Flying Model Project

Michele Marro

2022

1 Preliminary Aspects

This report is a summary of weeks of readings, research, and discussions on expert forums. The goal is to create something from scratch without referring to any specific existing model—from formulas to flight, including the wireless control part. That's where the fun lies!

I'm not an expert and I don't want to give the impression of being one with this report. The intent is to document the synthesis of what, for me, has been a small journey into a world that does not belong to me but that I am deeply in love with: aviation!

The project is very basic and many aspects (of which I am unaware) were not considered. However, the central part follows a consistent development aimed at the practical side.

I based my work on these books:

- [Sim10]: beautiful, clear, and comprehensive book. Excellent reference.
- [Len96]: technical and very detailed, more complex and suitable for those who already have some background knowledge.

2 General

The main formula I relied on is the classic lift equation:

$$L = \frac{1}{2}\,\rho\, v^2\, S\, C_L \tag{1}$$

where ρ is the air pressure, v the airspeed over the wing, S the wing surface generating lift, and C_L the lift coefficient.

I don't yet know the physical parameters of my flying model, but at least the C_L can be estimated from a chosen airfoil.

My priority is ease of construction. I'm looking for an airfoil with a fairly straight lower surface, since cutting wood precisely is a skill I might lack. I look for an airfoil on Airfoil Tools [Air25]. Obviously, the wing will have a rectangular shape.

Since I don't know the weight, I set a maximum weight that I must not exceed. If the actual weight is lower, I'll gain performance. Including the battery, electronics, and fuselage, I aim to stay under 800g. It's a reasonable weight, maybe even a bit generous, but better to err on the side of caution. Apparently, smaller models are below 300g.

3 Wings

For the wingspan, which I obviously have to decide, I'll stick to something portable and not too bulky—say between 80 and 100 cm. I'll then adjust S (wing area) accordingly based on the width, losing some C_L since it generally decreases as the aspect ratio AR increases, which for me is simply the ratio between the wingspan and the width of the wing (since it's rectangular). If needed, I could extend it by 5–10 cm per side for more lift.

A plausible cruise speed is around 50 km/h, maybe even less. For this value, I need to evaluate the Reynolds number RE. In my case, I find a Reynolds number of:

$$RE = \frac{v \cdot length}{\nu} \sim 10000 \tag{2}$$

Which is acceptable and not turbulent for the kind of plane I'm building. So I'm looking for an airfoil suitable for low-performance regimes. I choose an AG35 (details of C_L and moment C_m are plotted in Figure 1).

For the chosen airfoil, I should aim for $C_L = 0.75$, which is obtained at an angle of attack of about +3 degrees. Assuming an aspect ratio of 8 (a generic and acceptable value that doesn't decrease C_L too much) on an 80 cm wing (10 cm wide, so $S = 800cm^2$), in standard conditions ($\rho = 1013hPa$), the numbers are consistent with the imposed 50 km/h. This isn't a trivial calculation—it gives an early idea of whether the project is realistic.

At 3 degrees, I'll have a negative moment (Figure 1 right), meaning a tendency for the model to nose down, which I'll have to counterbalance with an adequate tail and control surface.

The maximum C_L before aerodynamic stall is just below 10 degrees and about 1.2. So, ideally, the plane should lift off at around 40 km/h. That's not too high, so I'll try to reduce it a bit.

The wing control surfaces will be 25% of the maximum width and 25% long. There's no exact correct value, but these are generic reliable values. We can adjust later with servo offsets.

4 Tail

I mainly refer to the formula:

$$V_h = \frac{S_h \cdot l_t}{S \cdot c} \tag{3}$$

where V_h is the horizontal tail volume coefficient, S_h is the surface of the horizontal stabilizer, l_t is the moment arm (distance between the CG, ideally at 25% of the MAC, and aerodynamic center of the tail), S is wing area, and c the mean aerodynamic chord.

To save effort, I measured the length of typical propeller aircraft (Bonanza, Cessna 152...) from photos to get an idea. The moment arm is usually 3–4 times the chord. So in my case, between 30 cm (chord of 10 cm) and 50 cm (chord of 12.5 cm, for $AR = 8$ on a 100 cm wing). This is somewhat arbitrary, but it affects drag. A different length would lead to different surface areas.

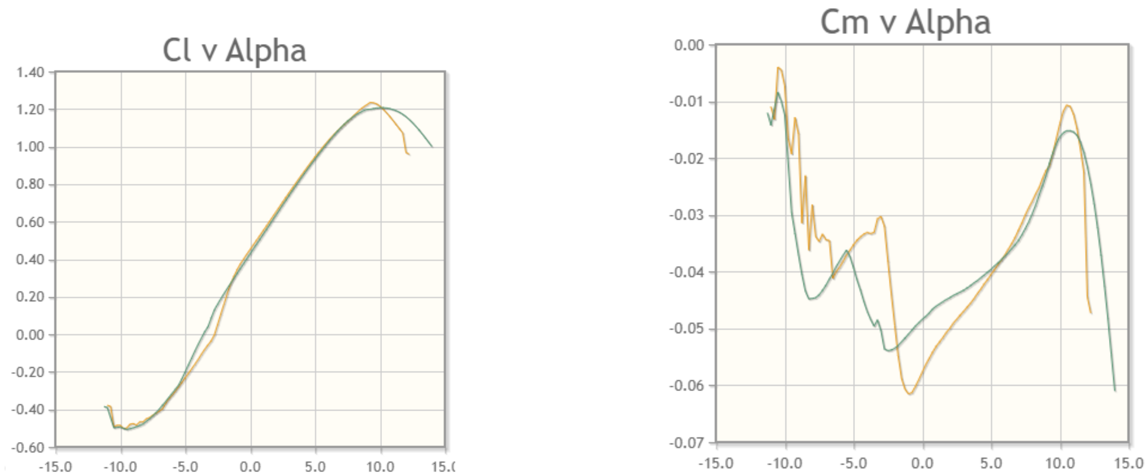

Figure 1: Plotted details of the chosen AG35 airfoil. Figures taken from [Air25] for $RE = 10^5$.

Typically, V_h is set based on the aircraft type. In my case, 0.75 could work well (a small powered aircraft, close to a glider). Based on calculations, S_h should be between 150 and 312.5 cm^2.

For the vertical stabilizer, I'll use a similar formula to compute its area S_v:

$$S_v = V_v \frac{S \cdot length}{l_v} \tag{4}$$

Where V_v is a similar coefficient to V_h, here set to 0.06 (ideal for small powered glider-like planes), $length$ is the wingspan (80–100 cm), and l_v is the moment arm (same as l_t for simplicity). So the vertical stabilizer area should be between 100 and 200 cm^2.

Again, control surfaces are set based on general values: 30% of S_v will be mobile surface, and 25% of S_h will be control surface. Fine adjustments will be set via the servos.

5 Engine

The motor will be a brushless one bought on Aliexpress. I'm not sure how reliable it will be, but let's try. According to specs (Figure 2), with a 3-cell LIPO battery (i.e., 11.1 V) and a 1045 propeller, it delivers about 1 Newton of thrust, which is impressive! I specifically bought 8060E propellers (more than one, in case of breakage), so I expect about 600 g of thrust—which is great for my max 800 g model.

6 Electric Circuit

The most complicated part of the project was the electric circuit. Which battery suits my needs? Which ESC to buy? What's the best battery-ESC-engine combo? The

Features/Specs

- Model: A2212/10T
- KV: 1400
- No load Current : 10 V : 0.5 A.
- Current Capacity: 12A/60s
- No Load Current @ 10V: 0.5A
- No. Of Cells: 2-3 Li-Poly
- Motor Dimensions: 27.5 x 30mm
- Shaft Diameter: 934;3.17mm
- Shaft diameter: 3.175mm.
- Minimum ESC Specification: 18A (30A Suggested)
- Thrust @ 3S with 1045 propeller: 1000gms approx
- Thrust @ 3S with 0945 propellers: 650gms approx
- Thrust @ 3S with 0845 propeller: 550gms approx
- Length: 72mm
- Width : 27mm
- Weight: 72gm

Figure 2: Brushless engine technical specifications.

engine specs suggest: 2–3 cell LIPO battery, 1400 KV (i.e., 1400 RPM per volt); a 30A ESC is recommended.

The battery I bought is a 3-cell (11.1 V), 1300 mAh, 30C, so it delivers up to 39 A peak. Specs are quite aligned with what's needed. With 8060 propellers and an average 10A draw, flight time should be about 7–8 minutes—not much, but enough to see it take off!

The circuits are managed by two Arduino Nano boards. Two nRF24l01 wireless antennas are used for transmission and reception. Since joysticks are expensive, I salvaged them from an old PC controller, measured the potentiometer pins with a multimeter, and soldered them to Arduino's analog pins. See Figures 3 and 4 for circuits. Code is available on my GitHub.

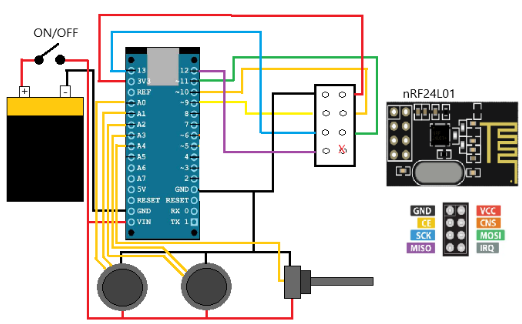

Figure 3: Transmitter circuit powered by a 9V battery. Two joysticks (from an old PC controller) and a potentiometer for thrust.

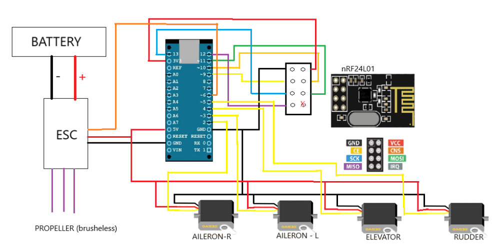

Figure 4: Receiver circuit with servo and ESC management system.

7 Fuselage

For the fuselage, my main principle is: simplicity and lightness. I want something easy to build without excessive use of wood (and thus weight). I found balsa wood in a local store—ideal for this hobby: light and fairly strong. I also bought poplar wood for the fuselage cross sections (which must be stronger) and to reinforce the wing center, which bears all the flight load. Initial assembly phases are shown in Figure 5.

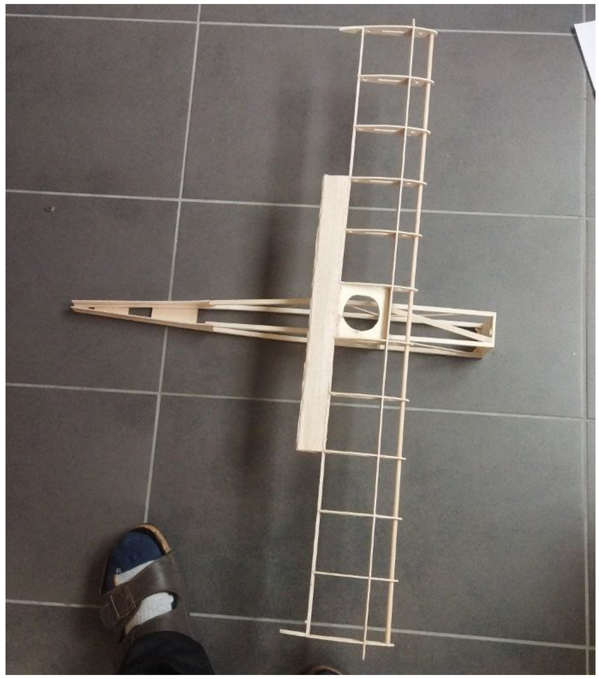

Figure 5: The plane shape starts to take form.

After assembling with glue and designing a system to detach wings for transport, I worked on covering it. To save money (since proper products are expensive and need shipping), I used tissue paper glued to the fuselage, then lightly sprayed it with water and let it dry near a radiator. I hoped it would shrink, but the result was not great.

Eventually, I opted for a very thin adhesive plastic film. The glue and the material slightly increased the weight but made it more durable and a bit more aerodynamic due to the smooth plastic.

8 Putting It All Together

The calculations are obviously approximate. Some were ignored altogether; for example, I have no idea about the drag. But at least I played safe with some coefficients and structural values that I can theoretically adjust using the control surface offsets.

I chose a wingspan of 85 cm mounted on a 5 cm wide fuselage, so 80 cm of lift-generating wing. The width was set at 14 cm to avoid very short chords, which are hard to build manually, resulting in $AR = 5.7$ and $S = 1140cm^2$. Tail size follows the reasoning in the respective section.

The good news is: once fully built, the plane weighs 520 g—280 g less than the maximum! That leaves room for a GoPro (128 g!).

I had to optimize the limited space inside the fuselage. I installed the rudder and elevator servos upside-down for space reasons and connected them to the wings using metal wires with support sleeves to prevent bending. Not ideal, but functional.

Under these conditions, the plane takes off at around 30 km/h, and the overall performance is better than expected for an 800 g model.

References

[Air25] Airfoil Tools. Airfoil tools website. http://airfoiltools.com/, 2025. Accessed: 2025-07-21.

[Len96] Andy Lennon. *Basics of R/C Model Aircraft Design: Practical Techniques for Building Better Models*. Air Age Publishing, 1996.

[Sim10] Martin Simons. *Model Aircraft Aerodynamics*. Special Interest Model Books, 5th edition, 2010.