Rocket Gliders part 2 – How do they work?

Learning Objective	In the first part of this lesson we learned about the model rocket glider. In part two we will continue our study into Rocket Gliders and discuss how they work.
Grade Level	9 – 11

– Introduction –

Recall, if you can, the first time you successfully flew a kite. The day was windy or, more probably, there was a steady breeze; your friend helped launch the kite whilst you ran a bit to get it up in the air. Suddenly it felt different, there was a steady pull on the line and you looked back to see the kite high in the air, holding its position. In this article we will discuss the same aerodynamic concepts and how they apply to rocket gliders.

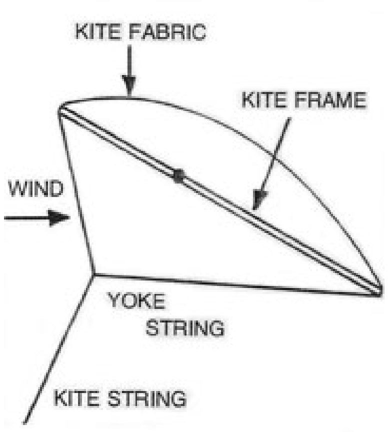

Figure 1 – How a kite works

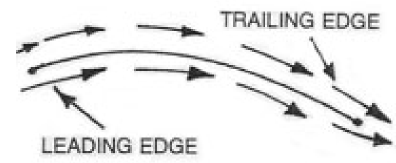

Figure 2

That steady pull encouraged you to let out more and more line until you came to the end of the kite string. When you finally tried to wind up the string to bring back the kite, the pull increased and your arms ached.

That pull on the line was the lift being generated by the kite; it was the force that kept the kite flying and if the kite had been large enough it would have generated enough force to lift you in the air.
Gliders rely on the same force produced by the wings to keep the aircraft up. How is it produced? Let`s go back to the kite; when it is flying properly it is inclined to the wind as shown in Fig. 1. Notice that the kite fabric is billowing up to form a curve and this is what generates the lift. Let’s look at the kite fabric without the frame, strings etc. The air must flow along the fabric surface on top, but can take a bit of a short cut on the bottom surface (Fig. 2).

Bernoulli’s Principle

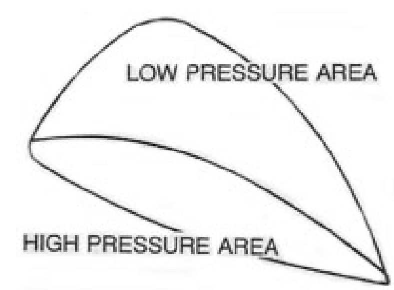

Figure 3

If you look carefully you will see that the air travels further along the top surface than it does on the bottom and thus for the air to reach the trailing edge at the same time after it splits at the leading edge the air on top must go faster than the air on the bottom. One of the well known phenomena in physics is the reduction in pressure in a fluid when it travels faster, and the increase in pressure when it travels slower. This is known as Bernoulli's principle. Therefore on our section of kite fabric we have a pressure distribution that looks like the one in Fig. 3. You will see that the fabric is being sucked upwards by the low pressure area over the top and is being pushed upwards by the high pressure area underneath. The sum of these two forces is called lift force. If you make the kite fabric rigid and let it travel forward through the air instead of the wind blowing over it you have exactly the same effect and you now have one of the early airfoil sections used for pioneer aircraft.

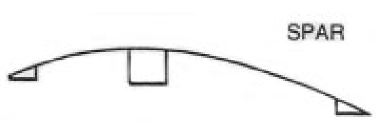

Figure 4

This section has its problems because to make the fabric rigid and to carry the lift force generated out along a wing, you need a stiff structural part called a spar, as well as a leading edge and a trailing edge section (Fig. 4). Now the airflow under the wing is not smooth and is resisted by various structural parts.

Learning from Nature

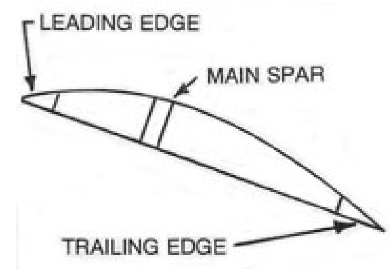

Figure 5

This produces a force very similar to the one you experience when you try to walk into a high wind. You are constantly being pushed back and you bend your body forward to reduce this force which is called drag. Those of you who ski will be well aware of this and will know that to reduce it you must crouch and try to get the top part of your body almost horizontal. The drag force slows down an airplane considerably and to reduce it on the wing it is best to cover the bottom surface as well.

Now you have a section like the one shown in Fig. 5. When the early aircraft pioneers did this they found that they not only reduced the drag but also increased the lift and the reason, of course, is because the lower surface is now much shorter than the upper surface so you get a much greater pressure difference, hence greater lift.

Nature has known these principles much longer than man and has produced birds that can glide and soar, like the eagle, the hawk, the seagull and many others. The airfoil on a soaring bird’s wing looks like that in Fig. 6.

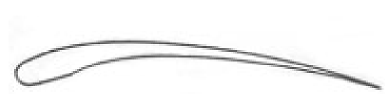

Figure 6

This is what is known as an undercambered airfoil and is similar to the ones used on the large model gliders for international competition. These gliders fly very slowly whereas high speed gliders use a much flatter section since they have low drag at high speed. We can learn from this in designing boost or rocket gliders, because we fly at very high speeds in the boost phase and very low speeds in the glide phase.

An undercambered section has high drag at high speed and will reduce the altitude that can be reached with a given rocket motor, but the glide will be better than a flat section. In actual fact the glide is not that much better than that obtained with a flat bottomed airfoil. A flat bottomed airfoil will also give a much higher altitude because of its lower drag compared to the undercambered section. Two types of model aircraft have the same problem, hand launched gliders and free-flight power models. For this reason, both tend to use flat bottomed airfoils. Since hand launched gliders are similar in size to large boost and rocket gliders, many of their design techniques are similar.

Making our rocket glider stable

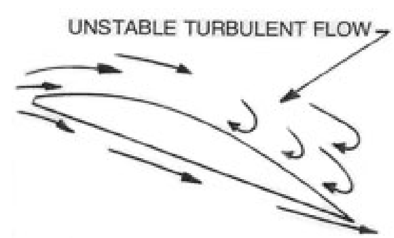

Figure 7

Before we look at airfoils in more detail we must look at how to make our glider stable so that it won‘t decide to get into a spin or just flutter around. If you try to fly a wing by itself you will see it gradually increase its angle to the wind until it starts tumbling like a falling leaf. What has happened is that the wing has increased its angle to the wind (angle of attack) to the point that the air cannot stick to the top surface and just breaks away near the leading edge (Fig. 7).

The wing is now stalled and has virtually no lifting force. How can we prevent the wing from automatically increasing its angle until it stalls? One of the most common ways is to add a fuselage and at the tail end of the fuselage mount a small wing known as a stabilizer. Now as the wing angle increases so does the angle of the stabilizer. As the angle of attack increases so does the lift created and thus the stabilizer will bring the tail back up to the horizontal position (Fig 8). In level flight the lift created by the wing and the stabilizer balance each other around the centre of gravity (CG) of the model by the simple principle of moments (Fig. 9), such that wing lift x wing moment = stabilizer lift x stabilizer moment.

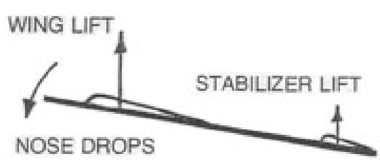

Figure 8

From this, it is obvious that using a lifting section on the stabilizer gives a centre of gravity (CG) position that is behind the point through which the wing lift acts (usually taken as a point 1/4 of the chord from the leading edge). It is also obvious that the longer the stabilizer moment the smaller the area of the stabilizer need be. This is one of the reasons why high efficiency, international class, model gliders use long stabilizer moments and very small stabilizer areas to give a higher lift wing. This same corrective action occurs in a dive situation.

When the angle of attack on an airfoil is negative (Fig. 10), the lift force reverses and operates downwards instead of upwards. The stabilizer will create downward lift in a dive and bring the nose up again (Fig. 11).

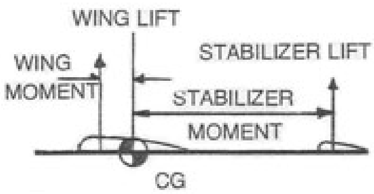

Figure 9

For all these corrective forces to be effective the wing must be arranged so that it stalls before the stabilizer, so that the stabilizer will still be effective even when the wing stalls. One of the easiest ways of achieving this is to mount the wing at a more positive angle than the tail. On boost/rocket gliders the wing is usually mounted with the flat bottom at zero degrees (horizontal) and the stabilizer with – 1/2° incidence (Fig. 12).

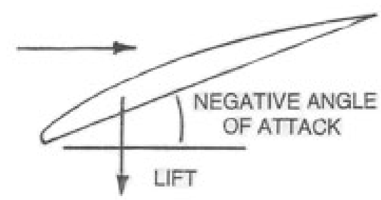

Figure 10

Similar unstable effects around the horizontal axis along the fuselage (causing roll) and around the vertical axis through the centre of gravity (causing yaw) are corrected by arranging lifting surfaces that increase in lift to bring the model back to its normal flight path. Thus roll is cured by adding dihedral so that as the model rolls, one of the wings has slightly more area (in other terms, its shadow on a flat table would increase in length). This wing gives more lift and rolls back to the normal position (Fig. 13).

The fin or rudder placed in a vertical position at the tail does the same job in yaw and brings the model back into straight flight (Fig. 14).

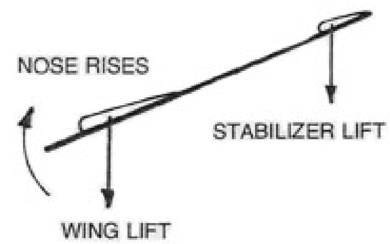

Figure 11

The design of our airfoil

Now we can return to the design of the wing airfoil. From your own experience you will know that thin, sleek shapes have lower drag than thick, bulky shapes and therefore a thin airfoil will have lower drag. This means that in boost, you will get to a higher altitude using a thin airfoil. but due to the low, top surface curvature, the lift will be lower than that produced by a thick airfoil.

This means that the thin airfoil has to fly faster than the thick airfoil to generate enough lift to keep the model flying in a flat glide. Does this matter? Unfortunately it does, because the slower the glide the better the chances you will have of catching a thermal. If you are flying in competition, catching thermals is one way of making sure that you win.

Figure 12

Another problem occurs in the low speed glide portion of the flight. All rocket and boost gliders are small enough that the air has a tendency to break away from the top surface at normal glide speeds. This causes a very serious drop in lift and hence a poor glide.

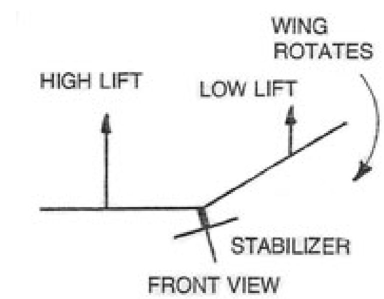

Figure 13

One of the best ways of overcoming this is to make sure that the airflow reattaches to the top surface. This can be done by adding what is known as a turbulator, either in the form of a sharp edge (Fig. 15) or just a rough top surface.
An example of the effect of a rough suiface on flow reattachment can be seen in the dimpling of a golf ball surface. The dimples ensure that the flow remains attached to the surface, hence the drag is greatly reduced and the dimpled ball goes much further than a smooth ball.

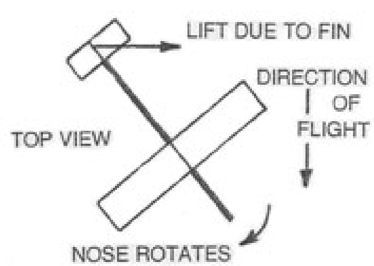

Figure 14

What sort of airfoil do you use on a boost or rocket glider? The answer is-the one that gives you the flattest glide, hence the lowest sinking speed to give maximum duration. Hand launch glider designers have developed some very good guidelines for the shape of the airfoils. They fit our requirements very well and are outlined in Fig. 16. The rough top surface can be easily achieved by covering the wings with lightweight model tissue. This adds greater strength to the wings while adding very little weight. Another way is to seal the surfaces with sanding sealer and lightly sand them with a 300 or finer garnet paper. Do not polish the surfaces because this will reduce the glide performance significantly even though it will give a higher boost.

Having decided on the airfoil you want to use, you then have to decide on the wing and tail areas to use. A boost glider only needs to support its own weight, but a rocket glider carries an empty motor case as well; therefore, the areas needed for each type of glider are different for any given motor size. You will also recall that the stabilizer area depends on its distance between the wing trailing edge and the stabilizer leading edge, two and one half wing chords (measured at the wing root). The stabilizer area should be about 20% of the wing area.

Table 1 – Boost Glider Sizes

Motor Size	**Wing Area (cm^2)**	**Total Weight (g)**
1/2 A	MIN 75, AVG 100, MAX 125	MIN 6, AVG 7, MAX 8
A	MIN 125, AVG 150, MAX 175	MIN 8, AVG 9, MAX 10
B	MIN 175, AVG 210, MAX 240	MIN 10, AVG 13, MAX 16
C	MIN 240, AVG 300, MAX 340	MIN 16, AVG 22, MAX 28
D	MIN 340, AVG 420, MAX 480	MIN 28, AVG 40, MAX 50

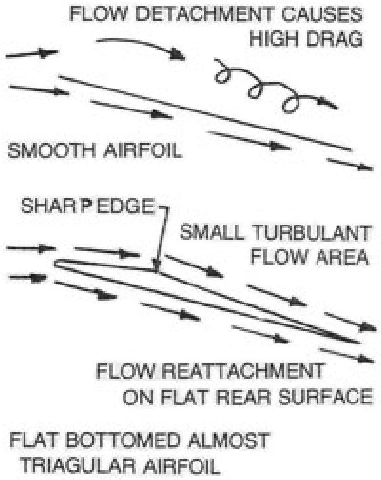

Figure 15

Table 1 will give you some wing areas to work to in designing your own boost gliders. It also gives you the weights that should be aimed for at each size. You will note that minimum, average and maximum areas and weights are given.

With your first designs you should aim at the average, later you can experiment with larger or smaller sizes for that motor size.

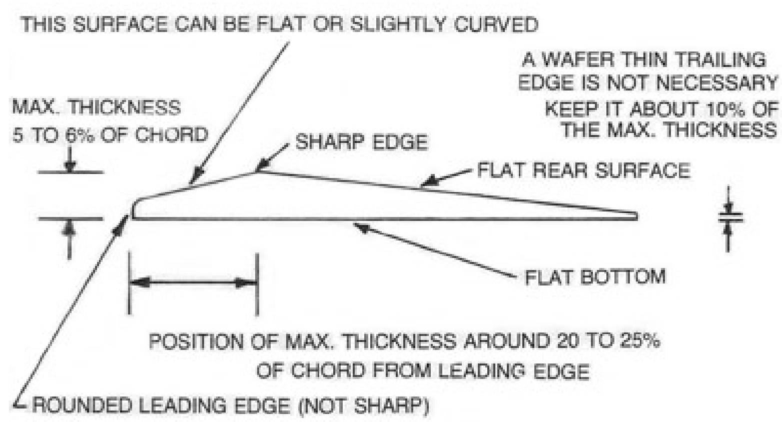

Figure 16

Because rocket gliders carry extra weight, they should be designed with the average area for the next motor size. The weight of the empty motor case and motor mount must be added to the average weights. The length of the fuselage nose, ahead of the wing. should be as short as possible. This permits the glider to turn more easily, but this portion of the fuselage is used to connect it to the booster.

Note: This article is an edit of the article "Rocket and Boost Gliders" by Bill Henderson from the Spring 1982 edition of Space Modeller magazine. Re-printed with permission.