Radio Controlled

Soaring Digest

January 2015 Vol. 32, No.

Modelling the Eta

the worldís largest sailplane

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Original Eta History

The sailplane Eta (Efficiency, from the Greek letter) has been designed for record fight, where searching for a FAI glider distance record requires an optimal usage of energy, from thermal flight phase to transitions at maximal gliding ratio. The 30m span is the result of the uncompromising design, 'the state of art' in aerodynamics and composite materials. <http://www.leichtwerk.de/eta/>

The full size Eta made its maiden flight on July 31st 2000. The father (not only, but...) of the glider is the well known world record holder Hans-Werner Große, owner of 50 FAI world records. His free distance record, with an ASW12 from Lübeck (Germany) to Biarritz (France) in 1972 was broken only in 2003 by Klaus Ohlmann, but in Argentina. The Eta is still today the largest glider, even with open class sailplanes like the Concordia, EB28...

The Model Story

When I discovered the Eta in a sailplane magazine a few months after the first flight with its amazing aspect ratio, I imagined to build a scale model. In 2004, I discovered that Gérard Risbourg made 1/4 (See Figure 1) and 1/3 scale drawings, and Jean Poulou realized them in the 1/2 size. <http://lesgpr.free.fr/construire/eta/eta-1/eta-1.htm>

In 2006, I contacted Jean Poulou who was selling a fiberglass fuselage of the 1/3 model. Jean invited me to Perpignan (France) to pick up this huge part (3.2 meters length) and discuss building. He explained to me how he made the master, from an ASH25 form, removing the cockpit, increasing the beam and the drift. I got also 25mm glass fiber wing joiner rod and lots of information about his building experiments.

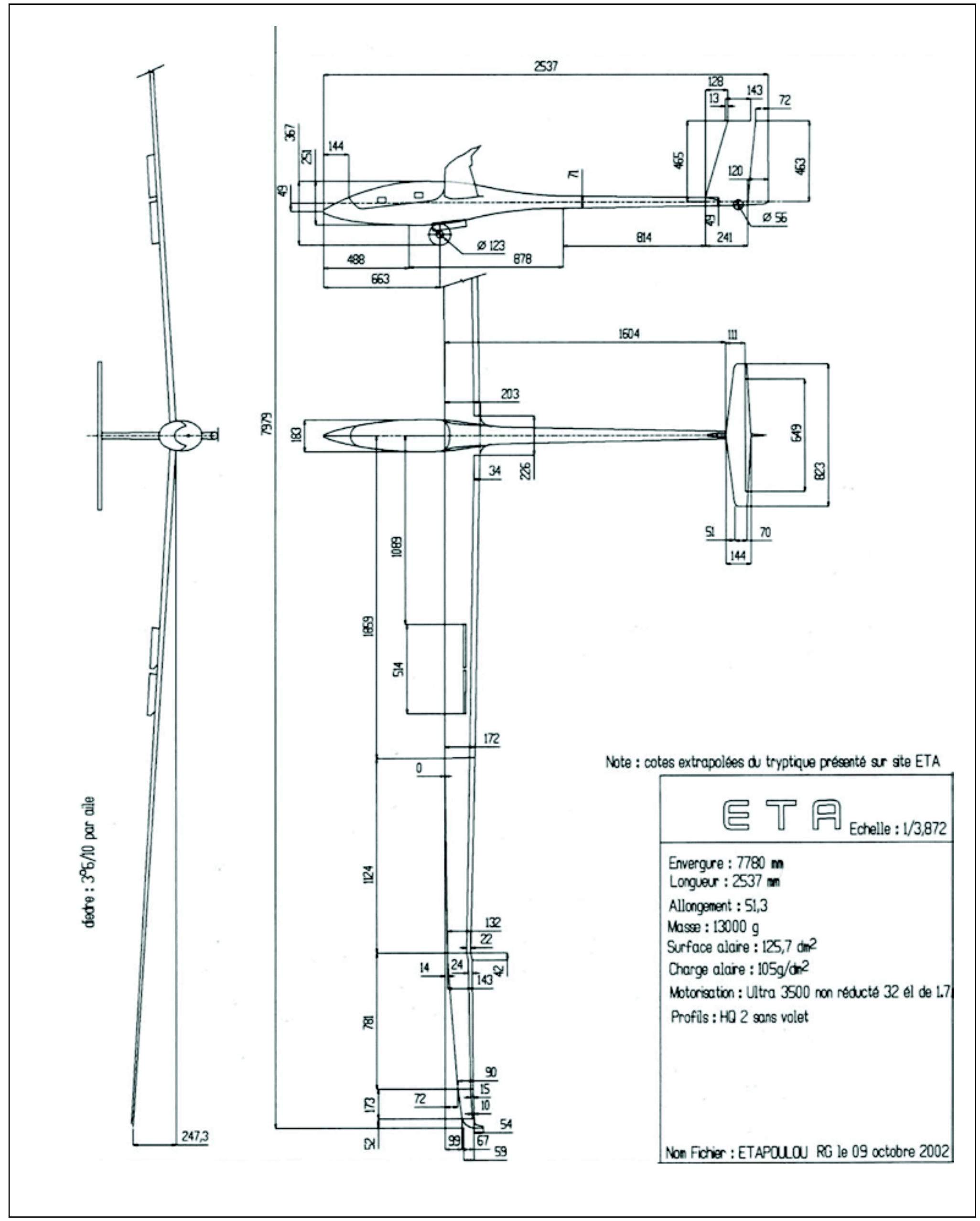


Figure 1: Dimensioned 3-view for 1/3.872 Eta

Before Building

Back home, I feel not immediately ready to start such building (the wing). First of all, the material resistance calculation was difficult to handle (with simple tools) for the wings. I decided to experiment, using carbon uni-directional and bi-directional glass on a similar project (from mechanical constraint point of view): the standard class 'CB15 Cristal' 1/3 scale (5 meter span), with a low aspect ratio of 23 but using an unusual F3B foil, HN354 - 7.88% thickness. The famous XFLR5 analysis by André Deperrois was used for wings and model simulation. <http://sourceforge.net/projects/xflr5/>

(See Figures 2, 3, 4 and 5)

After flight experimentation, I was happy with the longitudinal flexibility of the wing but I realized that torsion was too soft, so that at 'relative' high speed, the wing started to flex, not as a classical flutter, but at low frequency (as a bird ☺). The glass rowing put at 45° was too soft. From this conclusion, and also by extrapolation of Thierry Pasquet's 9 meter ASW22, I decide, for the future Eta wing, to increase dramatically the torsional rigidity by a full surface of 160 g/m2 carbon and 160 g/m3 bi-directional glass to 2.8 meter also at 45°.

Let's talk about the wing design and the building techniques used. From the aerodynamic design, the wing is a set of five trapezoids plus a winglet.

For technical limitations of the cutting machine, I split the foam into nine sections. The airfoil progression starts with a HQW 2.5 - 15.6% at the body, and is then reduced by about 1% each 700 mm to reach 10% thickness at 6 meter of span and finishes at 9% at the wing end.

Unlike Jean Poulou, who kept the thickness between 14% and 12%, I made this choice of low thickness on the smaller wing chord in order to avoid a laminar bubble that can appear at low Reynolds numbers. I had discovered poor flight quality at low speed while flying a 'small' 4 meter span Nimbus 4D some

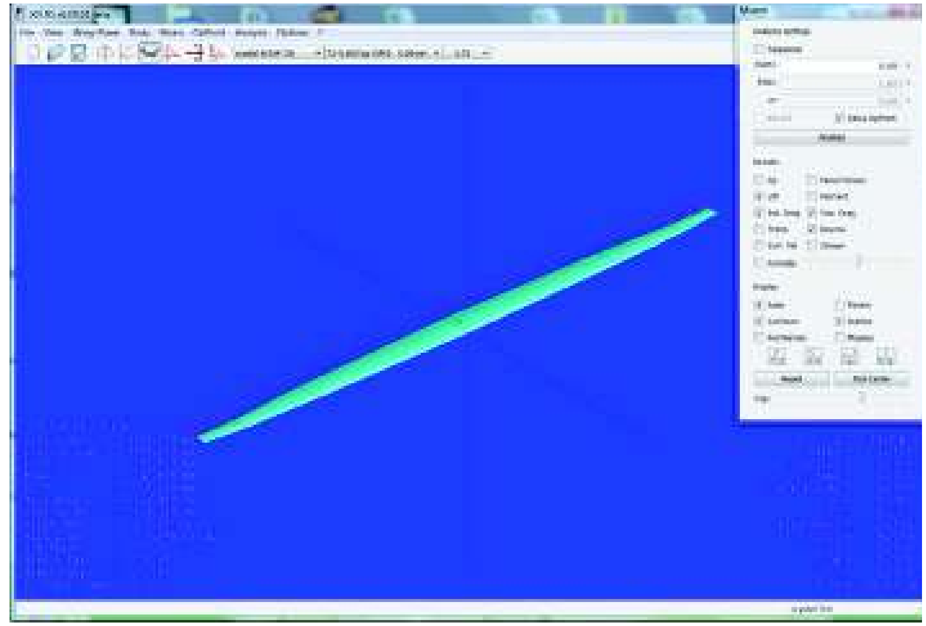


Figure 2: Cristal wing simulation in XFLR5

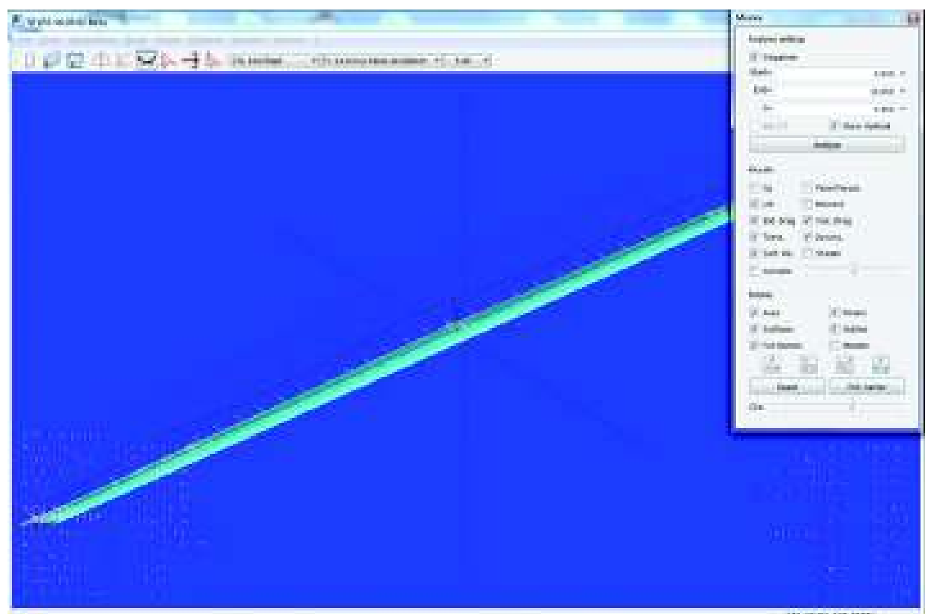


Figure 3: ETA wing simulation in XFLR5

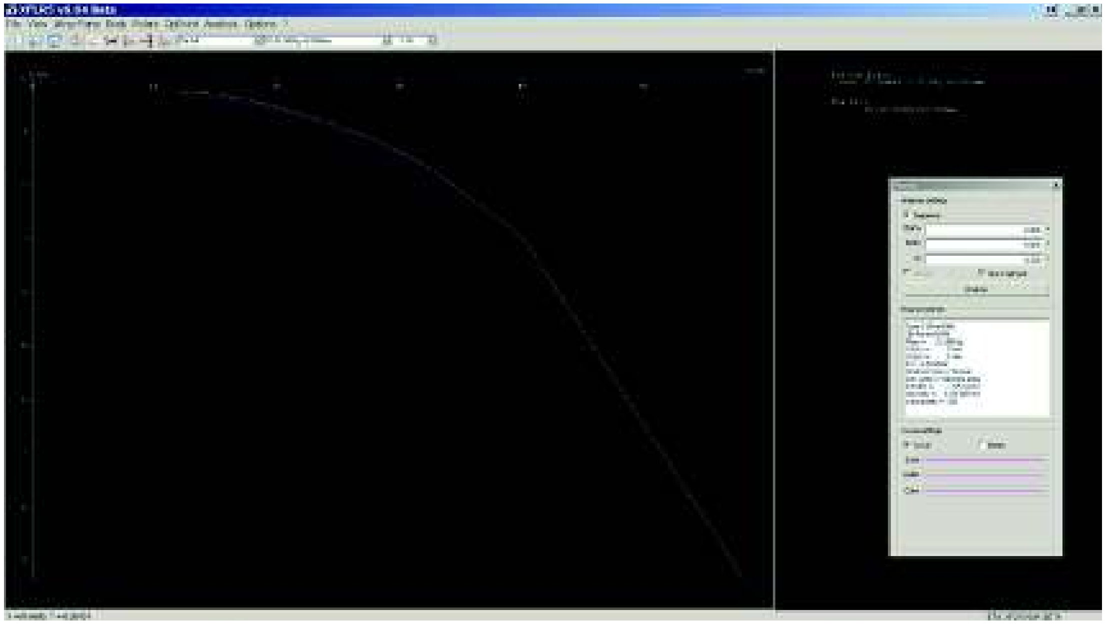


Figure 4: Eta polar simulation

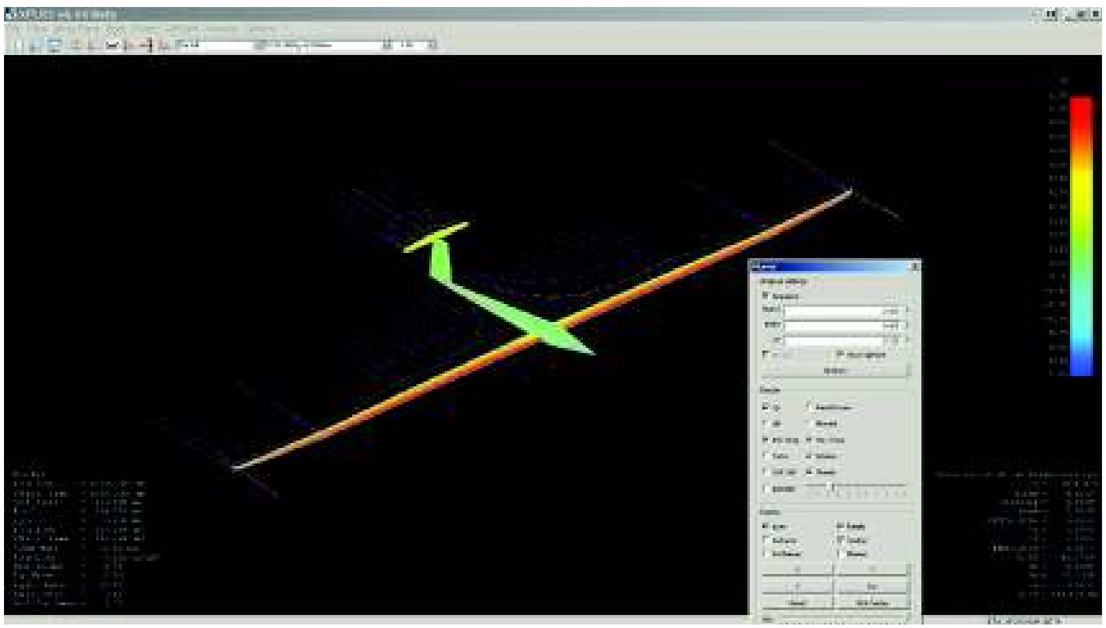


Figure 5: Eta full simulation

years ago. At medium and high speed (flap 0 to -2°) the Nimbus was good, but at low speed I was never able to say if the center of gravity was good or not, because of the divergent behavior of the model.

I exchanged mail with Mathieu Scherrer, at this time a SUPAERO student, who had the same issue with his model. He used Xfoil and MIAReX to evaluate the CM0 variation. The final solution was to add a turbulator as used on light and slow free flight sailplane and this cured the problem. A very good English article from Mathieu: <http://scherrer.pagesperso-orange.fr/matthieu/aero/nimbus4e.html>

Now it's time to build

In the meantime, I built several gliders: a Pilatus B4 4.5 meter and Pegase (close to ASW20) 5 meter thanks to my friend Dominique for his mold. The acquired experience in epoxy resin, glass and carbon usage, and vacuum was important, but never enough... I discovered later some errors that I was not able to identify before.

The wings are made by the classical foam method, assembly is prepared by half wings (5 meters) and covered with 1mm of samba (wood). Inside the samba, reinforcement is made with carbon and glass fabric for torsion (45°) and the longitudinal part with uni-directional carbon (300g 40mm wide). The number of layer s is digressive, calculated by a dedicated excel sheet originally designed for F3B, adapted and experimented for large sale plane by Jean Luc Delort.

(See Figure 6)

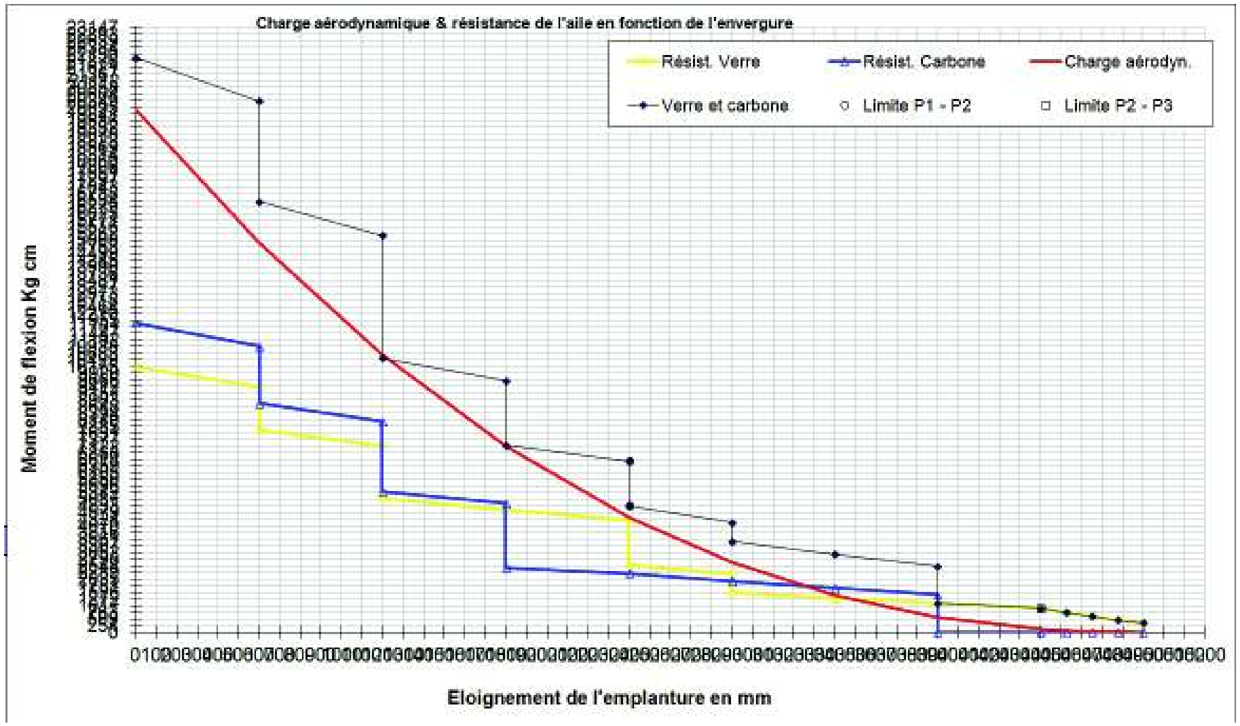


Figure 6: Eta wing bending moment

An intermediate 14mm carbon fiber wing joiner rod is used to split the wing into two parts after 2.8 meter from the root.

The wing was assembled in one operation, starting from the foam and joiner tube, local reinforcement for servo and wires.

I chose this method in order to get the maximum resin resistance and grip, but honestly it's very difficult to realize. First because each panel is difficult to move with all layers of glass and carbon, second because it needs a lot of space, and the resin must be prepared in small parts using a flat container to avoid resin heating. And last, the carbon uni-directional spar adjustment in the foam is not stabilized, so that it creates a hollow fault that must be filled.

The main advantage was that I got a strong closed box, with good mechanical characteristics. From the root of the wing, to the end, this is a huge amount of work.

I got an unpleasant surprise: the woven fabric under the wood had too much resin, so I was not able to use this for flaps; thanks to silicone for that job.

Despite the size, the servo installation is hard, there is no more place than on a 4 meter span wing, but with very long flaps and wires. The wing assembly on the fuselage was a bit funny because I had to support the wing at several points to avoid flexing, and estimate the dihedral so that the wing will not touch the ground at both extremities - around 4° dihedral per side.

The main wing joiner rod was assembly in a tube in the fuselage and geometry was made by using a laser gauge and strings.

After sanding, I covered all the surfaces with light 50g/m^2 glass, prepared and painted (polyurethane). Thanks to my friend Michel for a perfect finish.

Final mounting, verifications

Most of the building was made in 2010-2011, but due to familial constraint, I finished the last radio installation in 2013. The radio used is a Graupner MX24 (12 channels 41 Mhz APCM), receiver and servo are powered by a DPSI RV box from Emcotec and two 5000mah Lipo batteries. The box provides signal amplification (important regarding the distance to the extreme servo about 5 meters from the box), it protects the receiver against interference from wires and servos, and for safety each servo

supply is independent. Servos used are 15kg.cm (for rudder (1), 5kg.cm for elevator (2), for airfoil (4), ailerons (6), 2kg.cm (2) for small ailerons, 15kg.cm for flaps (6), 20kg.cm for retracting gear (1) and 30kg.cm for tow release (1): total 23 servos!

Maiden Flight

All was ready by April 2014, but due to the bad spring weather in France, the first flight was delayed to October 18-19 in Saint-Auban. Saint-Auban hosts the famous National French Sailplane Training Center (Centre National de Vol à Voile, CNVV), dedicated to training competitors, but it's not only open to individuals, but also teams, organizations or companies which need 'on demand' training, from initiation to the higher levels of competition and aerobatics. <http://cnvv.net/>

This platform is also exceptional for aeromodelling, thanks to the very good relation between the local aeromodelling club and the CNVV. The weekend of October 18-19 was reserved for aeromodelling (see Gérard Risbourg GPR site: <http://lesgpr.free.fr/manifestations/reportages/2014-st-auban/2014-st-auban.htm>). There were over 50 sailplane pilots and a top level of tugs.

As Pascal Tournache writes to conclude what all the participant felt, "If searching for the Grail is often closer to chimaeras than reality, this weekend we were very close..."

Well, a perfect choice for me...

On the Saturday morning, I was not in a hurry. The Eta was ready for several months, but the pilot was not.

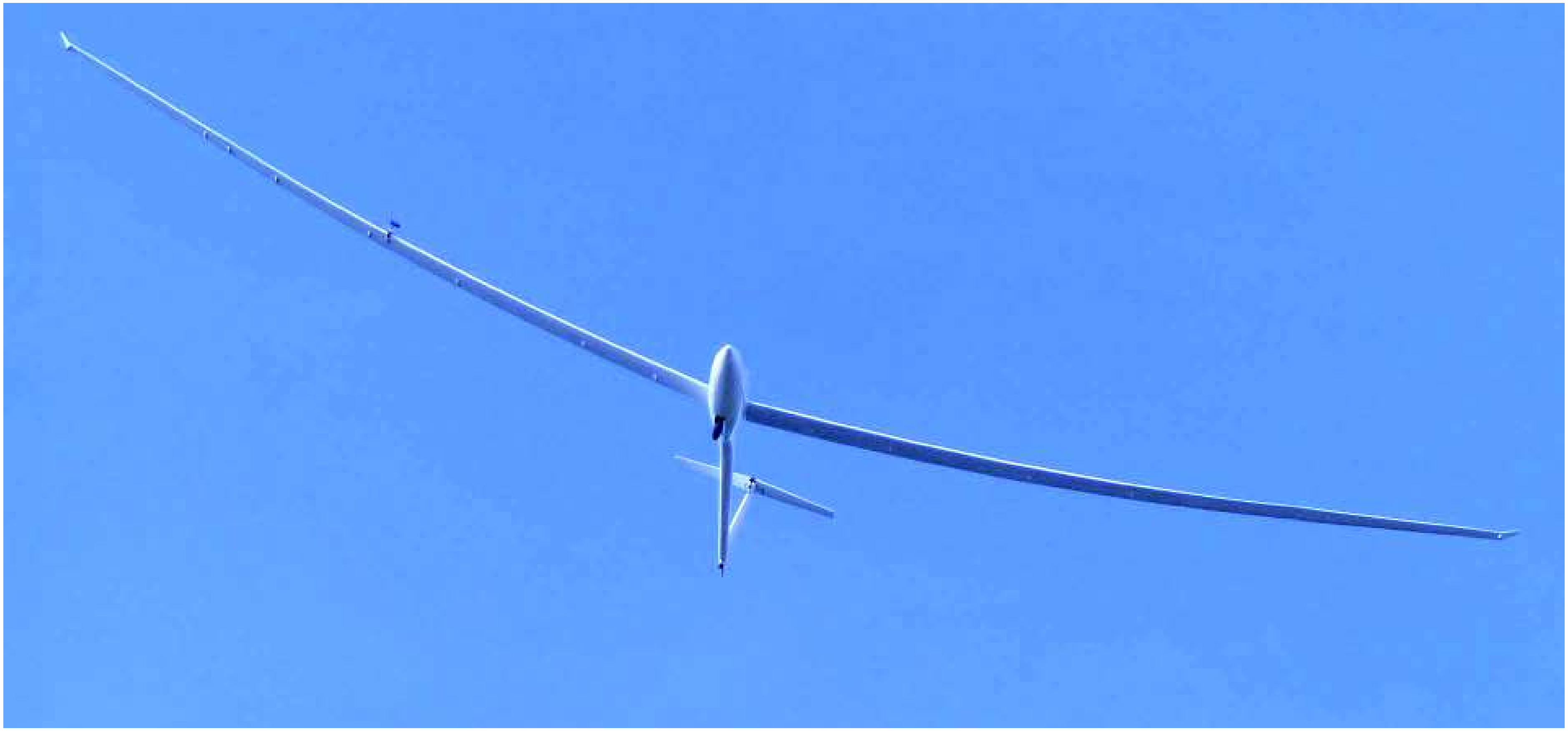
I verified the model several time, and decided to try. The first take off was as in a dream, few trims needed, the wing takes the wind perfectly and takes off.

The main difficulty is to anticipate rolling; I estimate at least 3 seconds for what we call the 'time constant' in the servo loop system. So you need to anticipate the tug turns, but also in straight line the corrections to keep the axis. I was very

surprised by the longitudinal stability, very little compensation to keep the towing attitude.

After drop, the flight seems not so bad, probably a too much advanced center of gravity (already 40% but to increase), certainly a too high speed, but difficult to estimate because of the low chord, it seeks a greater Reynolds number. (Speed is the only remaining factor.) Before landing, a test of airfoil and flaps was done. Airfoil seems OK, flaps need an important compensation, so decided to not use it for landing.

Unfortunately, on the last landing I got strange yaw and roll behavior; associated with the high roll inertia I was not able to understand what happened. Some days



ago, the embedded video shows one of the four airbrakes open. During the four test flights, all landings were a bit difficult as each time I had to open the airbrakes by pulsing. Video: <https://www.youtube.com/watch?v=f7k3nlYuWpk>

One other difficulty was a too short travel of the flaps. This limitation will be difficult to manage because the joint is on the top of the airfoil, a bottom position can solve it (as on many flaps).

Next:

This winter I have a some work to do.

First to replace the airbrakes as I discovered mechanical backlashes that block at least one airfoil under constraint. It's the first time I got this kind of issue, critical in final landing phase on such a model.

For the flaps, I will study if I can modify the hinges, a hard job on a finished model... Other finishing stuff will be easy to perform. I plan also to rework on the aerodynamic side because it seems that there is a lot to gain by working on centering and flaps management. It will probably take me a lot of time, I hope to get the help of embedded instrumentation (air speed and vario, GPS, camera...), and I need to invest in those.