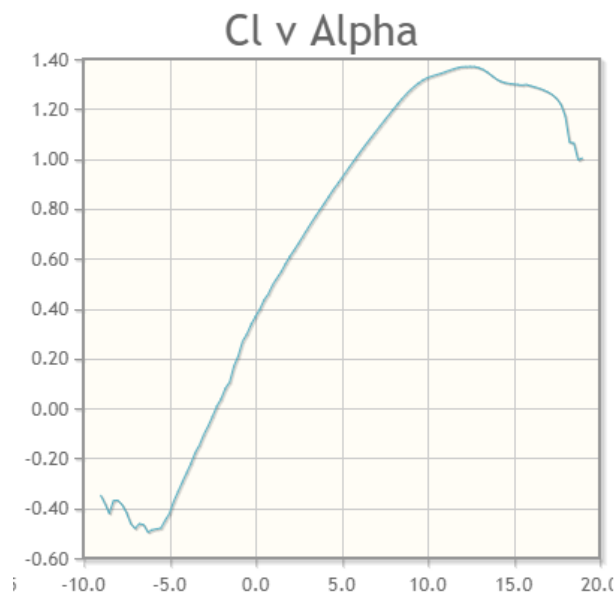
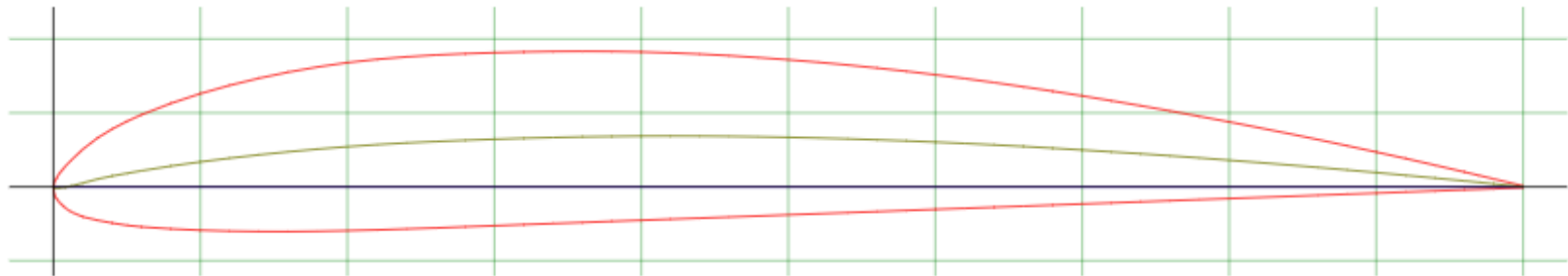
Common airfoils that can be used

NACA2412

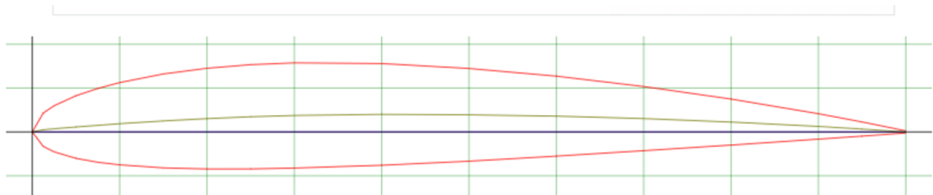


Common airfoils that can be used

Clark Y



Example of calculation Lift and Drag forces using NACA2412



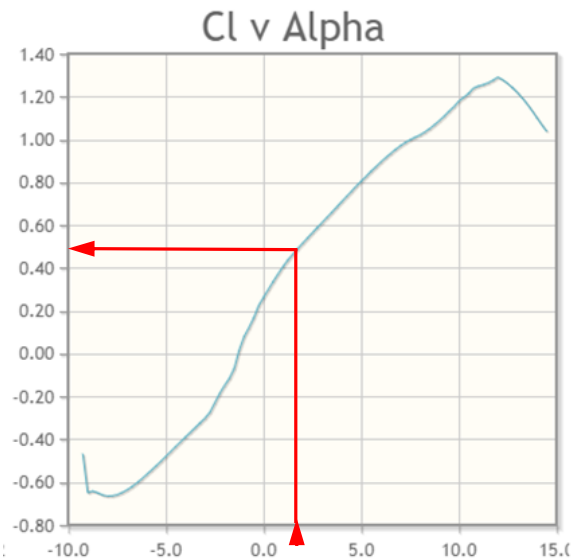
$$L = \frac{1}{2} \rho v^2 A c_L$$

Data for calculation Lift and Drag

	Value	Units
Air density	1.23	Kg/m ³
Air velocity	10 (36)	m/s (km/h)
Wingspan	909	mm
Chord	110	mm

Wing Area

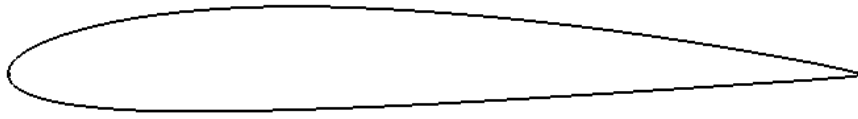
$$A = 909 \times 110 = 10000 \text{ mm}^2 = 0.10\text{m}^2$$



Assuming an angle of incidence of 2°
(value when aircraft is launched)

$$C_L = 0.5$$

How to build your ribs with the right section



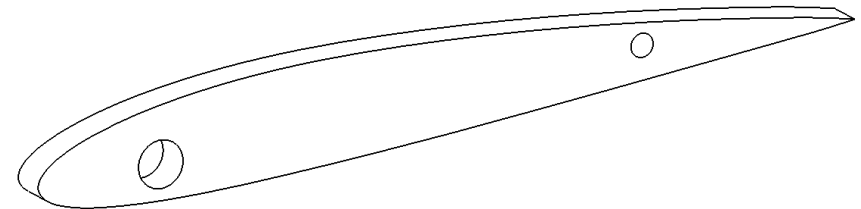
Example of a 2D geometry, section NACA 2412

3D printing the section

- If you have a 3D printer available, you can print a mould for wire cutting (see section 4.1.2).
- You need to protect the surface of the printed mould where the hot wire passes, with for example aluminium tape, to avoid burning it with the wire.

Having defined the right section you must build the ribs. For that you probably need a mould.

- As an example, can be used the link of Airfoil Tools - <http://airfoiltools.com> to get the coordinates of the geometry.
- Most of the CAD software available allow to import these points and draw the geometry for you. You can find in internet the best way to do it.
- Printing the section in a sheet you can use this drawing to cut the sections



Example of a 3D geometry, section NACA 2412

6. Aircraft Design

6. 8. Wing Drag

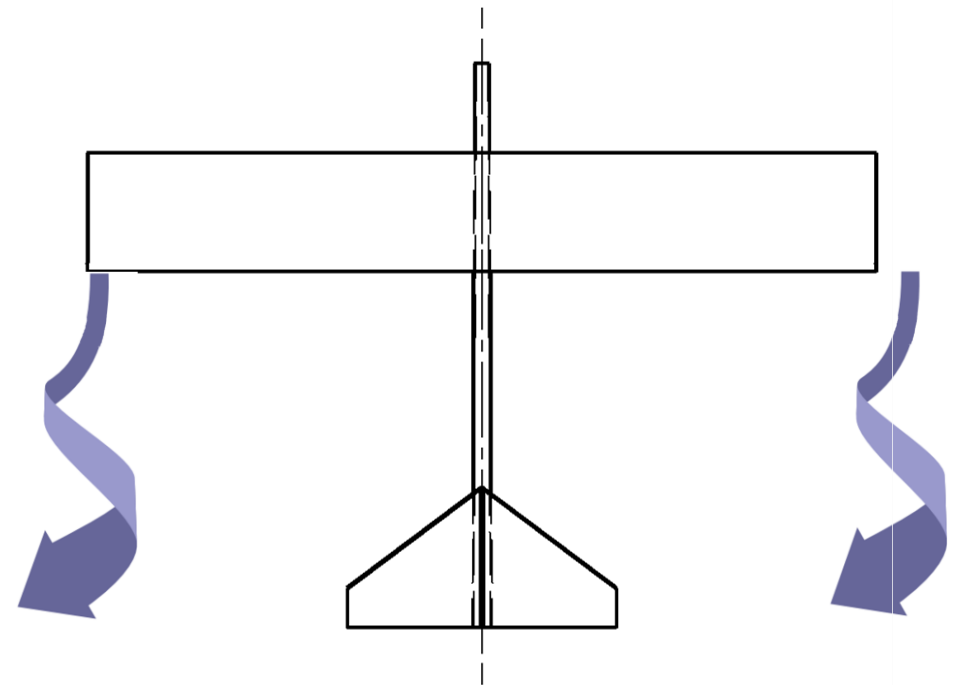
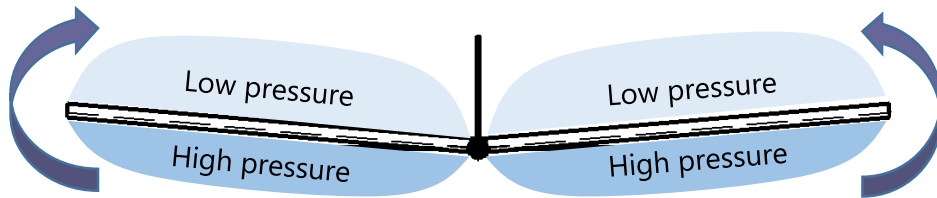
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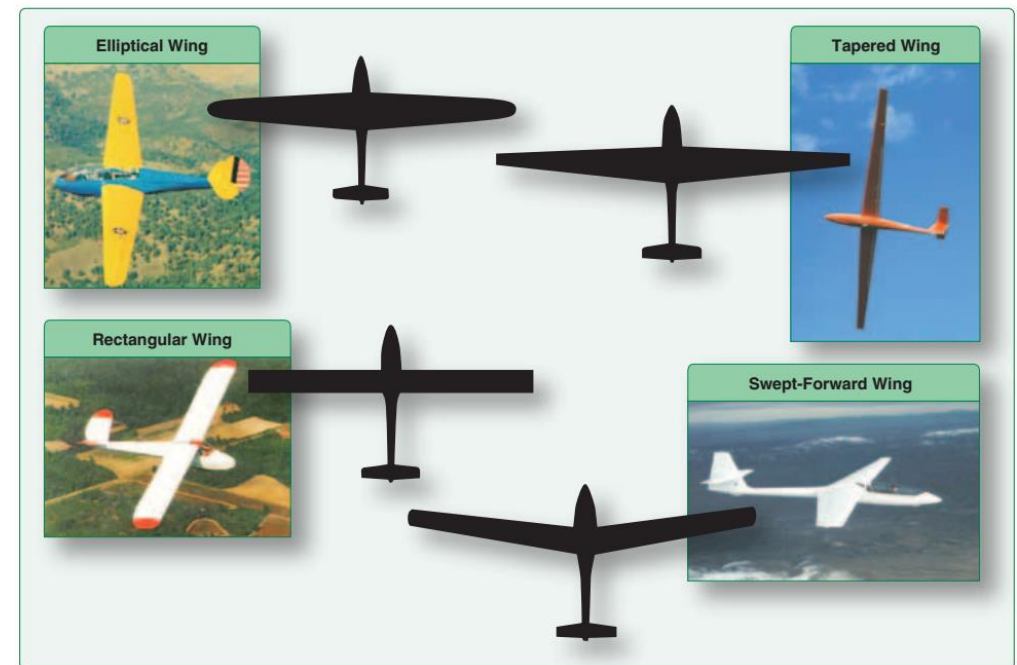
One of the most important factors that reduces wing efficiency is the wing tip

- Produces vortices, losing energy
- The lower pressure above the wings produces an inward lateral flow



The shape of the wings also affects the amount of lift and drag produced. The more commons are:

- **Elliptical**
Minimizes the induced drag but is very difficult to build
- **Rectangular**
Much easier to build than the elliptical shape
- **Tapered**
More frequent in gliders. Less drag than rectangular because wing tip is smaller
- **Sweep-forward**
Used in some two seats gliders to move CG and to increase maneuverability.



Glider Flying Handbook, FAA, FAA-H-8083-13A, 2013



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6. 9. Lateral Stability

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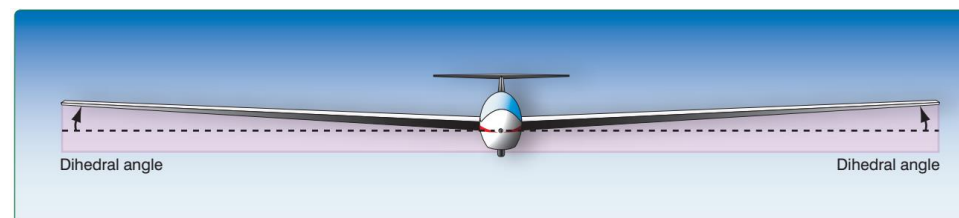
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Sometimes the aircraft has a tendency to do some rolling movement, turning to one side.

This is not wanted in the “Learn&Fly Challenge”, since only the distance travelled according to the ideal flying patch (which is a straight line) is accounted for .

To reduce this effect you may add an amount of dihedral angle as shown in the image bellow.

- If one of the wings goes down, the angle of attack increases, because the air is moving up past it, increasing the lift and turning the aircraft again to the horizontal position



Glider Flying Handbook, FAA, FAA-H-8083-13A, 2013

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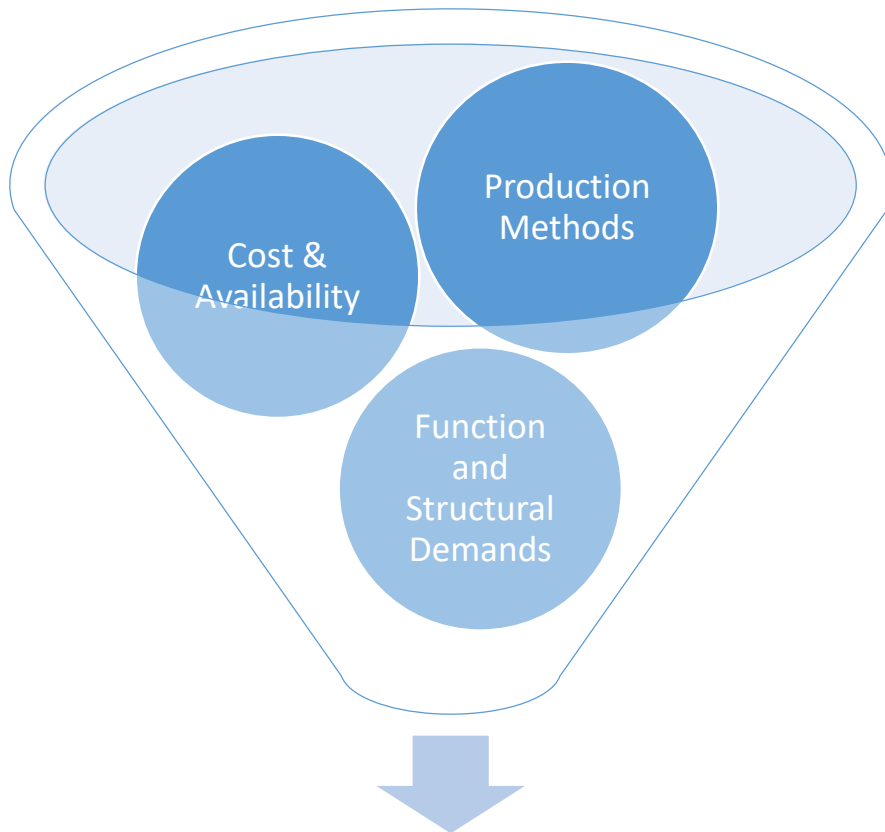
6. 10. Material Selection



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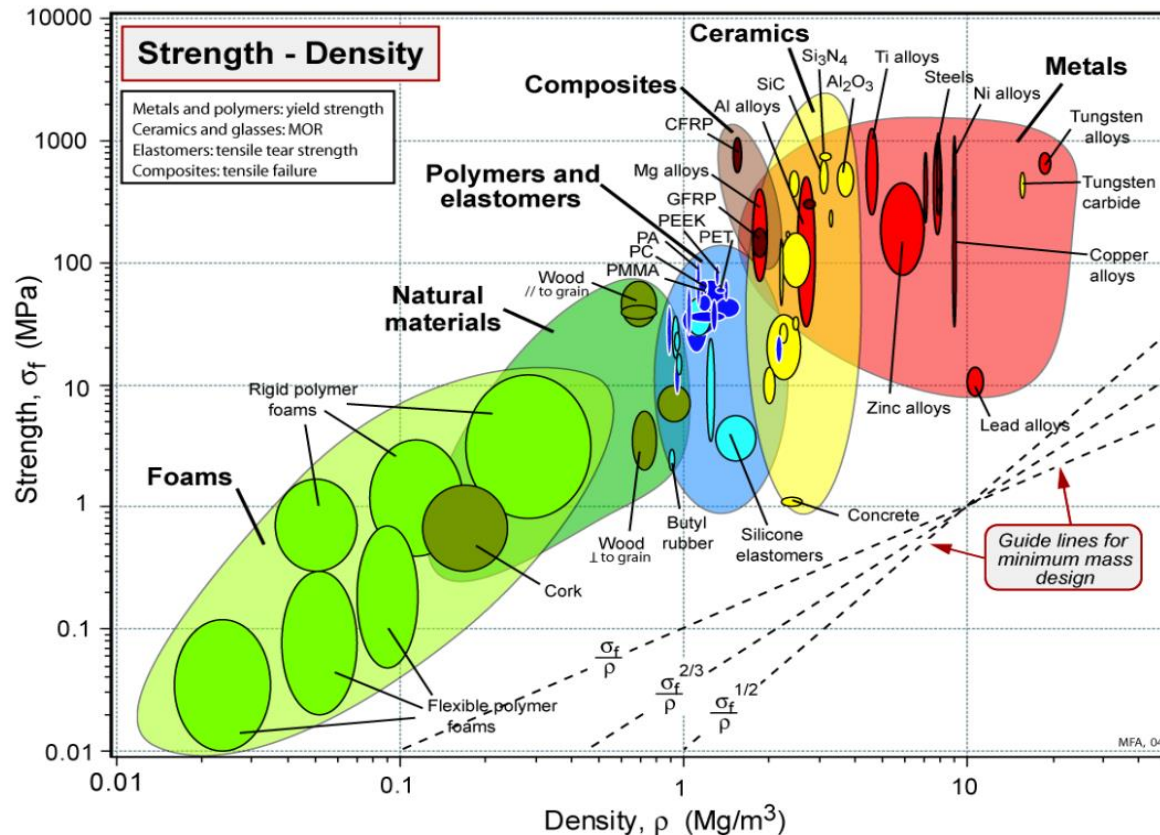
Correct Material Selection

There are several ways to choose the materials for your aircraft. You must optimize materials selection mainly regarding the following items:

- Materials must render a lightweight aircraft
- Materials function in the structure and the imposed demands
- Materials cost and availability in the market
- The production methods available for you to transform those materials

For other applications you may also take notice in interested in aspects such as:

- Market or user demands
- Design
- Environmental impact
- Lifetime



Materials and Process Selection Charts, Granta, 2010

- Select the most appropriated materials according to your vision of the aircraft and the related requirements. Remember that in aeronautics is crucial to use materials with optimised Strength vs Density ratio
- Possible implications in the model aircraft:
 - Foams are very light weighted but have low strength
 - They can be appropriate to shape wing ribs
 - Composites have very high strength, but much higher density than foams
 - They can be appropriate for specific structural parts, such as wing spars

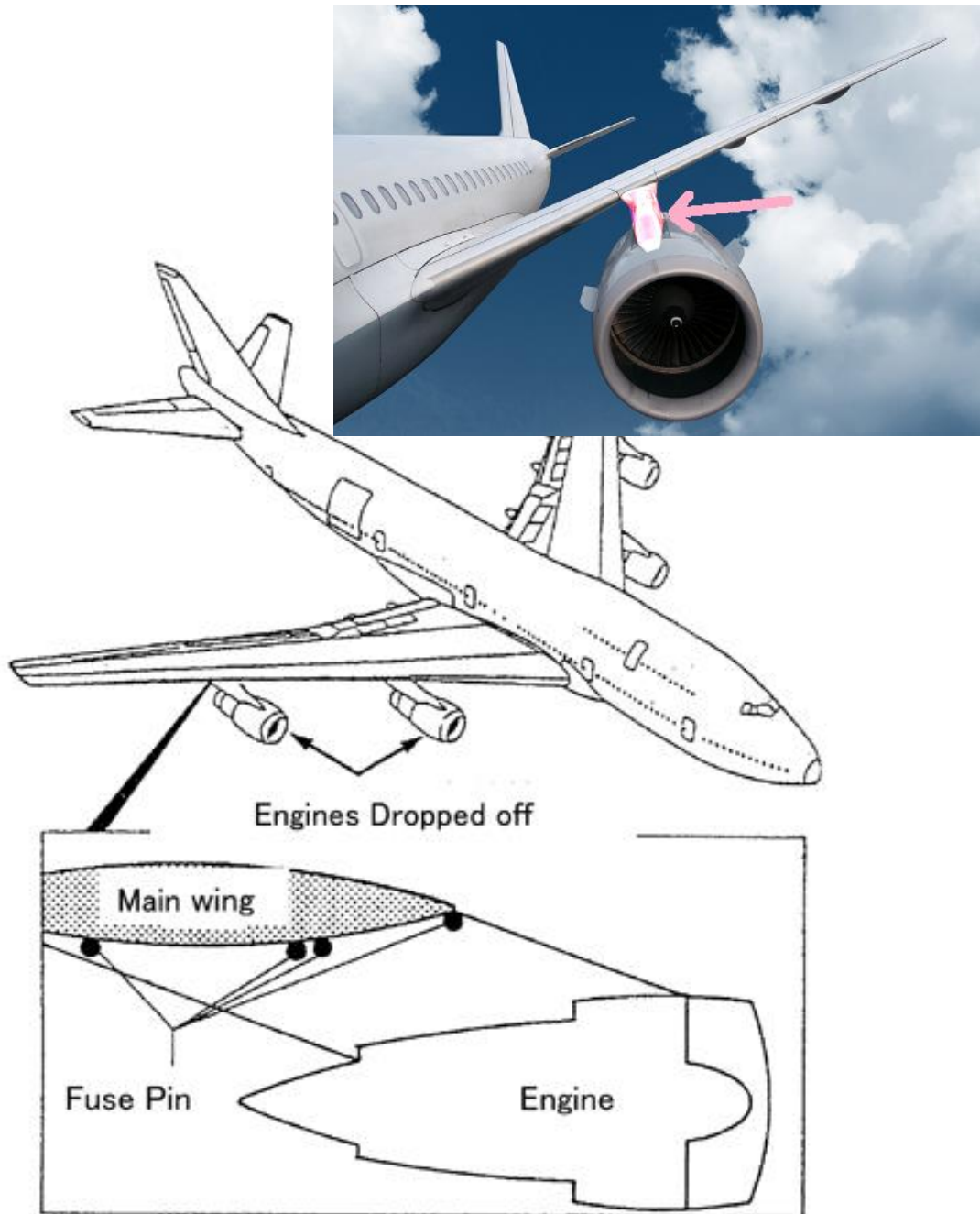
6. Aircraft Design

6. 11. Fuses

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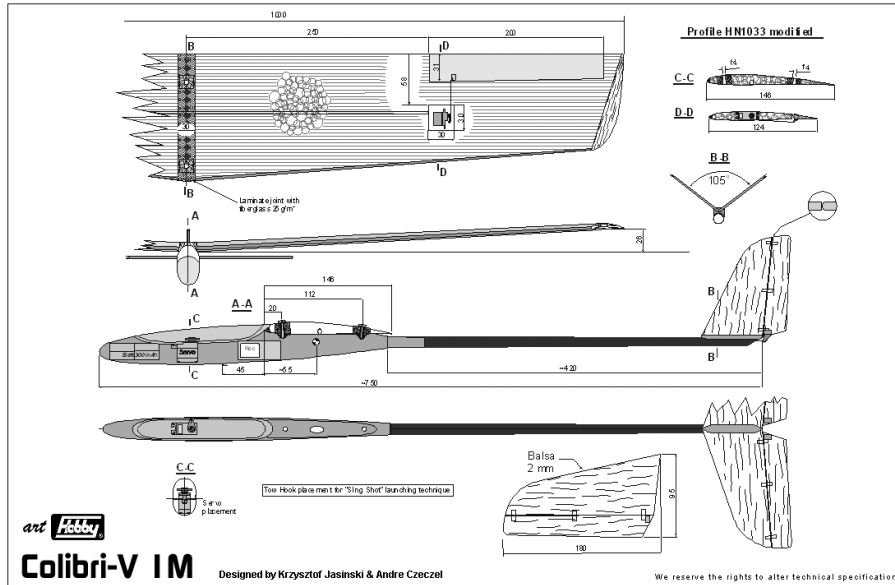
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- In many situations fuses are used to protect mechanical systems.
- In aircraft fuses are frequent. For example fuse pins are used to sustain the engines. In the event of large engine vibrations, crash landing or other hard landing in order to protect the fuselage the fuses break, losing the engine, protecting the wing and fuselage of the aircraft.
- In your aircraft model you can also use mechanical fuses to avoid losing your aircraft when it crashes in the ground. It may help you to pass the drop test that is expected at the end of “Learn&Fly Challenge”.

6. Aircraft Design

6. 12. Drawings



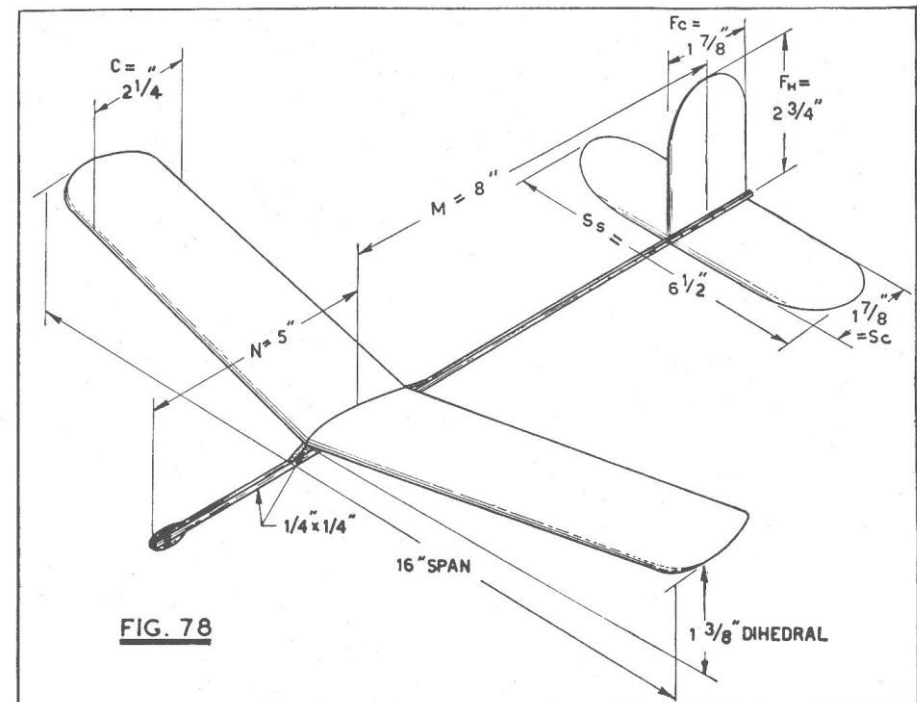
You can also attach a drawing with general dimensions using an isometric representation.

You can do it by hand with the aid of the sheet grid provided in section 5.5.7.

You must provide detail drawings of your project, which for “Learn&Fly Competition” can be made by hand using the multiple view representation

- Detail attachments of the wing and stabilizers
- Show how do you separate the wing in two
- Where should be the centre of gravity
- Show special features of your aircraft, like dihedral angle etc...

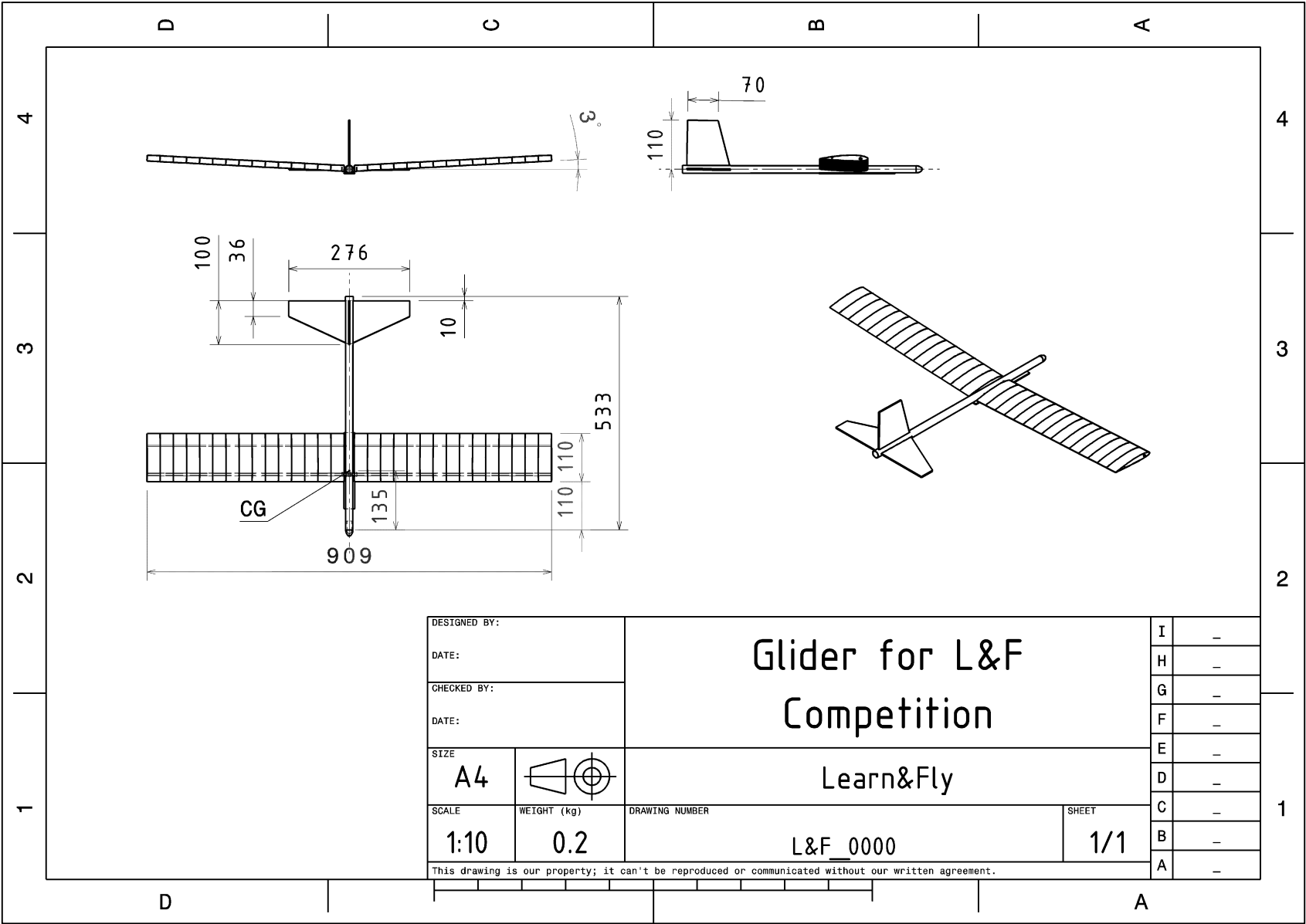
Remember that these drawings must be understood by everyone

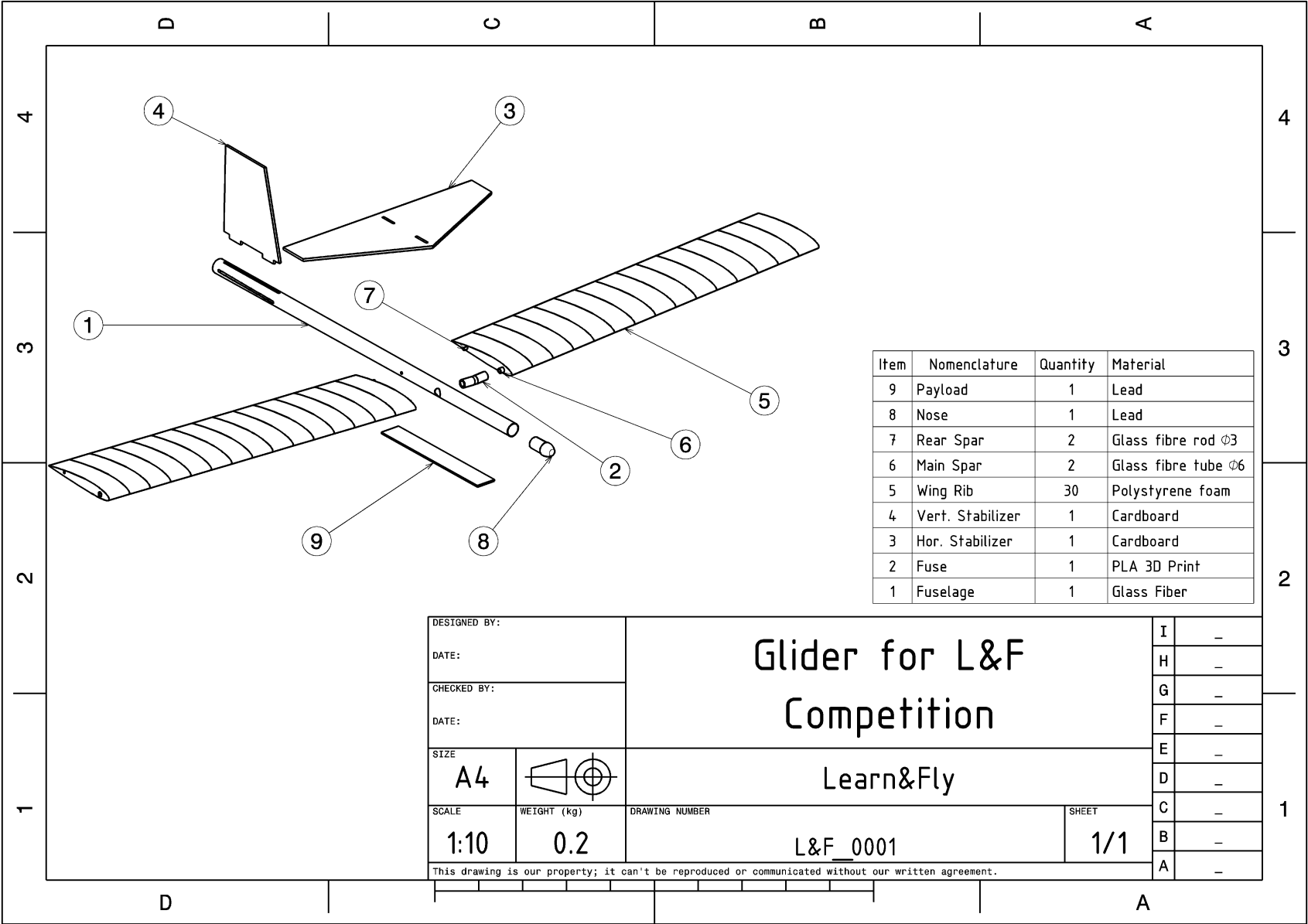


Material	Component	Weight ¹ (kg)	Cost (€)	Obs. ¹
High density polystyrene foam (0.85m x 0.6 m)			4 €	Provided
Glass fibre tubes (φ6 x 1 m)			3 €	Provided
Glass fibre rod (φ2.5 x 1 mm)			2 €	Provided
Glass fibre tube (fishing rod) (4 elements)			6 €	Provided
Cardboard 3 mm (0.5x0.35 m)			2.5€	Provided
Glue for polystyrene foam			4.5€	Provided
Velcro strip band			0.5 €	Provided
Payload		0.1	0 €	Provided
...				
Total				

- In aeronautical drawing is frequent to present the Bill of Materials (BOM) in a separate list.
- For “Learn&Fly Competition” you must include this list in the report as fellows.
- Include also the cost of the materials:
 - Full size row materials
 - 50% reduction for reused materials
 - Materials provided must be accounted as presented in the table

Total budget: 50€





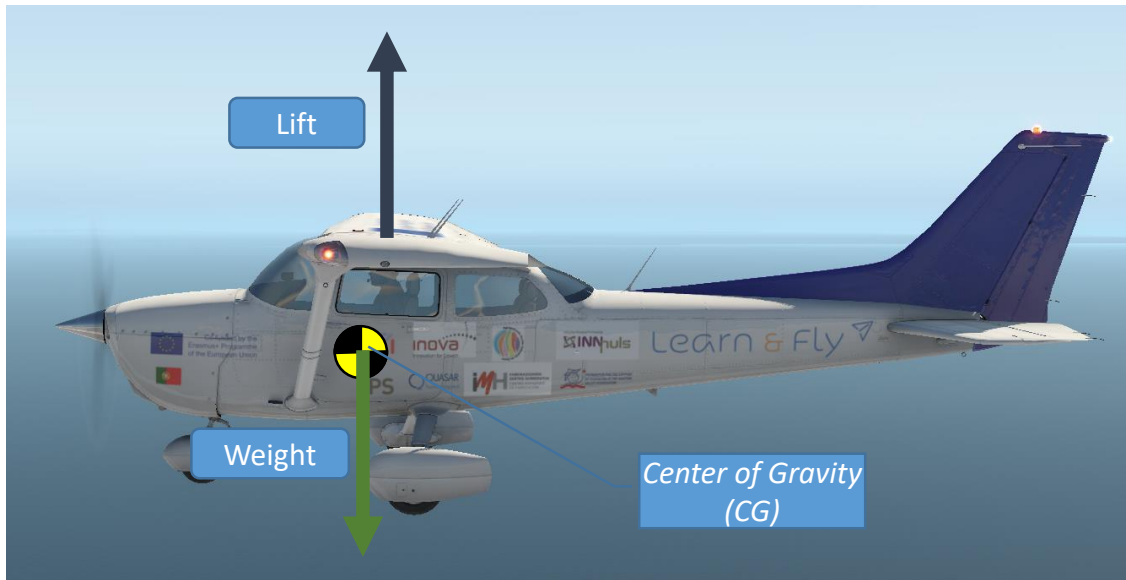
6. Aircraft Design

6. 13. Mass and Balance

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- The centre of gravity (CG) position is quite important that your aircraft to fly, and that flies efficiently
- During “Preliminary Design” you must calculate the correct position of CG
- In general you must add mass close to the nose of the aircraft to balance

To calculate the CG position you must define a reference (Datum Line) that in this case can be the nose (distance d)

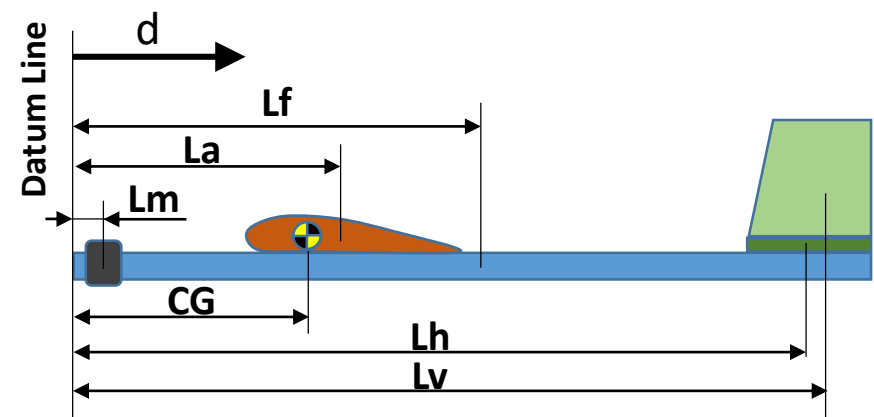
According to section 3.4.1, the CG position can be calculated as follows:

$$CG = \frac{\sum \text{Weight} * d}{\sum \text{Weight}} = \dots$$

being the Weight the individual weights of each component and d the distance of each component (L_f , L_a , L_m , L_h , L_v ...) to the datum line (CG position of each one)

$\sum \text{Weight}$ represents the weight of the whole aircraft

The CG value will come in the units that you used for d , and measured from datum line reference.



CG - Centre of gravity position
L_f - Longitudinal position of fuselage
L_a - Longitudinal position of wing
L_m - Longitudinal position of added mass
L_h - Longitudinal position of horizontal stabilizer
L_v - Longitudinal position of vertical stabilizer

	A	B	C	D	E
1	Component	Material	Expected Weight	Longitudinal Position "d"	Weight*d
2	Wing				=C2*D2
3	Fuselage				=C3*D3
4	...				=C4*D4
5	TOTALS		=sum(C1:C4)		=sum(E1:E4)
6	CG				=E5/C5

You can use a spreadsheet to calculate the CG position

Use formulas to obtain:

- the "Weight" multiplied by "d"
 $=C2*D2 \dots$
- the total weight (sum all the individual weights)
 $=sum(C1:C4)$
- the total "Weight* d" (sum all the individual "Weight* d")
 $=sum(E1:E4)$
- The CG position can be obtained in the spreadsheet by calculating in a new cell the value of:
 $=E5/C5$

You can find another example how to calculate the CG in section 3.4.3.

Mass of some materials provided

Material	Weight/Unit	Unit
High density polystyrene foam (20 mm tick)		g/m ²
Glass fibre tubes (ϕ6)	25.50	g/m
Glass fibre rod (ϕ3)	18.30	g/m
Glass fibre tube (fishing rod) (1st element ϕ 24 to ϕ 21)	76.40	g/m
Glass fibre tube (fishing rod) (1st element ϕ 20 to ϕ 16)	65.00	g/m
Glass fibre tube (fishing rod) (1st element ϕ 15 to ϕ 8)	28.86	g/m
Glass fibre tube (fishing rod) (1st element ϕ 7 to ϕ 2)	10.72	g/m
Cardboard 3 mm (0.5x0.35 m)	404.8	g/m ²
Payload	100.0	g

- You can check if your aircraft is correctly balanced by supporting it close to the centre of gravity (aprox. $\frac{1}{4}$ of the wing chord) on the extremities of the wings
- A well balanced aircraft will remain horizontal
- A simple way to balance the aircraft is to add or remove mass in the nose



6. Aircraft Design

6. 14. How to launch your aircraft



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Hold on firmly the aircraft close to the CG position

Remain in a fixed position

Launch the aircraft horizontally with a good impulse force

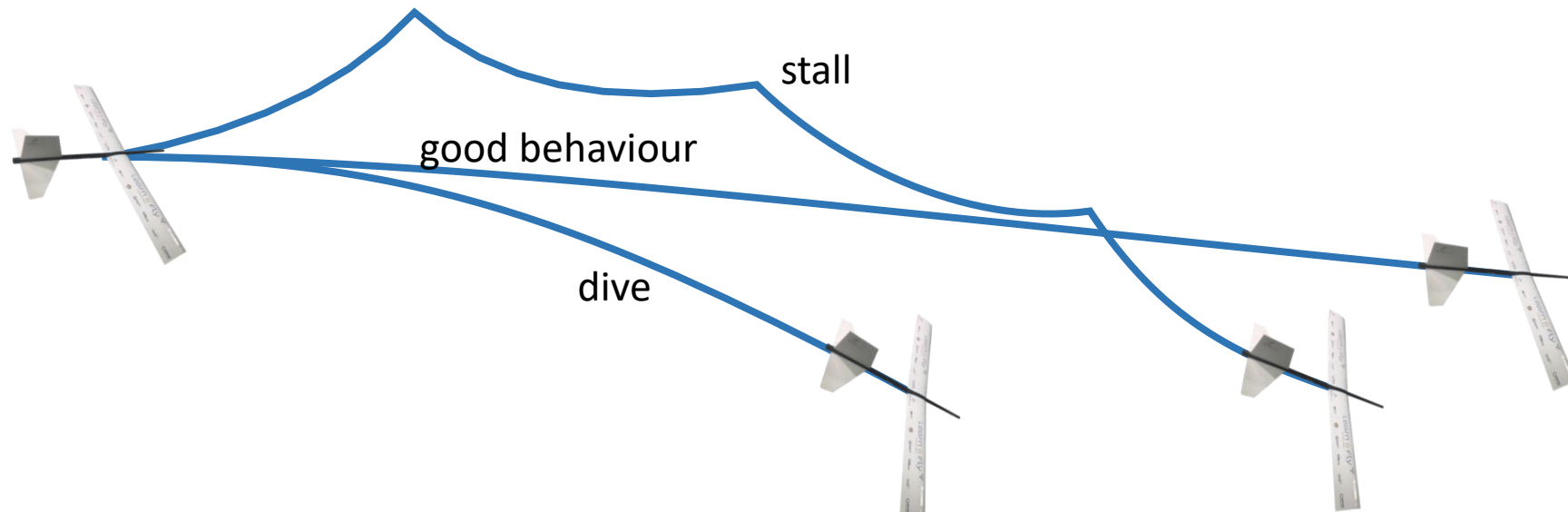
- It's better to launch it horizontally than to launch it with a very high speed

Remember that for “Learn&Fly Competition” your aircraft must be in balance without payload

- You must demonstrate that the aircraft is able to have a stable fly without payload

Watch how your aircraft behaves.

- If the model stalls or dives, you must adjust the position of the CG by adding or removing weight in the nose. You can also adjust this if you can change the horizontal stabilizer angle.
- If your aircraft is loaded with the payload mass you can adjust the payload position.

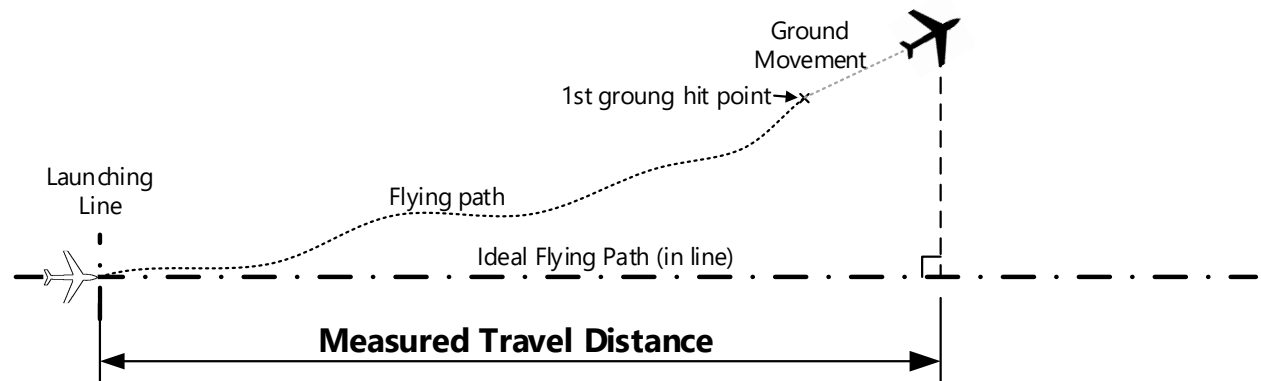




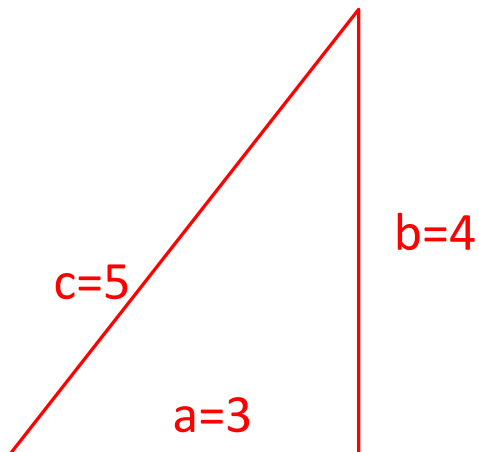
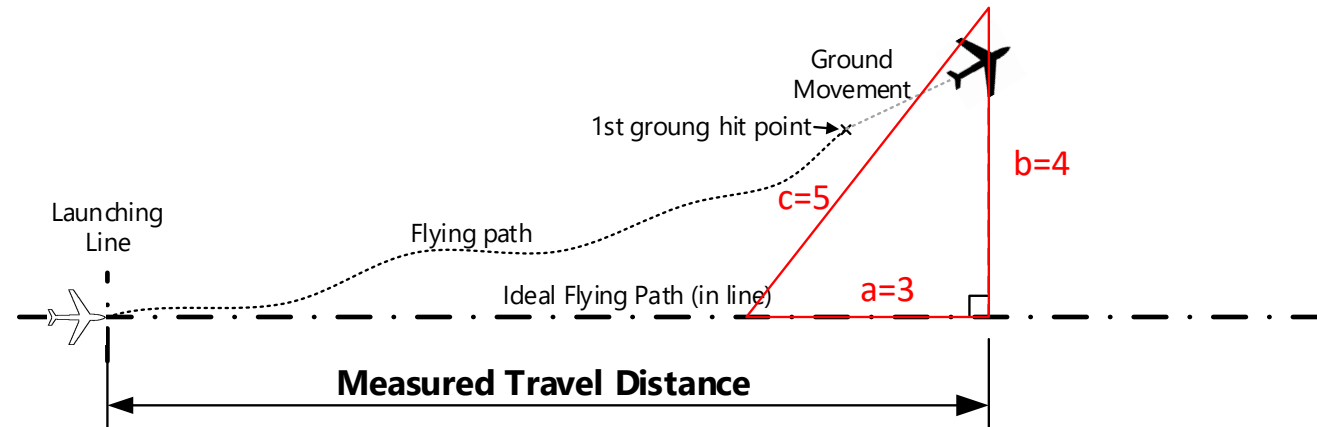
6. Aircraft Design

6. 15. How to measure travelled distance

- In “Learn&Fly Competition” the travelled distance is measured projecting the CG to the ideal flying path
- Even is the aircraft disassembles, what matters is the CG of the fuselage



- If you can not obtain the project point easily you can use Pythagoras theorem
 - Cut a thread with size $(3+4+5 = 12 \text{ meters})$ and make a mark with 3 meters, 4 meters and remain one will have 5 meters. You can use multiples of the side dimensions to define the triangle. For example 1.5 X more will have $(4.5 + 6 + 7.5 = 18 \text{ meters})$
 - Define the triangle in the ground according to next figure (red lines). The angle formed between sides with 3 meters and 4 meters will have 90° .



According to Pythagorean Theorem the triangle is rectangle (has one angle with 90°) if the sum of the sides square 2 are equal to the hypotenuse square 2. Using the formula

$$a^2 + b^2 = c^2$$

$$3^2 + 4^2 = 5^2 \Rightarrow 9 + 16 = 25 \Rightarrow 25 = 25 \text{ (verified)}$$



See you on the
Module #7

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