

The Airship Simon

The Construction of the Blimp Simon

Airship Science Applied in Real

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1. First Steps

a) Hull Shape

The most important aspect of the blimp Simon was its overall design and the dimensions of its envelope. Because the actual size could not be evaluated before the weight of the structure was known, a first design only included the form and ratio of the hull and not its final dimensions.

Two aspects were important when designing the front or tail piece of the blimp. There was the look of a zeppelin, an aerodynamically formed nose and a tail possibly pointed or round. Also, there was the volume to surface ratio affecting air resistance, wind influences and most important, cost. Simon took a special approach to a design of an ellipsoid of revolution (EoR), giving it the look of a blimp.

Different length to width ratios were drawn and their volume graphs had to be calculated to be able to compare the advantages of each design (done with the mathematical computer program Maple V).

A ratio of 1 : 3.27 was finally chosen. The advantages are a large volume even for small radii and thus a large lifting force and low air resistance. At the same time, the ratio looked good.

In the same way, a middle cylinder (MC) was fitted into the system. Its length was determined to be two thirds of the length of half the ellipsoid.

b) A Gondola

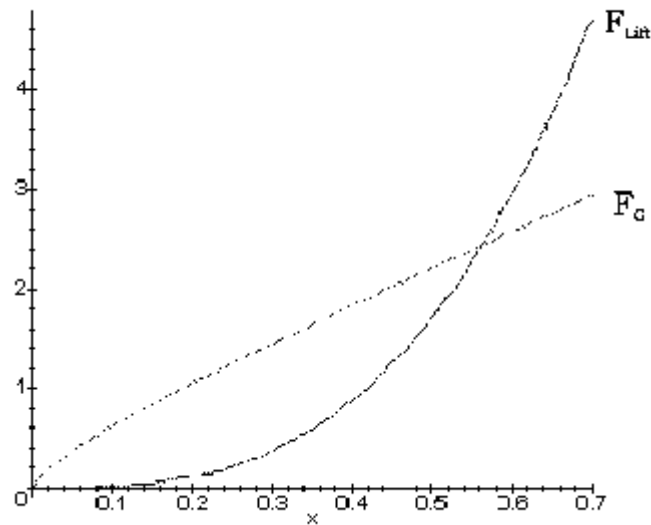
The gondola design proved to be quite hard. Since computer models were not satisfying, the form of the gondola was developed by hand, simply by drawing various sketches. The result was a drop-like, aerodynamic shape. A size of 0.60m x 0.28m x 0.10m was chosen because of considerations including the size of the accumulators, a width supporting the tilting axle and the weight of the motors and propellers, and space for the electronics. The axle would be at the largest width of the gondola. The material to be used is GFC, light and tough.

c) Dimensions

It finally got time to set Simon's actual size. Thus, the electronics, a servo, two motors, two speed controllers, a receiver, and 16 accumulators were bought and weighted. Mylar foil was also weighted, together with the balsa wood needed for the stabilizers.

It can be said, that the dimensions of an airship depend on the power output of its motors, since the motors and accumulators make up for the largest part of its weight. The more power the motors produce and the more accumulators are needed, the bigger the airship gets.

The volume to radius ratio, and thus also the lifting force for a given radius of Simon had previously been evaluated. Because motor power output - and the weight of the motors - also depend on the size and volume of an airship, the following relation between f_g and f_{lift} was drawn as shown in the graph below. Since Simon was meant to be an outdoor blimp, fighting against wind and turbulences, it had to be motorized sufficiently, meaning a quite large motor weight. Not expressed in the graph are the influences of inertia and other more complicated aspects, since the graph itself is only an approximation.



From the graph, the minimum dimensions of Simon could be determined. They lay around a radius of 0.5 m and thus an overall length of 4.3 m. As previously mentioned in [General Airship Design](#), 110 percent of these values were used for Simon to take precautions against any eventualities. [See Simon's dimensions.](#)

2. Calculations and Model Construction

a) Hull Values

It is always best to find out the main data of an airship, to see where possible problems might come up. Is f_{lift} large enough? How large is the surface of the blimp? etc.

The exact volume of Simon had been calculated by formula (3) and (4) already mentioned in [General Airship Design](#). The origin of (3) derives from the equation of an ellipsoid, (6) and (7).

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \quad (6)$$

$$f(x) = \sqrt{b^2 - \frac{b^2 x^2}{a^2}} \quad (7)$$

The formula for any body of revolution and thus also for Simon's EoR is expressed through

$$V = \int_{-a}^a \pi f(x)^2 dx \quad (8)$$

When substituting (7) for f(x) one gets the final formula for an EoR

$$V = \int_{-a}^a \pi \left(b^2 - \frac{b^2 x^2}{a^2} \right) dx \quad (9)$$

$$V = \frac{4}{3} \pi a b^2 \quad (3)$$

When formulas (3) and (4) are evaluated, the volume of the ellipsoid and cylinder equal to 3.42 m³. f_{lift} of 100% pure helium (ideal gas) in air at 0°C and 1.013 x 10⁵ Pa is equal to 10.9 N per cubic meter. Using equation (1), a f_{lift} of 37.4 N results. This value may change through pressure and temperature influence, expressed in equation (10)

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \quad (10)$$

Also, it is important to know the surface of the envelope to estimate the weight and price of the envelope material needed. It is given by the equation for the surface of revolution of a body, derived from the length l of a curve

$$L = \int_{-a}^a \sqrt{1 + \left(\frac{\partial}{\partial x} f(x) \right)^2} dx \quad (11)$$

$$S = \int_{-a}^a 2 \pi f(x) \sqrt{1 + \left(\frac{\partial}{\partial x} f(x) \right)^2} dx \quad (12)$$

where, again f(x) is substituted by equation (7). Also, the equation for the surface of Simon's MC must be considered. it is

$$S = 2 \pi b l \quad (13)$$

The final surface is expressed through

$$S = 2 l \pi b + \int_{-a}^a 2 \pi \sqrt{b^2 - \frac{b^2 x^2}{a^2}} \sqrt{1 + \frac{b^4 x^2}{\left(b^2 - \frac{b^2 x^2}{a^2} \right)^4}} dx \quad (14)$$

Simon's surface equals to 14.3m^2 .

b) Calculating Hullparts

How may one build a three-dimensional blimp from plane mylar foil? This was a central question when building the blimp Simon. Obviously, it could not be done with one piece, but needed the more, the rounder the structure had to be. Too many pieces, however, would have made the construction last forever. Thus, it was decided that Simon would be made of 26 pieces, 12 for the front, 12 for the tail and 2 for the mc. each of them had an additional glue fold.

The hullparts were obtained by dividing the circumference of the ellipsoid by 12 at every point x of the x-axis below.

$$L = \int_0^x \sqrt{1 + \left(\frac{\partial}{\partial x} \sqrt{b^2 - \frac{b^2 x^2}{a^2}} \right)^2} dx \quad (15)$$

$$W = \frac{1}{6} \pi \sqrt{b^2 - \frac{b^2 x^2}{a^2}} \quad (16)$$

To be able to draw and afterwards actually cut out Simon's hullparts, the l and w values for a given point x needed to be evaluated.

c) First Models

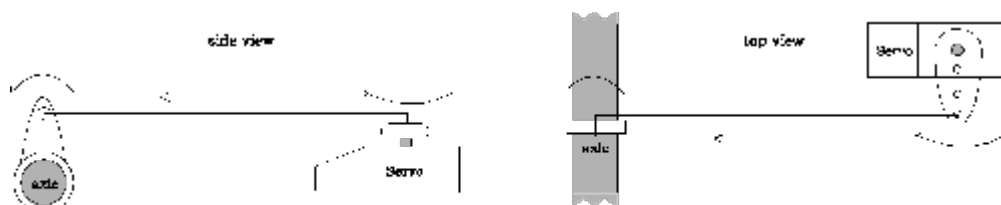
To control the correctness of the hullpart calculations and see the gondola in 3D, both, the hull and the gondola, were built as a model first. From paper, a hull was put together in the actual design of Simon in a scale of 1:5, and from a polystyrene cylinder, a gondola was cut out true to scale. It could afterwards be used as a positive form of the real gondola.

A model shows the dimensions in the room. It also helps doublechecking the theoretical work.

3. Construction of the Main Parts

a) a tilting axle

The application of vectored thrust (VT), as already described in [General Airship Design](#) made it necessary to construct a tilting axle. For Simon, a simple construction as shown below was chosen. VT allows for two different options. Either only the propellers or both the motors and propellers are mounted at the tips of the axle. To mount only the propellers rises the problem of connecting the motors with the propellers through the axle. To mount the motors and the propellers causes a stability problem: The axle has to support the weight of the motors and the propellers. It was decided that Simon would support a system with the motors and propellers mounted at the tips of the axle; an aluminum pipe (diameter: 8 mm) was used to overcome stability problems.



b) Construction of the Gondola and the Hull

Since a polystyrene model of the gondola was already made, it was used further to construct the gondola. From the polystyrene shape, a negative form of plaster was cast. After a week the plaster was dry and a layer of wax and one of GFC were laid inside the negative form. the wax kept the

plaster from sticking to the GFC. Once the shape of the gondola was finished, holes for the tilting axle were drilled and supporting aluminum braces were glued to the axle and the gondola. The axle was additionally supported by four ball bearings.

Next, the hull had to be put together. Conducting various tests, it was found that contact glue was the ideal adhesive for making the hull heliumtight, since welding was not an option for a polyurethane like mylar. Because the outermost front and tail parts were extremely difficult to glue threedimensionally, a polystyrene body to fit the front and tail of the airship was sanded. It could be used as a 3D surface for gluing. It took 30 to 40 hours of gluing and four tubes of glue to put the envelope together. A valve and two pieces of wood were then placed inside the hull. The valve, with a diameter of 0.01 m, would be used to inflate the blimp, the two pieces of wood to mount the gondola to the hull. The gondola would be coupled to the envelope through four mounting points. Four screws from inside the envelope went through the pieces of wood and attached the gondola to the rest of the airship with wing nuts.

c) The Electronics

Inside the gondola, the electronics needed to properly control the airship were arranged. They included a servo to tilt the motors, sixteen 1.2 V accumulators, two speed controllers, the receiver of the radio-control system and four batteries supplying it with power. Eight accumulators made up an accu pack, connected to each other in series. The receiver controlled the servo and the two motors with their speed controllers. This way, the motors made up two independent circuits.

See a scheme of [Simon's electronics](#).

d) The Fins

At last, tail surfaces were designed. Simon's four fins became huge with a height of 0.55 m each, and a length of 0.40 m, but compared to the envelope, they seemed extremely small.

Made of monokote and light balsa wood, the fins are extremely light. Still, they needed to be considered when evaluating the center of gravity of the blimp. The exact center of gravity could only be located empirically, in Simon's case with a large wooden scale.

4. First Experiences and Improvements

a) Flight Preparations

When all parts were built, they needed to be put together. After connecting all the electronics inside the gondola and turning the power on, the gondola could be mounted. Then, the helium was filled in through the valve until Simon started to float. The fins were attached to the tail by tape. Because of the extra weight of the fins, more helium was filled in. When Simon floated again, the helium was substituted by air, filling the envelope all the way, giving it its final shape and producing a slight overpressure.

b) Flying a blimp

It is no secret now: Simon got too small. Even with little wind, the airship was shaken by ever little airstream. The problem was not caused by undermotorization or too small fins. With absolutely no wind Simon obtained speeds of up to 5 m/s and flew completely steady. Thus, the small airship Simon involuntarily got only a calm-weather-blimp. One simple measure helped a little to avoid unpleasant winds: flying at little altitudes!

c) Improvements

After the first practical experiences, many new and sometimes demanding problems arose. The valve was a little small: With a valve of a larger diameter, it would not take as long to inflate the blimp. Also, a safety valve would be preferable. This means some sort of a radio-controlled system to control the opening of the valve, or even an additional valve. There were many possibilities to solve the problem, but none of them was easily applicable. There would be the option of an electromagnetically controlled valve, a coil with an iron core and an applicable current. A one way version of a safety valve would be a thin membrane to be destroyed by a movable and sharp tool such as a needle. Third, there would be the mechanical valve, controlled by a servo. For Simon none of the above has been used yet, but the construction and use of a mechanic valve is heavily discussed at this very moment.

The motors also proved to be difficult to handle. For strong currents, they were not powerful enough, for calm weather, they were more than sufficient. Also, during the course of various flights, it was found that the motors heated up very fast because of a large current flow. It even occurred once that

one of the motors melted out of its fixture! Thus, the use of other, less resistive motors turning at a lower frequency is discussed at the moment. The fixture of the motors has already been reinforced by ring clamps. Also the supporting aluminum braces of the axles have been reinforced. Previously, they often got damaged during hard landings.

The envelope problem: in the beginning, the hull was amazingly very heliumtight. But after a few crashlandings and many transportations of the blimp, it started to leak. The weak points are the vertical glue folds between the ellipsoid and the cylinder. However, the hull itself got damaged, as well, and many little holes, invisible for the eye, grew larger. Now test are being conducted with lacquers such as silicon to seal those holes.

5. Completion

a) Motor Thrust - an Experiment

How powerful are the motors, with the given propellers? The motors currently used are two Robbe Power Plus 410/12 with two 9-6 propellers. To experimentally determine the thrust of one of them, a scale with a fulcrum was built. A thrust of 3.3 N per motor was determined.

b) Air Resistance - an Approximation

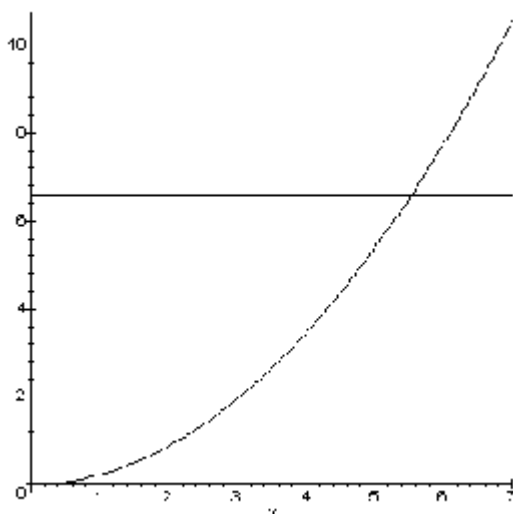
Since thrust was known, it became interesting to determine air resistance. The difficult part was not the calculation, but the approximation of the index of air resistance c_r , since no wind tunnel facility was available. For a perfect sphere, c_r is 0.47, for a streamlined body 0.05. Also, equation (5) is only valid for turbulent streams. For the blimp Simon, turbulent streams were guessed to appear from a speed of 2 m/s up. Thus, equation (5) could be written as following

$$F_r = \frac{1}{2} c_r \rho v^2 \pi b^2 \quad (17)$$

Where $2 < v$

and $S = \pi b^2$.

ρ is the density of air, in this case 1.293 kg/m³. For c_r an approximation of 0.35 was chosen, in the middle of the values of a sphere and a streamlined body, a little closer to a sphere. The graph below shows the relationship between speed (x) and air resistance (y). It may be seen that Simon has a theoretical maximum speed of 5.54 m/s. Beyond this value, motor thrust of 6.6 N is lower than air resistance.



c) Helium Recycling

Helium is very expensive. Why not recycle it then? The problem is: To get the helium out of the blimp envelope, a vacuum pump is needed. Cheap solutions for a vacuum pump are refrigerator compressors or pumps used to inflate rubber dinghies. Their capacities are very low, though, and it

takes a while to fully deflate a huge blimp envelope, even with a big pump. However, the main problem is storage. A heliumtight receptacle, possibly under overpressure has not been found yet. Maybe it will in the future of the blimp Simon...

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