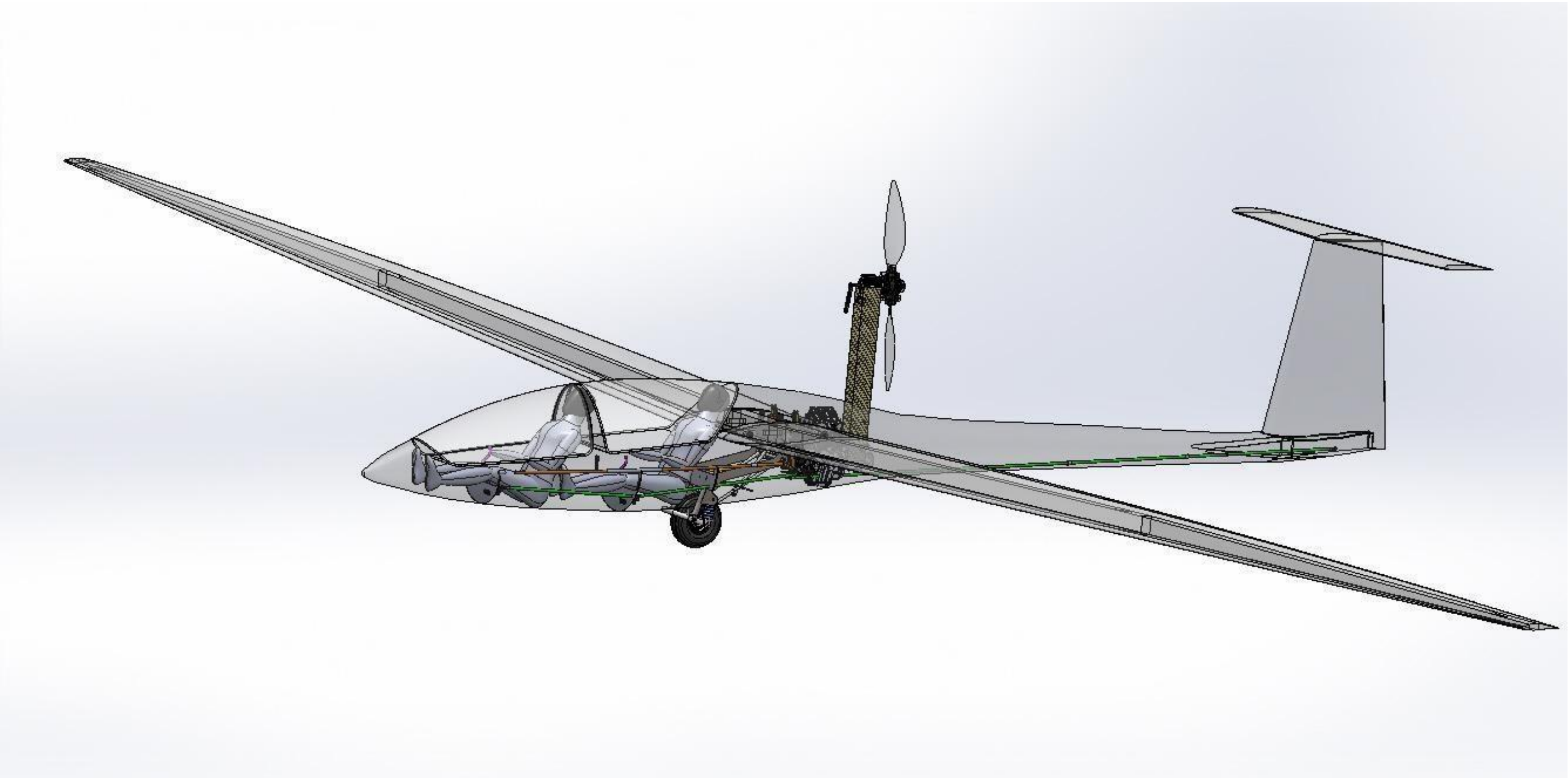
MOTORGLIDER e^+



DESIGN AND INNOVATION

In the design of the e+ Motorglider, the main focus was to create a versatile, multipurpose glider, suitable both for the enjoyment of soaring flight and as a high-performance aircraft, thanks to the characteristics of its engine.

To achieve these objectives, multiple challenges had to be overcome, leading to the use of cutting-edge technologies, computer-aided design, and special materials. This makes the e+ Motorglider unique in its versatility and one of the best-performing aircraft, combining the aerodynamics of a sailplane with the capabilities of a 4-stroke engine.

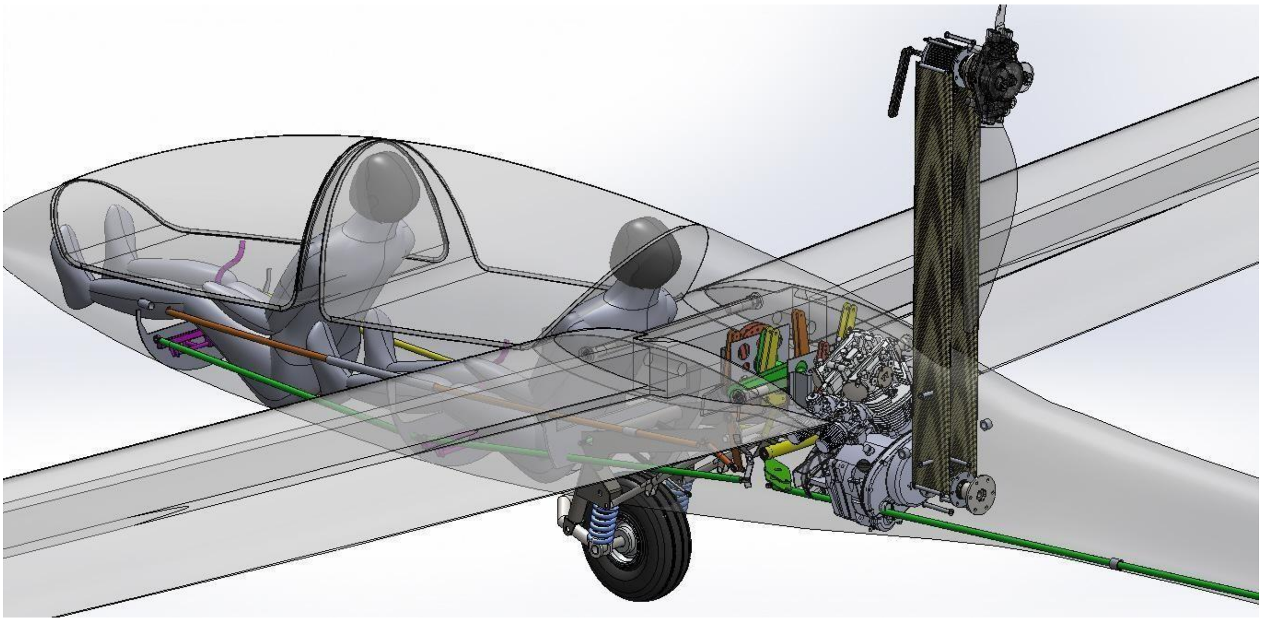
It is generally inspired by the Glaser Dirks DG 1001, although that aircraft uses a 2-stroke engine mounted on a pivoting pylon, while the e+ features a 4-stroke engine on a fixed pylon (for now). In gliding flight, only the propeller blades fold back along their hub.

- Wingspan: 18.5 m, with a calculated maximum weight of 650 kg
- Wing area: 17 m², aspect ratio A = 20
- Wing loading: 36 kg/m² (or daN/m²)
- Glide ratio: 36:1 (at 112 km/h)
- Minimum sink rate: approx. 0.58 m/s (at 88 km/h)
- Wortmann FX 61168 airfoil used in the first panel (from root to break), and an interpolation between this profile and the FX 66126 for the second panel (from break to wingtip)

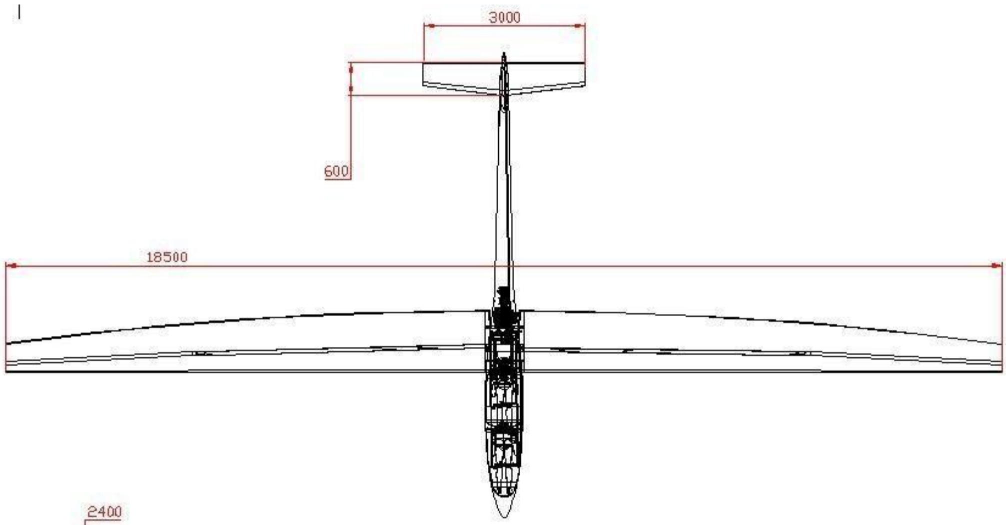
CHARACTERISTICS

- Two-seat, dual control
- Electrically retractable main and tail landing gear (steerable)
- 4-stroke, twin-cylinder engine, 71 HP, 4 valves per cylinder
- Electrically actuated variable-pitch propeller
- Hinged folding blades
- Can be used in glider mode or airplane mode

The entire aircraft is built in fiberglass, using RU 460 (460 g/m²) unidirectional roving cloth for bending loads and T220 (220 g/m²) at 45° for shear.
Only recently, with access to carbon fiber, were all the engine support mounts and the reinforced engine cowling structure built in this material.



3D MODEL:
This model was used to visualize the aircraft's lines, determine capacities, surfaces, the center of gravity, and to run a fluid dynamics simulation.
It can also be "sliced" into sections to generate the bulkheads. Roughly 50 HP are needed for climb, while only 15 HP are sufficient for cruise, if one wishes to use it as an airplane.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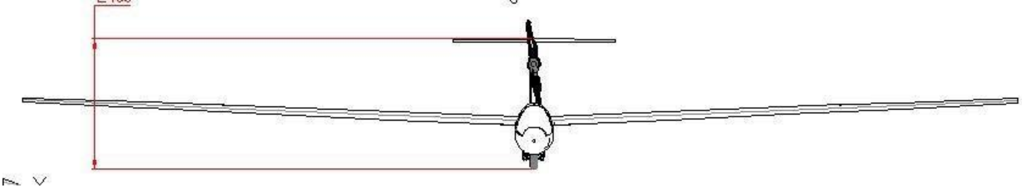
18500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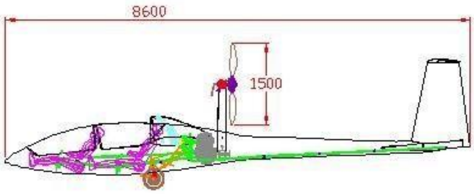
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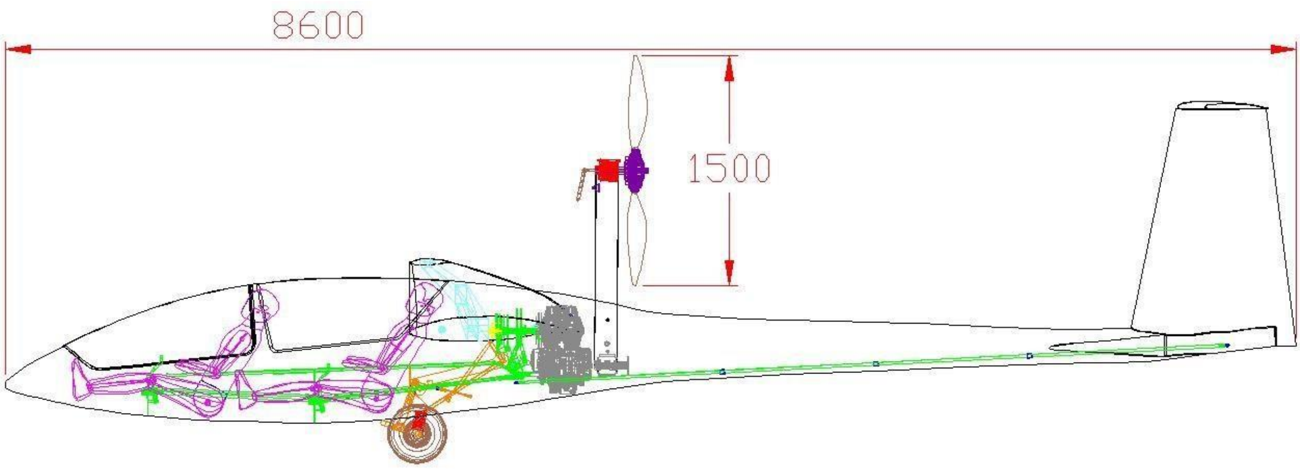
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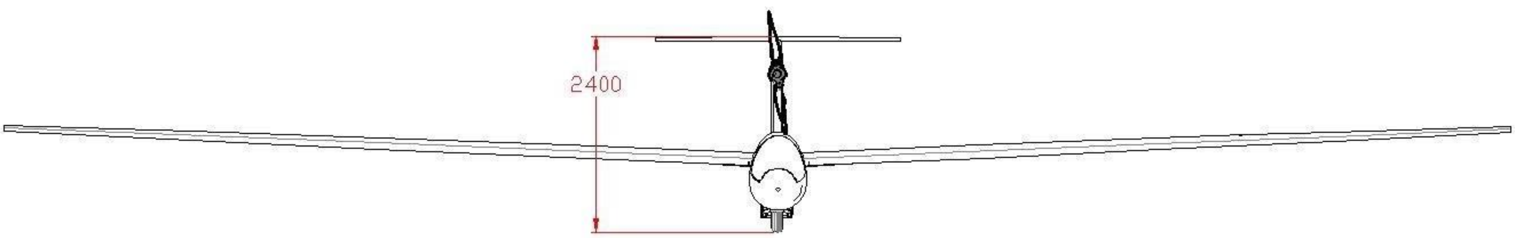
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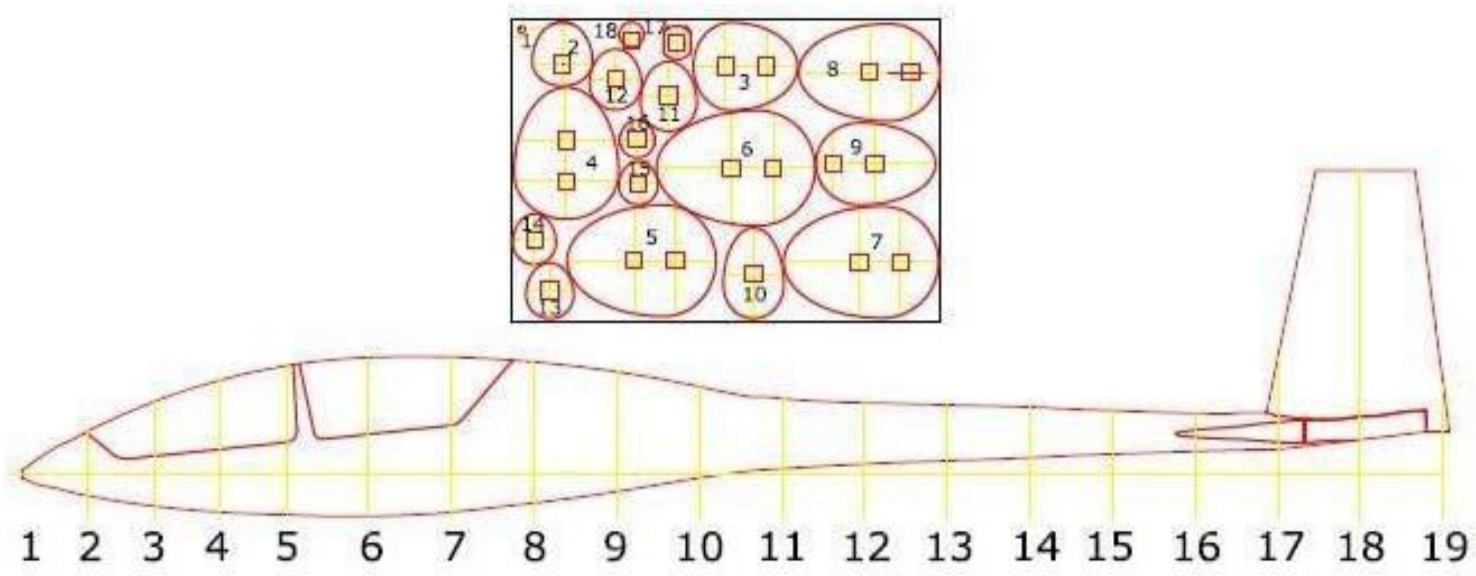
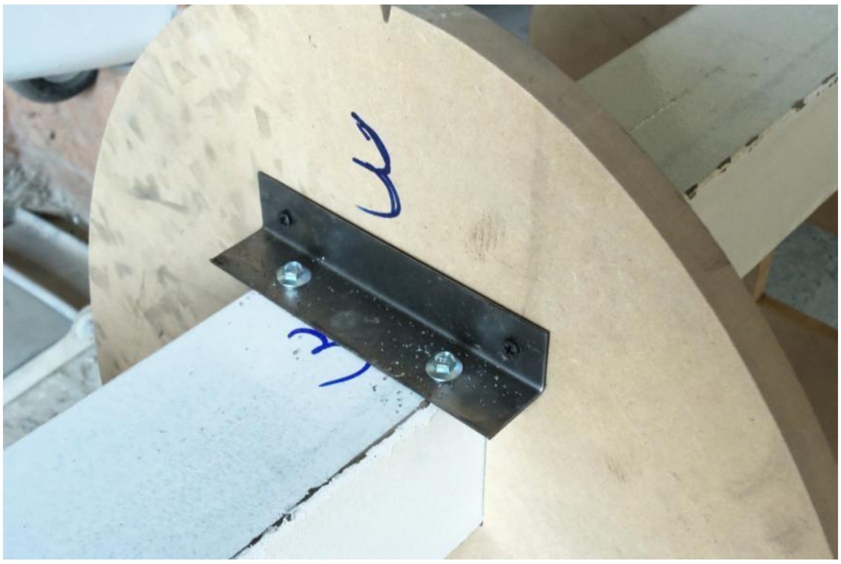
Well, with the 3D fuselage section views it was possible to print each section at full scale and “thread” them onto beams to form the **“Fuselage Mold Skeleton”**, as shown in the figure below. An MDF sheet was used to save on wood.



tal como se ve en la figura abajo en el fondo de mi casa en Ledesma- Jujuy año 2007

It can be observed that a **male mold** is being built. The actual fuselage will be laminated over this mold and then cut vertically along the symmetry plane. Afterward, the **structural stiffeners**, **aileron torque tubes**, **rudder and elevator control linkages**, **landing gear assemblies**, and other reinforcements will be installed. Finally, both fuselage halves will be **bonded with epoxy adhesive** to form the complete structure.



The mold covering was made using **3 mm Kiri (Paulownia) wood sheets**, which are highly flexible. Then, **filler and sanding** were applied until obtaining the **finished mold surface**.

Here we were carrying out measurements in order to ensure its **symmetry**.

Ready for layup.

Before the layup, we installed the **wing root junction fitting**.

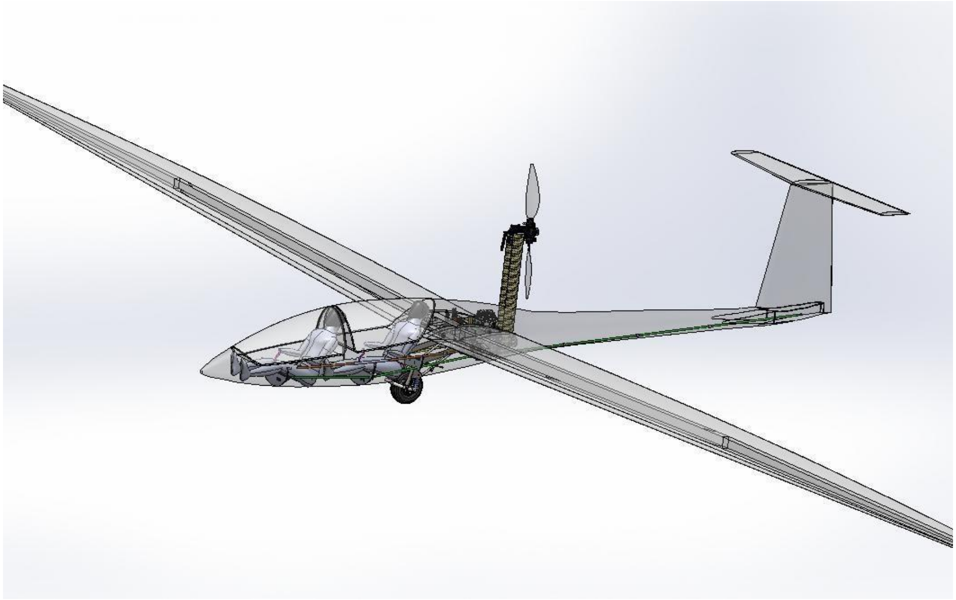
The number of laminate layers, both for **bending** and **torsion**, must be determined in advance through structural analysis. In this case, the fuselage was divided into **20 stations of 450 mm each** (total length 9 m).
The **bending moment** is mainly generated by the **elevator and rudder loads**, and it reaches its maximum at the **center of gravity** (very close to the wing leading-edge position). For this reason, more **unidirectional bending plies** were applied in that area. In practical terms, the tail cone was laminated with only **1 ply**, whereas the wing root region was reinforced with up to **9 plies**.
Torsion, on the other hand, is relatively constant and specifically induced by the rudder. Torsional strength is proportional to the product of thickness and cross-sectional area in a closed tube. Consequently, the tail cone—where the section area is much smaller—required **9 torsional plies**, compared to only **3 plies** in the wing section. These plies are always laid up at **±45°** orientations.
Stiffness requirements imposed an additional restriction: the **rudder deflection** around its longitudinal axis must never exceed **5°** under load. Since fiberglass is relatively flexible, this condition required the addition of **5 extra torsional plies**. This limitation would not apply to carbon fiber, which is much stiffer, but cost considerations ruled out its use for the entire fuselage.
In summary, fabrics were cut so that the number of plies varied every **450 mm** along the fuselage length. From tail to nose:
Telas de flexión de 1 a 9 telas.
Para eso la primera tiene el largo total del avión, los 9 metros, la segunda tiene 9000 – 450 mm = 8550 mm, cosa de destaparle los pies y dejar el cono de cola con 1 sola tela, la primera. La 3° capa tiene el largo de la última – 450 mm = 8100 mm y dejamos descubierto los últimos 900 mm de la cola y así sucesivamente.
Por otro lado, todo el Cockpit tiene sólo 3 telas de flexión, así que a partir de la 3° tela, se merman también 450 mm de la punta y así hasta que la capa 9° tiene sólo 450 mm de largo y cubre la zona del ala.
Telas de Torsión y Rigidez de 14 a 3 telas.

Bending plies ranged from 1 to 9.

- The first ply covered the entire fuselage length (9,000 mm).
- The second ply was shortened by 450 mm (8,550 mm), leaving only 1 ply in the tail cone.
- The third ply was again shortened by 450 mm (8,100 mm), leaving the last 900 mm of the tail uncovered by this layer, and so on.
- The cockpit area was reinforced with only 3 bending plies. From the third layer onward, 450 mm were also removed from the nose section with each successive ply, so that the 9th ply was only 450 mm long, covering exclusively the wing root area.

Torsion and stiffness plies ranged from 14 to 3.

- The same principle was applied in reverse: the tail cone was reinforced with 14 plies, gradually reducing to only 3 plies in the cockpit and wing root section.



Layup Process

Manufacturing the fuselage using the mold is a labor-intensive task, since the process must be carried out quickly to ensure proper curing of the resin once all fabric plies are in place, and to guarantee adequate bonding of the **roving fabrics**. For this reason, all fabric plies must be **pre-cut** according to the laminate schedule described previously, allowing sequential placement without delays.

In our case, the layup process required a **full working day** with a team of **three people**.

The figure below shows the result, after the **cockpit openings were cut** and the **mold was removed from the inside**.

On the following page, another set of photos shows the **tail section** and the **complete fuselage** in the backyard of my former house in Jujuy.
It can be seen that the fuselage was occasionally damaged by **falling mangoes** from the trees.

After this stage, the **frames had to be reinforced**.
Finally, when I left Ledesma, I **loaded the fuselage and transported it to Buenos Aires**.

The **fuselage weighs 65 kg**, without equipment (bare structure only).
Currently, I am taking the **fiberglass canopies** as molds to have them manufactured in **Plexiglass (polycarbonate)** in Cañada de Gómez.

WINGS

The calculation of the wings involves a much more complex procedure.

It must be noted that the entire sailplane must be structurally designed and verified in compliance with JAR-22 certification standards. Among other requirements, this regulation specifies that:

At maneuvering speed and the corresponding load factor (G's), the control surfaces must be capable of full deflection.

At maximum permissible speed (VNE) and load factor, the control surfaces must be capable of at least 1/3 deflection.
The same principle applied to the ailerons also applies to the airbrakes, and for the fuselage, it applies to the elevator and rudder. The landing gear is subject to additional, specific requirements.

Therefore, both for the wings and the fuselage, structural calculations must be performed for bending moments, torsional moments, and shear loads. These loads must be multiplied by the design load factors (both positive and negative), and then by the 1.5 safety factor.

In the case of this Motorglider, the design was based on +5.3 G positive and –2.7 G negative. With the safety factor included, this results in +8 G and –4 G.

Assuming a maximum takeoff weight of 650 kg (fully loaded), the calculations are as follows:

Positive: 650 × 8 = 5,200 kg

Negative: 650 × 4 = 2,600 kg

These resulting loads are then used to calculate the distribution of forces and bending moments, which ultimately determine the required wing skin thickness, varying according to the distance from the wing root.

After this, a static test is performed. The wing is mounted on a test rig, clamped at the root, and sandbags or water containers are progressively applied to simulate the distributed loads up to 5,400 kg on one side. Then the wing is inverted and the test is repeated with 2,600 kg for negative loads.

The control mechanisms are built from aluminum rods, while the control linkages and bellcranks are fabricated in composite material, as shown in the photo below.

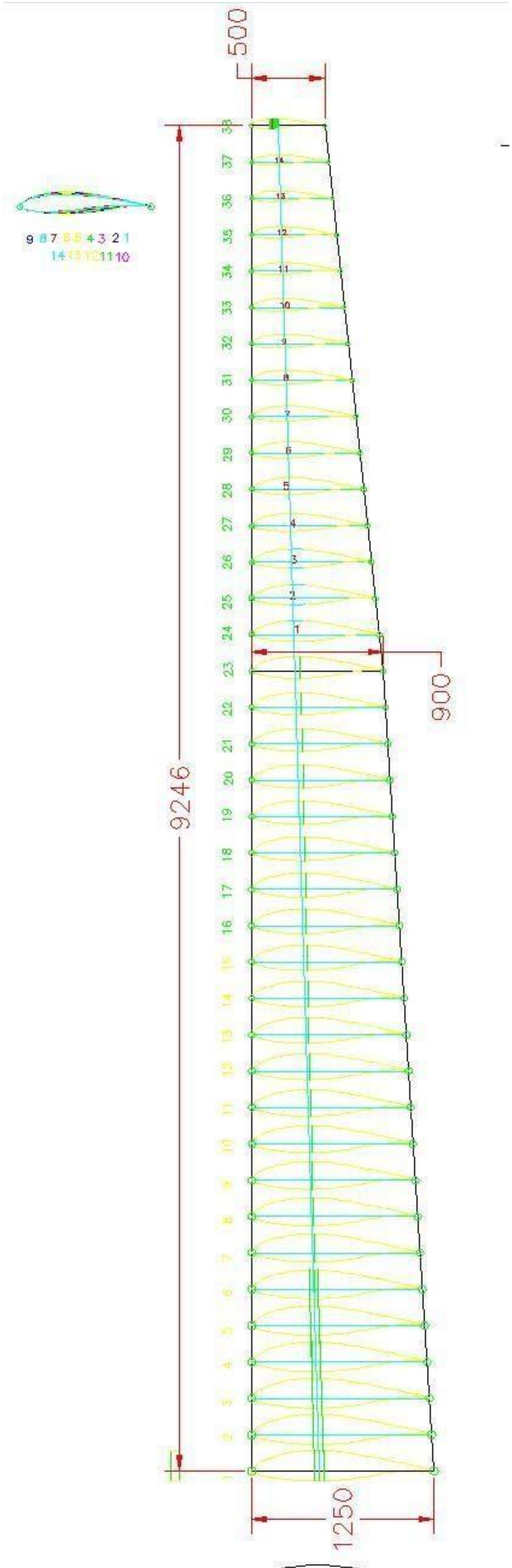
Airfoils

- **FX 61-168** for the **first wing panel** (root to first break).
- **FX 60-126** for the **second wing panel** (from the break to the wingtip).

Wings

The figure below shows the **ribs used to build the wing mold**. These MDF plates were **water-jet cut** (slightly more precise than laser cutting) from the CAD-defined airfoil profiles.
In the final wing panel, each rib was generated as an **interpolation between both airfoils**, depending on its position relative to the root or the wingtip.


24
24
16
2009 2 21


500
9246
900
1250

The cut airfoil ribs also include **rectangular-section openings** to allow the insertion of rods that stiffen the mold sheet along its entire span, perpendicular to the ribs. Each rib is **numbered**, since adjacent ones are very similar in shape and could otherwise lead to assembly errors.

All these rib sections are positioned at **400 mm intervals** along the span and mounted on longitudinal **spars**, forming a structural skeleton both for the **lower surface (intrados)** and the **upper surface (extrados)** of the wing.
On the edge of each rib, a **fiberglass sheet**—pre-cured on a glass plate to achieve a smooth finish—is placed. In the next figure, the ribs can be seen already mounted on **square-section spars**, together with the **rectangular-section rods** running longitudinally to support the fiberglass sheet bed, shown here in **red**.
At the top, in **green** (unpainted GFRP), the **main spar** is visible. This spar will be integrated into the wing to withstand the **bending loads**, while **torsional loads** are resisted by the wing's own composite skin.

Main spar location within the wing

Manufacture of the square-section spar

The **width of the spar mold** is measured, to be later adjusted to the **airfoil height** at that section.
Completed spars are shown next to the **lower-surface (intrados) mold bed**.

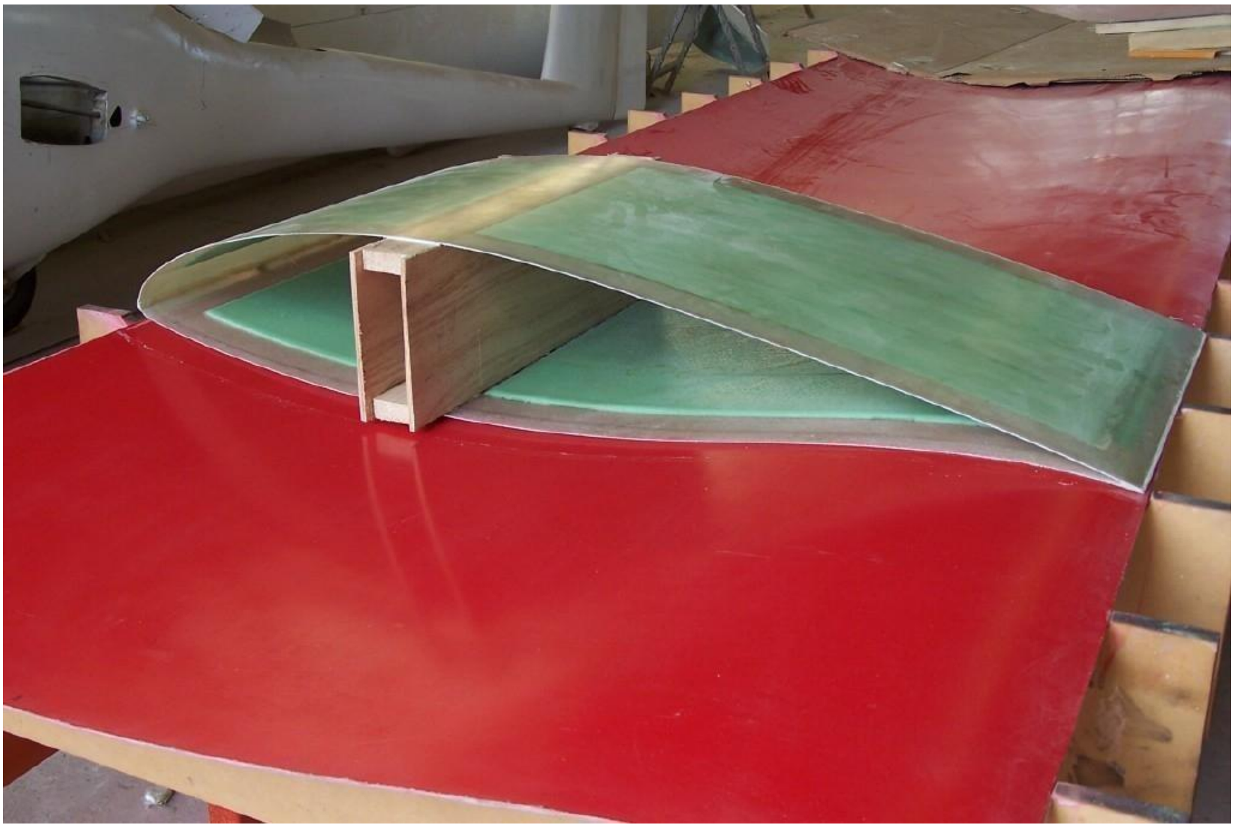
In the figure on the following page, the **positioning of the spar** and the **expanded PVC foam sheets** can be seen

The **expanded PVC foam** is used to prevent **local buckling** of the wing surface. It forms part of a **sandwich structure** designed to avoid wrinkling.
This sandwich is composed of a **PVC core** and **fiberglass skins**. The required thickness is obtained from a **local buckling analysis**, which considers the stiffness and strength of both materials, as well as the spanwise and chordwise dimensions between supports, all as a function of the applied loads on the structure.

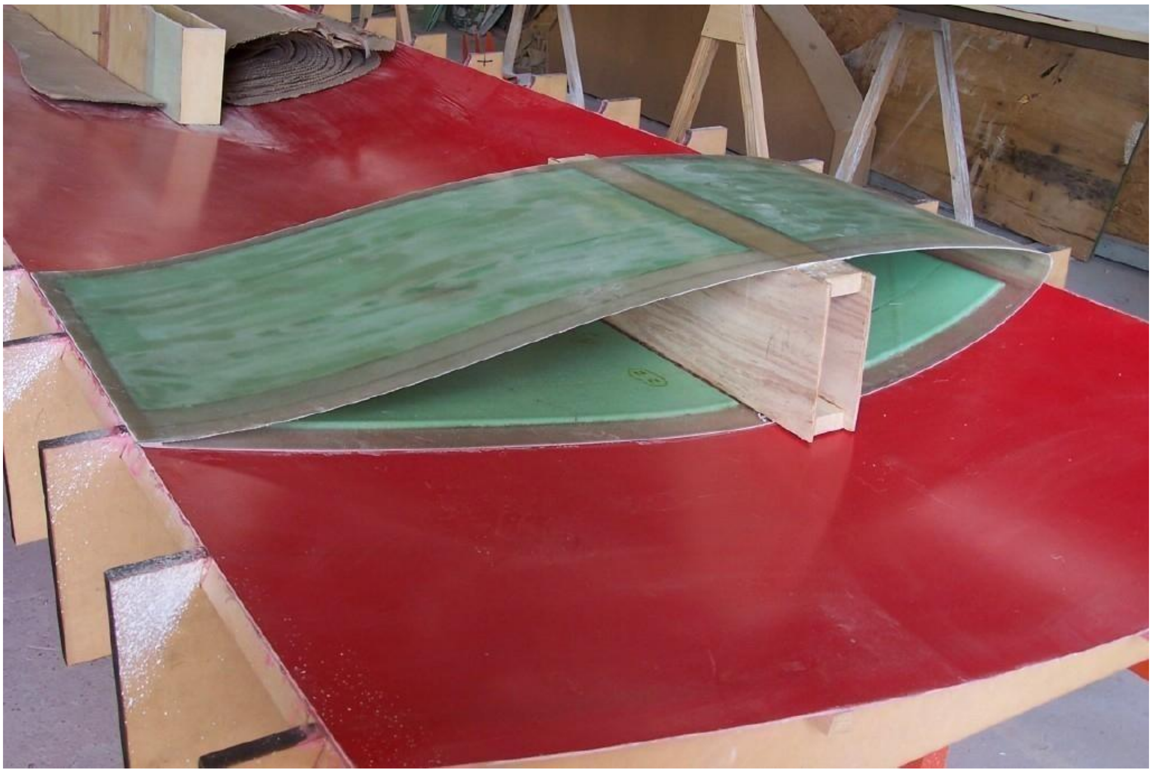
In the lower photo, the **aileron torque tube** can be seen in position, as well as how it slides over the **pulley rollers**.

In the lower photo, the **bellcrank** is shown attached to the spar. This bellcrank transmits the motion **perpendicular to the torque tube**, actuating the ailerons up and down.

In the two following photos, a **test fit of the wing profiles on the beds** can be seen. Over a **400 mm section**, all the wing components are represented: **fiberglass skin**, **expanded PVC core**, and the **spar simulated in balsa wood**.
What is missing in this setup are the **torque tubes and bellcranks**.



The previous photo showed the assembly on the **lower-surface (intrados) mold**, while the following photo shows the assembly on the **upper-surface (extrados) mold**.

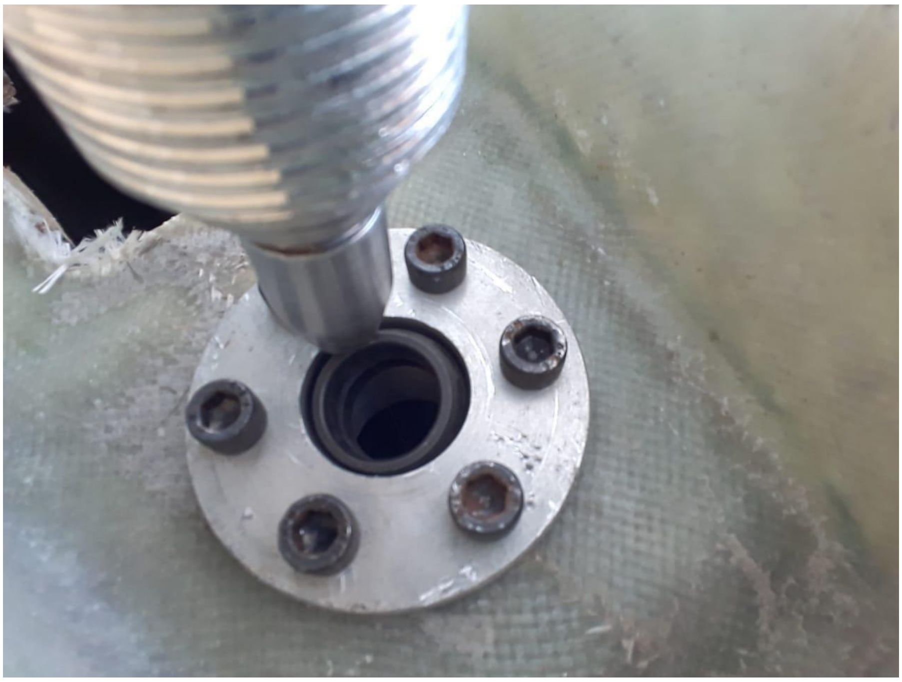


Finally, the **completed wings** can be seen in the photos below.
It is essential that they be built as **lightweight as possible**, while still fully complying with all certification requirements.
This is where **carbon fiber** offers significant advantages.

For the same **bending load**, a **carbon fiber laminate** can be up to **3.5 times lighter** than an equivalent **fiberglass laminate**.
For **torsional loads**, carbon fiber is approximately **2.6 times lighter** than fiberglass.

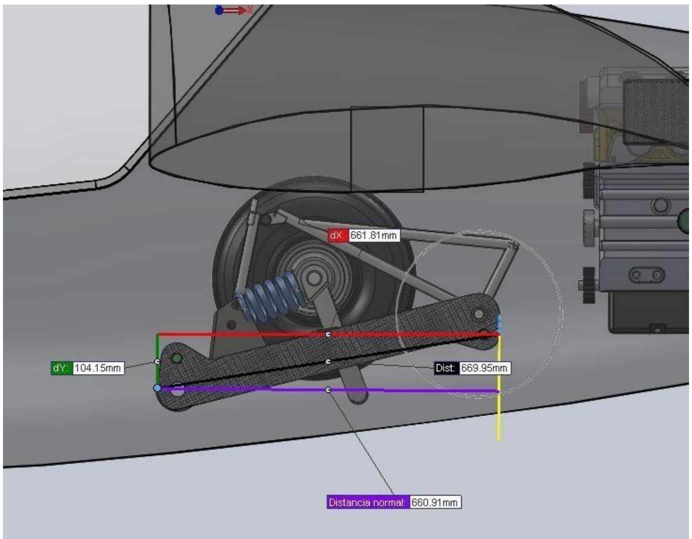
Finally, the photo below shows the **airbrakes**, disassembled and manufactured in **aluminum**.

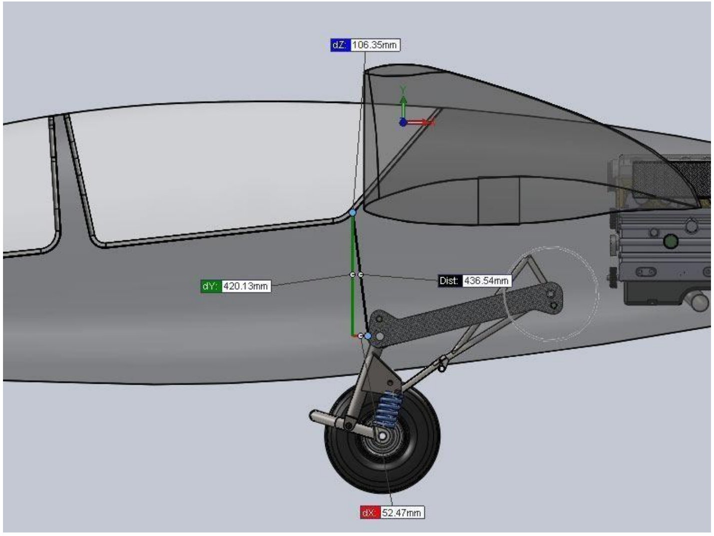
Wing–Fuselage Attachment



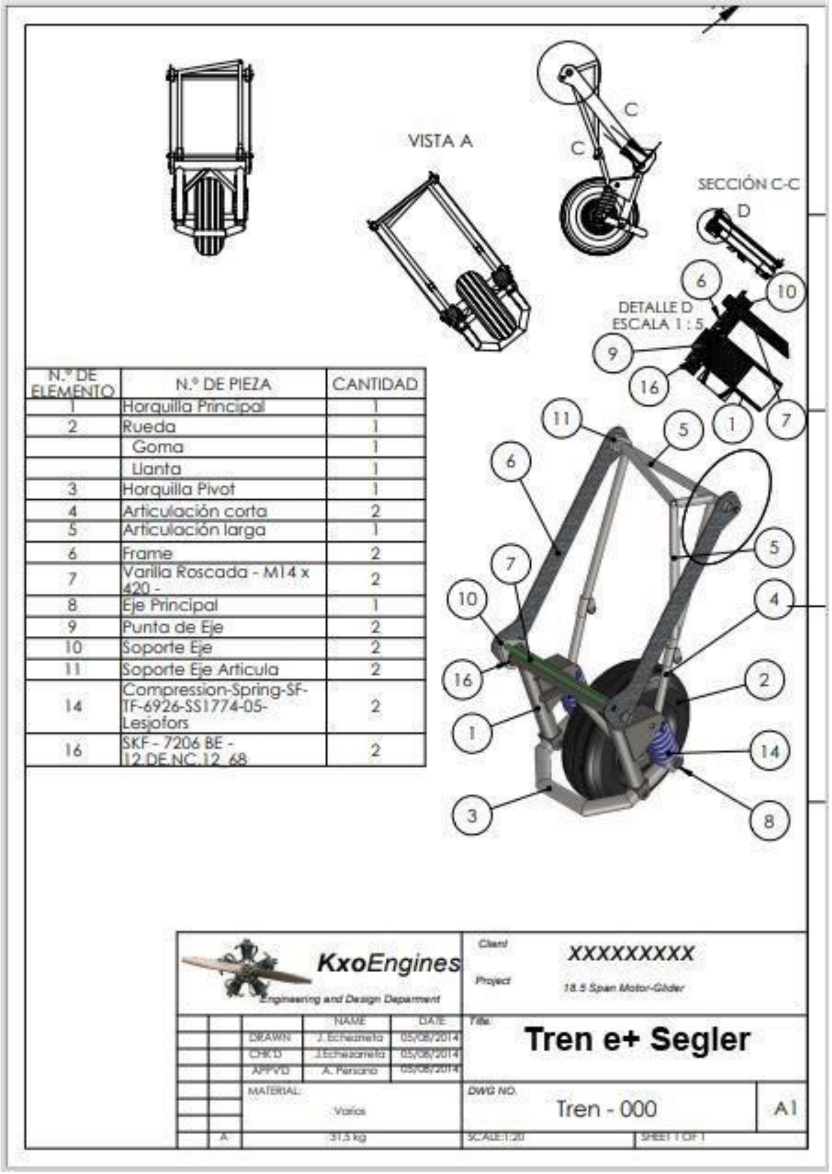
Landing Gear

For this motorglider, the design included a **retractable main landing gear** and a **fixed nosewheel**.
In the figures below, the configuration can be seen on the aircraft, both in the **extended** and **retracted** positions.

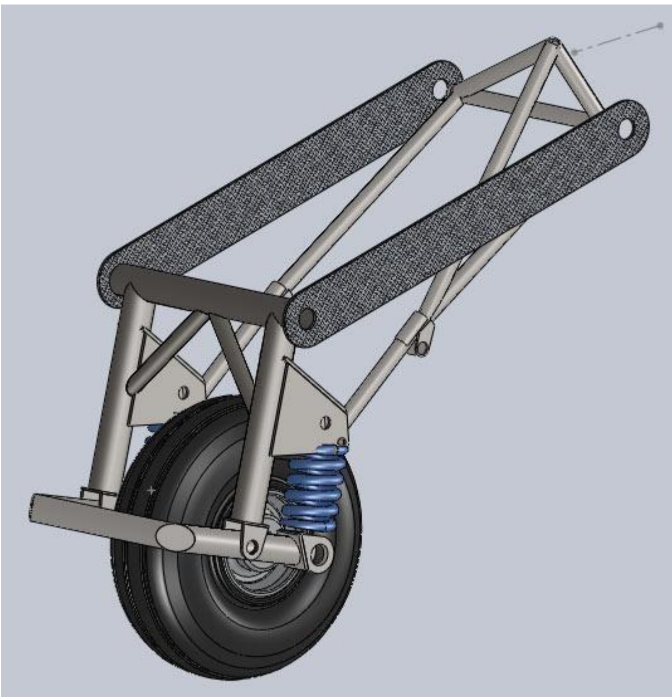




These are the **Drawings for the landing gear assembly**.



N.º DE ELEMENTO	N.º DE PIEZA	CANTIDAD
1	Horquilla Principal	1
2	Rueda	1
	Goma	1
	Llanta	1
3	Horquilla Pivot	1
4	Articulación corta	2
5	Articulación larga	1
6	Frame	2
7	Varilla Roscada - M14 x 420 -	2
8	Eje Principal	1
9	Punta de Eje	2
10	Soporte Eje	2
11	Soporte Eje Articula	2
14	Compression-Spring-SF-TF-6926-SS1774-05-Lesjofors	2
16	SKF - 7206 BE - 12,DE,NC,12_68	2



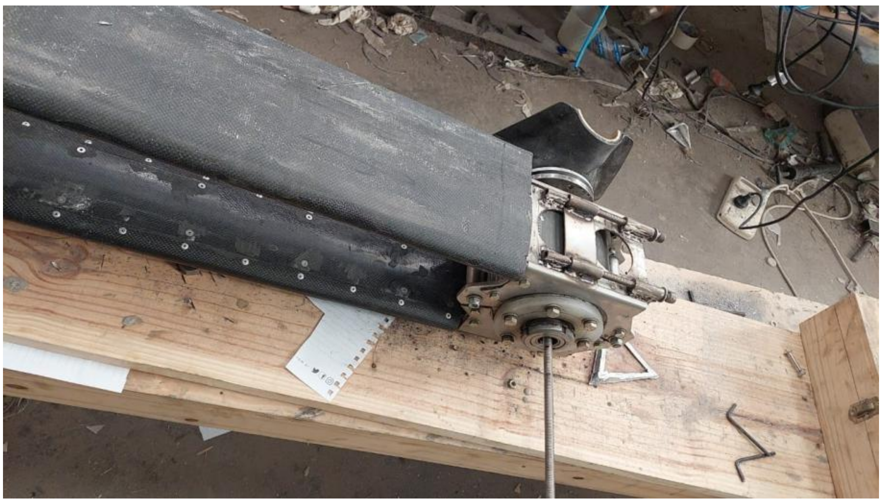
Engine

A **650 cc twin-cylinder motorcycle engine** was used, specifically the **Keller K65**, a Chinese version of the **Kawasaki Versys**.

The engine was sourced from a **written-off motorcycle** that had been in a junkyard for two years without running. It required servicing before operation: the **fuel injectors were cleaned**, the entire system was flushed, the **external fuel filter** was replaced, and the engine was tested and brought back into running condition on the motorcycle.

The engine was then **removed from the motorcycle**, and **engine silent blocks** were fabricated inside the fuselage to secure it. The engine fits precisely just behind the **wing root junction and associated mechanisms**.

Here we can see the beginning of the **engine mount installation**, with the engine already removed from the motorcycle, together with the **pylon** and the **toothed belt drive**.



A modification was carried out to extract power through the clutch planetary gear, taking the power output from that side.
A total of **9 kg were removed** by eliminating the original motorcycle gearbox, and the clutch friction discs were replaced with **aluminum plates with double engagement slots**, resulting in a **rigid coupling** in place of the clutch.
The engine delivers **71 HP at 8,750 rpm**, but using the **crankshaft–clutch transmission** (ratio 2.5:1), the output speed at the power take-off is reduced to **3,500 rpm**. From there, a **toothed pulley drive** with Z36 driving Z56 reduces the speed further, yielding a final propeller speed of **2,250 rpm**.

Propeller

The propeller is a **two-blade, 1,500 mm diameter, variable-pitch, folding unit**, built in **carbon fiber** with an **aluminum shank**.

Wing Load Test

A **wing test rig** was built to perform the structural load test by lifting the wings with the **intrados facing upward** using a forklift. A load of **2,500 kg** was applied.