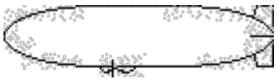


The Airship Simon
General Airship Design with Direct Relations to the Blimp Simon

1. Buoyancy and Lift

a) lift

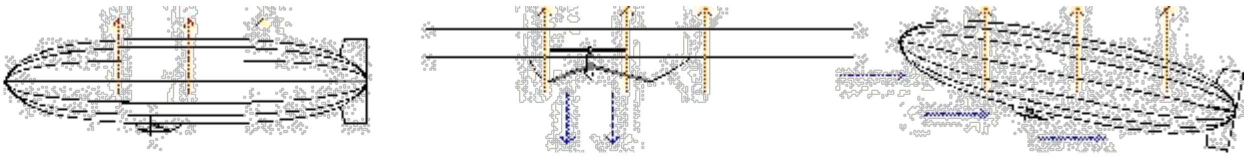
Any vehicle operating in a medium may obtain lifting forces from three primary sources:
static lift, dynamic lift, and powered static lift.

The most economical of these forces from the production of lift point of view is undoubtedly the static lift wherein buoyant force is generated by the displacement of a portion of the supporting medium by the body. For a waterborne vehicle, this lift is embodied in the displacement ship, and for airborne vehicles, this is the balloon.

The inefficiency of the static lift vehicle comes when it is required to move through the surrounding medium. Due to the nature of displacement buoyancy, these vehicles tend to be very large and, as a result, they develop a great deal of dynamic drag when in motion. The dynamic effects of the motion can be used to an advantage, however, if the motion can be used to generate lift. by shaping the body, or a portion thereof, as a lift producing foil, a lifting force may be developed to support the weight of the body, provided sufficient forward speed is attained. In air this is the airplane, while in water this the hydrofoil craft.

A principle disadvantage of the dynamic lift vehicle is that it requires forward motion of some finite velocity to generate the lift. As a result, this vehicle can neither fly very slowly nor can it remain airborne at zero forward velocity (hover). If these attributes are required, one must provide some sort of internal powering for the static lift, such as a vertical jet exhaust, or a propeller with a vertical downflow. In air this is the helicopter or special aircraft, and on water (or in close proximity to the earth) this is the air cushion vehicle or hover craft.

Having defined these primary sources of lifting force, one might observe that it is possible to use two of these sources, or even all three, in combination. By doing so, one moves from the pure lifting force source, for example static lift, to a hybrid source, such as a partial static lift and a partial dynamic lift. This is exactly the technique used with Simon. Its envelope produces static lift, while the two motors provide powered static lift and dynamic lift.



b) Static Lift of an Airship

Obviously, when looking at an airship, the amount of static lift is the most important. Because it plays the decisive role on whether an airship will float or not, it will be looked at closer in the following.

The principal tenet of static lift is that a body displaces a volume of the surrounding medium whose weight is equal to or greater than the total weight of the immersed body. If the weight is equal, the body is said to have neutral buoyancy, while if the weight of the body is less than that of the displaced air, the body has a positive buoyancy. The lift of he in air is obtained as following

$$F_{Lift} = (\rho_{air} - \rho_{He})\, g\, V \quad (1)$$

The greatest static lift is to be obtained from hydrogen with helium a close second. It has to be noted that although the weight of a given volume of helium is approximately twice that of an equal volume of hydrogen, inasmuch as the lift is the difference between the weight of the gas and the weight of air, the lifting capacity of hydrogen is but about eight percent greater than that of helium.

When considering the high degree of flammability of hydrogen, one might ponder why that gas is even considered as a static lift source. The answer lies in the economics of its procurement. Wherein helium must be mined or extracted from minute quantities in the atmosphere, hydrogen can be obtained inexpensively from the electrolysis of water.

Due to the natural impurities that are present in helium as it is recovered from the earth, and due to the cost of extensive refining, commercial helium is seldom available at greater than 98 percent purity. This means that the lifting force of helium depends on its purity and is never 100 percent.

c) Temperature and Pressure

Very important for the correct use of aerostatic systems is the knowledge of the weather and its tendencies. The most important influences emerge through air pressure and temperature changes. As the airship ascends, the lifting gas expands due to the reduction of the ambient air pressure. This pressure can be expressed as an index, the standard atmosphere (ISA), which indicates the air density for different altitudes above sea level . To prevent overpressure inside the airship hull as the airship rises, ballonets and valves are used to level out the differences in pressure. With valves, the pressure may be regulated by radio signals. Ballonets are small balloons inside the hull of an airship, filled with air and, as pressure rises, losing air automatically. There is some altitude at which, with the ballonets completely empty, it is just possible to return to the ground with the ballonets filled to capacity. This altitude is called pressure height. Flight above pressure height will result in the ballonets becoming completely filled prior to the airship reaching the ground on its descent and then some other measures must be taken to maintain the shape and pressure of the envelope. The most common measure is the addition of air to the lifting gas using the previously mentioned safety valve. Unless the pressure airship is considerably above the pressure height, a decrease in altitude or an increase in barometric pressure will have little or no effect on the static lift inasmuch as the lifting gas will contract and the airship will no longer be at pressure height.

Because of local heating, usually from the sun on the envelope, it is possible for the lifting gas to be at a different temperature than the surrounding air. If the sun heats the lifting gas so that it is at a higher temperature than the surrounding air, a condition called superheat, the same weight of lifting gas displaces a larger volume of air, and therefore a larger weight of air. This produces an increase in

static lift.
Inasmuch as the specific density of the gas is inversely proportional to the ratio of absolute temperatures, the percentage increase in static lift due to a temperature increase may be found from the relationship

$$F_{Lift} = 100\frac{T_1}{T_0} - 100 \quad (2)$$

Because of these large influences of the sun, winds and air pressure on aerostatic systems, it is recommended to let an airship fly at sunrise or sunset, in order to avoid strong currents.

2. The Envelope

a) Dimensions - the Look of a Zeppelin

The envelope or hull is the main part of an airship because, as the wings of a plane, the envelope decides if an airship is going to fly. Most radio-controlled airships are nonrigid and their envelope is usually in the shape of a cigar that is kept in form by internal overpressure. Rigid models often encounter serious overweight problems because of an adverse weight to volume ratio. The most difficult task is to choose a material which makes the envelope light, tough, and most important of all, helium-tight. The envelope is often the factor that keeps people from building model airships because it is something that cannot be found in other aircraft model building.
It is very important to give an airship its special design. Some people might find it nostalgic or even a waste of time to design an airship in its unique form. This is simply not true. The previously mentioned cigar-shaped hull gives an airship stability, low air resistance and a maximum amount of lift. Tried and tested, very reliable and effective designs are the Goodyear blimp design, Prill's semirigid design, or, of course, Zeppelin's own, more than 100 slightly variable designs . For Simon, another aspect was the feasibility of the hull construction with limited means and minimum expenses. Along with this considerations came the demands Simon had to fulfill. It had to be the smallest blimp possible for outside operation. Thus, the design of an ellipsoid of rotation (EoR) combined with a middle cylinder (MC) was chosen, as described in the construction of Simon, after the simple formula for the volume of an EoR (3) and a cylinder (4)

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

$$V = b^2 \pi l \quad (4)$$

b) Volume, Lifting Force, and Weight

In chapter 1. b) Static Lift of an Airship, it becomes clear that the lifting force of an airship is directly related to the volume of its hull by equation (1). The weight, however, determines both of these values. The airship needs a lifting force at least as big as the overall weight of its components to be able to float in the air. Since temperature changes and pressure variations influence the ideal lifting force, it becomes necessary to calculate an ideal lifting force and volume big enough to overcome these influences. More is better than less. Also, it is often very difficult to calculate the overall weight of an airship in advance.
It is recommended to actually construct as many of an airship's parts as possible, i. e. the gondola, the propulsion, the fins, before deciding on the exact volume of its hull.
For Simon, an ideal lifting force about 10% bigger than its weight was calculated. This left enough elbowroom for weather moods and eventual changes or improvements and additions to the blimp.

3. The Gondola

a) Funtions

In general, the gondola of a radio-controlled airship contains the receiver and batteries and has the motors attached to its outside or back. The easiest solution is probably to have one motor aft, but it is definitely more effective in terms of steering to have two motors, one on each side like on most of today's blimps. The alternative to gondola mounted motors is to have them in separate gondolas on the sides of the ship or underneath it, as it has been done with the historic zeppelins. Having them at a distance from the other equipment helps to distribute the weight load and avoids interference of their magnetic fields with the receiver. Also, the danger of damaging the hull is smaller. To completely avoid this danger, impeller motors may be used . Furthermore, if the motors can be operated independently, a wide separation increases the maneuverability of the airship.

b) Form and Dimensions

A gondola needs to combine two things. First, the weight of it has to be as small as possible and the stability very high, to bring up the question of the material to be used. Secondly, it has to be large enough to enclose the batteries and electronics. As a third aspect, an aerodynamic form might be considered. Because the exact center of gravity of an entire blimp can hardly be calculated, it is a good idea to leave space inside to move the batteries around and balance the blimp as a whole. Glassfibers and epoxy, GFC, is the preferred material in such situations because of their toughness and lightness. Processing may prove to be hard, since GFC is normally formed through overpressure or an applied vacuum, but if not done so, the outcome simply lacks smoothness.

4. Flight Dynamics

a) Steering

There are many possibilities to control and steer a floating airship in the air. For Simon, a most sensitive and weather conditions independent solution was developed. Simon has two motors, on each side, connected through a movable axle, that can tilt up and down. This feature is called vectored thrust (VT).

VT allows for very exact vertical steering of an airship. It may replace the less effective rudders, which tend to react slow because of the only low speeds of an airship.

VT produces powered static lift and may play an important role in fine-calibrating the float of an airship. It makes it possible for an airship to descend without the use of a valve or other means of letting off helium.

Since the two motors of Simon can be operated independently forth and back and are separated by over 1 m from each other, they provide a great horizontal maneuverability. One motor may thrust forwards, the other backwards. Backward thrust is a little smaller than forward thrust because of the special shape of the propellers.

As mentioned, a special feature important for any airship is the possibility to operate the motors forth and back, to produce thrust in both directions. in combination with VT, this enables the airship to ascend, descend, and make sharp turns in both directions.

b) Friction and Drag

In order to choose the right motorization for an airship, friction and air resistance may not be neglected. Friction depends on the material used. For Simon a Mylar foil is used for the hull, which is fragile but tough and insulating. With mylar, friction is very small, not relevant. It's different with air resistance. An aircraft always produces resistance, drag in the air, depending on its size and velocity after the equation

$$F_r = \frac{1}{2} c_r \rho v^2 S \quad (5)$$

The index of air resistance cr may be found through wind channel tests for different bodies. The index of an EoR lays in between 0.05 and 0.5, depending on the length to width ratio of the body.

In Simon's case, the calculation of air resistance is important because it determines the power of the motors to choose. All calculations conducted ignored possible winds and other atmospheric influences on air resistance since the calculation was only theoretically possible with a cr estimated to be 0.35. c) Stabilization

Tail surfaces are needed to stabilize an airship. At the University of Toronto, extensive studies showed the influences of stabilizers for an airship, and the conclusion drawn recommended to always use fins with an airship.

Tail surfaces and rudders need to be designed so that they allow effective control of the directions of

the airship. Because of Simon's VT and independently controlled motors, rudders are not necessary to further control him. Also, they are only of limited practical use because of small speeds as mentioned earlier in this report. Stabilizers are used and designed in a way to stabilize, but not to overstabilize. Overstabilization means a limitation of the airship's agility through too large fins. Again, with too small fins, the ship often progresses in a wave-like motion.
Tail surfaces for airships are built in the same way as those for radio-controlled planes, just lighter and especially with more surface. Light balsa wood or styrofoam structures covered with Monokote are recommended. That is exactly how Simon's stabilizers are built. Its four fins have an adequate height of 0.55 m each, and a length of 0.40 m.

5. Electronics and Motorization

a) Electronics

Inside the gondola, all the electronics needed to properly control an airship are arranged. They may include a servo to tilt the motors, accumulators, speed controllers, a receiver for the radio-control system and batteries supplying it with power.
Usually, accumulators are bought connected to one another in series . It is possible to use other accumulators than those for model planes and cars; Li-accumulators (used in notebook computers) are no more expensive and considerably lighter. Whatever is chosen, it has to be light!

b) Motorization

There is always the option of using either combustion engines or electric motors for model aircraft. The advantage of electric power is that it allows for very precise throttling combined with electronic speed controllers. Even though an electric system is generally heavier than a combustion engine, the added benefit of reversibility will drastically improve low speed maneuverability. In addition, an electric system keeps the same weight and does not affect buoyancy, unlike an engine that burns gas and makes an airship lighter during flight. Usually, large propellers with few rounds per mminute (possibly through a reduction gear) are more efficient than small, fast turning propellers.
Possibly, impeller propellers may be used. Because of their turbine-like making, they provide excellent protection of the hull from eventual propeller hits. Also, they are easy to glue to a tilting axle for VT. normal electric motors need to be welded to the axle. Their disadvantage is fewer thrust compared to normal propellers.
Simon uses normal 0.115 m, 6-9 propellers for thrust, combined with two 110 W motors. They proved to be dependable and efficient.

6. Etceteras

a) Flight Certification

Fundamentally, radio-controlled balloons and airships are subject to the same restrictions as other radio-controlled flying models.
There is the question of the use of hydrogen as the lifting gas for balloons and airships instead of the much more expensive helium. Common belief is that it is forbidden. The rumor is wrong; a restriction only exists for commercial employment of manned airships with hydrogen. Still, hydrogen is usually much harder to obtain because of its dangers.
There are no exact building regulations and determinations of "small and light" aerostats. When planning a craft of more than 20 kg total mass, sketches and calculations should be shown, however, to the authorities for permission.

b) Meteorology and Atmospheric Effects

As mentioned in chapter 1. c) Temperature and Pressure, the lift of the different gases changes through many different meteorological influences, and a small airship is hard to control in even weak currents. Additionally, the danger of losing the airship due to an upward current is always high for an inexperienced airship pilot. If possible, the tryout and inaugural flight of a small airship should be made indoors, or if not possible during the morning of a calm summer day.The authors are talking from experience...

Questions? Recommendations? Feedback?
To contact the authors of this page, send an e-mail to Nati, Cyril & Mo in Switzerland.

We are always ready to share our experiences with you!