Design Rules for Boost and Rocket/Gliders

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INTRODUCTION

The arc of a boost/glider from launch rod to three hundred feet, followed by a gentle thermal-hunting glide is a grand sight. But designing a B/G to climb steadily at speeds approaching 200 ft/sec and then to descend at speeds below 20 ft/sec is one of the most challenging problems in model rocketry. Unfortunately, many young model rocketeers, after a few frustrating and unsuccessful attempts at boost/glider design, abandon the effort, believing such design problems are too difficult. This is not true. Only a few aerodynamic rules need to be followed to build good flying gliders. The purpose of this paper is to outline the design concepts that will guarantee good performance.

To illustrate these simple aerodynamic concepts, a "Basic Boost Glider" (called the B B/G from now on) will be used. A three-view drawing of BB/G is shown in Figure 1. Note that no dimensions are given on the drawing, only letters. Don't let the lack of dimensions throw you. This has been done to emphasize that any size glider can be built with these basic rules. Similarly, any shape wing can be used for your version of BB/G; the wings are shown rectangular in the plan to make calculation of the wing area easy. For a rectangle, the area is just the length times the width. Later, a few reference formulas will be given to show how the areas of other wing planforms may be found.

AREAS OF THE FLYING SURFACES

Gliders usually have three flying surfaces: the wing, the horizontal stabilizer and the vertical stabilizer (or fin). Some gliders combine two of these surfaces, like the Manta, which uses a portion of the wing as a horizontal stabilizer. Each surface, as we shall see, has a purpose, and the relative size of each surface must be correctly proportioned to assure proper flight.

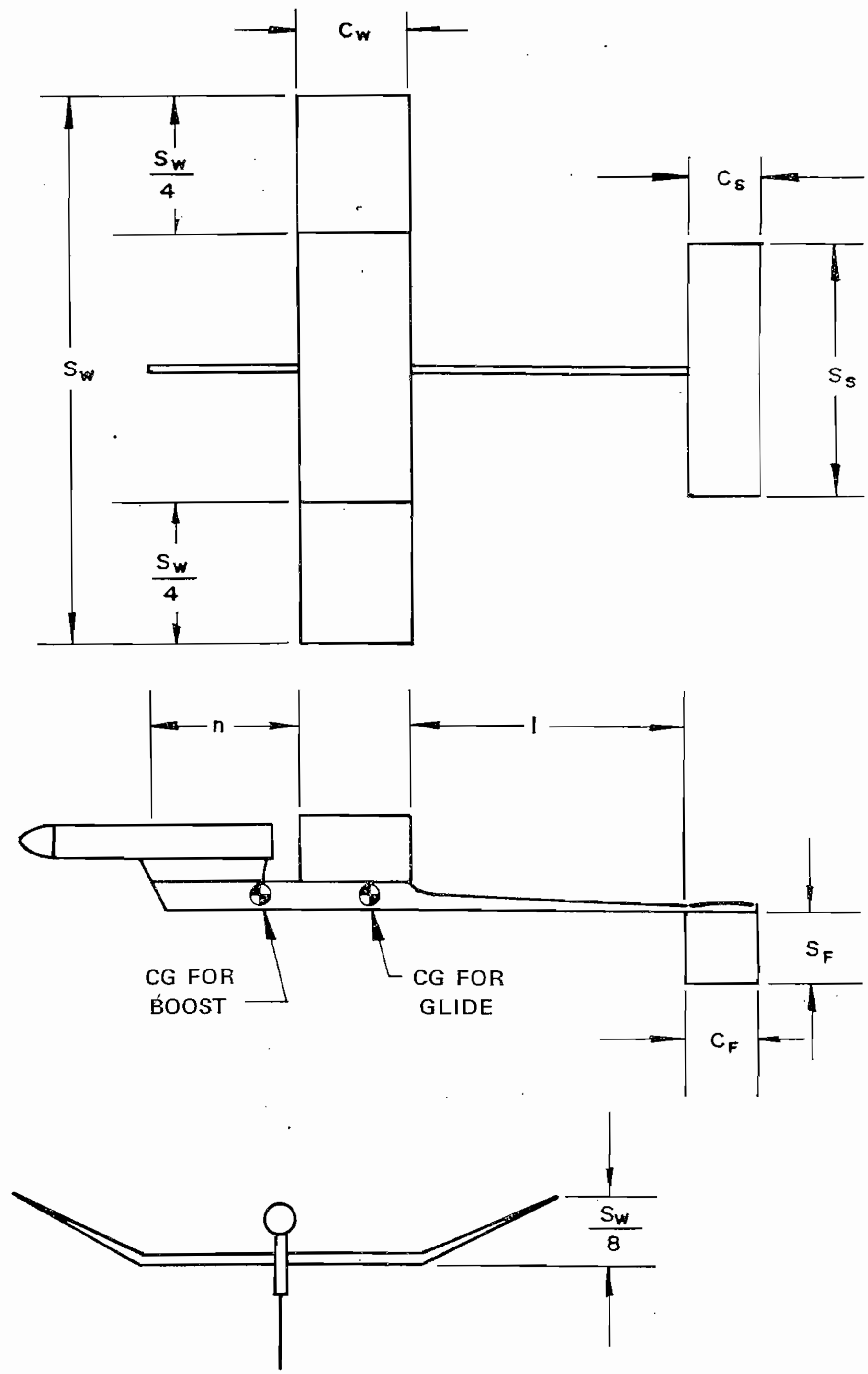

TABLE 1
TYPICAL VALUES FOR BBG

COMPONENT		*"½A"*	*"A"*	*"B"*
Wing	C_W	2	2.5	3
	S_W	10	12.5	1.5
Stab	C_g	1.2	1.5	1.8
	S_s	5.0	5.75	7
Fin	C_f	1.2	1.5	1.8
	S_f	1.0	1.2	1.5
Body	l	5	6	7
	n	2.5	2.5	3

Figure 1—The Basic Boost Glider

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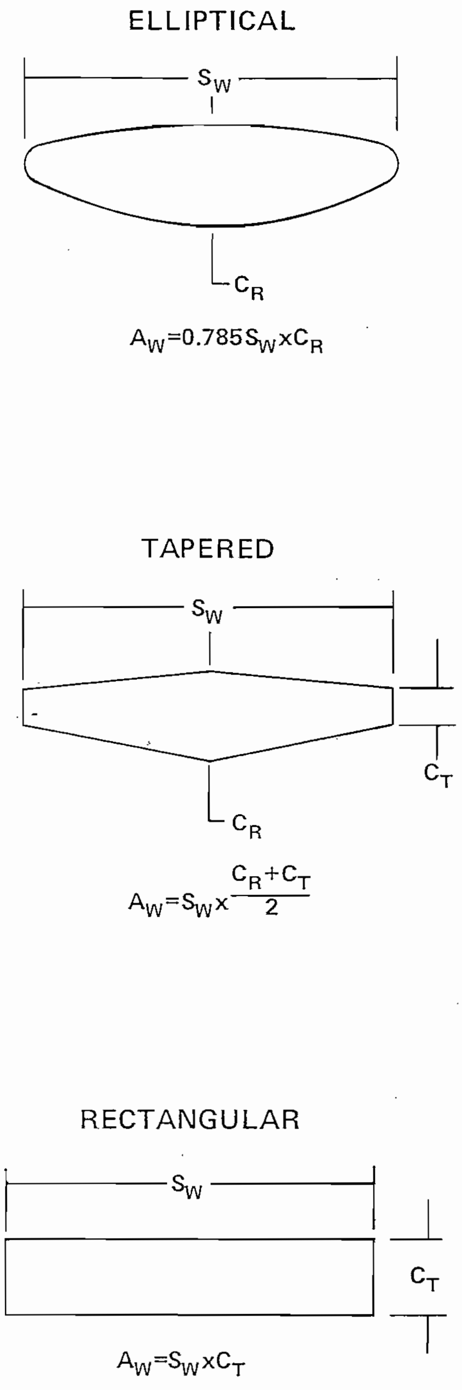
DRAWN BY PHIL RHEINFRANK



Reference Formulas for Wing Area

For any glider, the wings are the most important surface. The wing's size, shape and airfoil determine the performance of a glider. The size of the wing is measured in square inches of area, and called A_W. The value for A_W depends upon the rocket motor to be used. In general, for 1/2 A powered B/G's, 15 to 25 square inches can be used; for A powered B/G's, 20 to 40 square inches, and for B powered B/G's, 25 to 60 square inches of wing area can be used effectively. In each engine category, the smaller areas will produce the most rapid and highest climbing birds, while the larger areas will result in better gliding B/Gs. The selection of the area is up to you as a B/G designer, and you can choose the kind of flight you want.

Once A_W is selected, the area of the horizontal stabilizer, A_S, can be determined. Incidentally, if you've ever dropped a glider wing by itself, the need for a stabilizer should be clear. A wing alone will rotate about the spanwise axis as it falls. Our gliders would rotate like this also if we didn't have the horizontal "stabilizer". The stabilizer area necessary to overcome this rotating tendency is between one-fourth and one-third of the wing area.

If we were to launch a glider without a vertical stabilizer, we would find that the glider starts to spin about a vertical axis. To prevent this spinning tendency, we must add the fin, with an area A_F of about one-tenth of A_W.

Table 1 summarizes flying surface areas for BB/G powered by 1/2 A, A, and B rocket engines. If a rocket/glider is to be designed, these areas can be increased by 25% to help carry the weight of the engine.

BUILDING IN STABILITY

Our gliders do not have any pilots in them to help control the flight, so we have to build in stability. Stability refers to the ability of our gliders to return to a gentle descent once disturbed. For example, a gust of wind can tilt the wings causing a steep bank; we want our glider to return to a level attitude. One of the most common disturbances is a late pod release which will leave the glider in a dive; we want to make sure our gliders will pull out before crashing into the ground.

Stability in bank is provided by the "dihedral angle". As shown in the front view of the BBG, this is obtained by raising the tips of the wings. The proper dihedral angle is obtained by raising the tips of the wings 1/8 inch for every one inch of wing span. Three different methods for providing this roll, or bank, stability are illustrated in Figure 2. Any method can be used; the choice is up to you as a designer. BB/G uses the second method because the wing can be glued directly to the flat upper surface of the body. The other two techniques require a "V" notch in the upper surface for a good, strong glue joint.

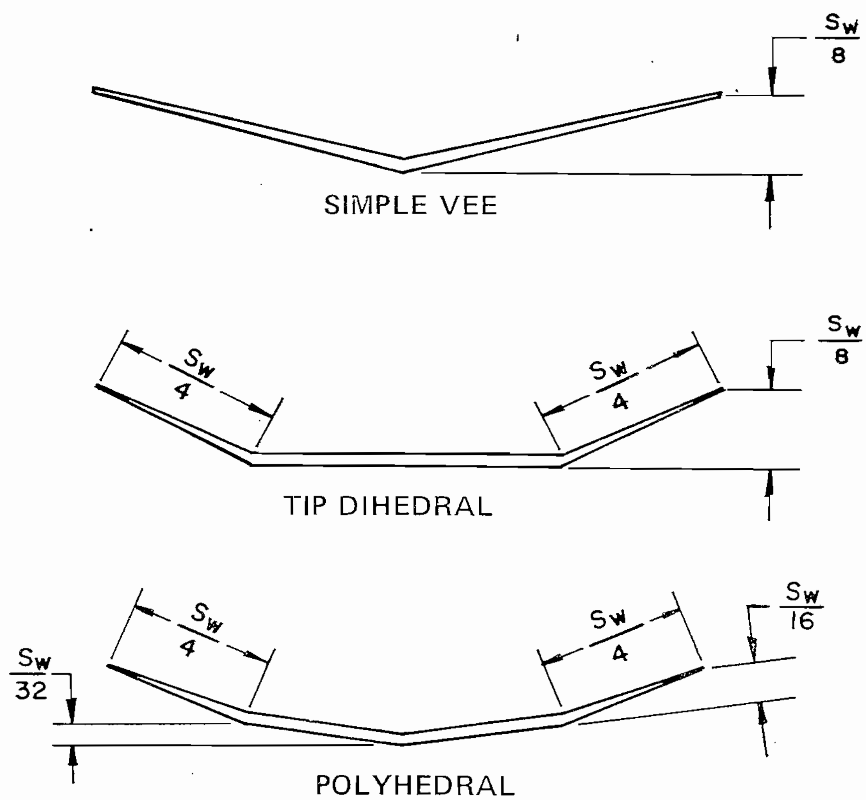


Figure 2—Types of dihedral

To increase the pull-out from dives, we can use "decalage", that's a term that refers to the angle between the wing and horizontal stabilizer, as shown in Figure 3. For most gliders, the correct amount of decalage is obtained by raising the trailing edge of the stabilizer 1/32 inch to 1/16 inch, relative to the stabilizer leading edge. The larger the decalage, the more rapid recovery the glider will make from a dive. Associated with this angle, however, are an increase in drag and an increase in nose weight necessary to produce a smooth glide, so large amounts of decalage should be avoided. Of course, the engine of a rocket/glider may be used for nose weight. Don't forget that rocket/gliders must be trimmed with the engine in place.

DETERMINING BODY SIZE

The two dimensions which control the body length are "l", the distance between the wing and horizontal stabilizer, and "n", the distance from the nose to the leading edge of the wing. The distance l should fall between 0.4 and 0.6 of the wing span. S_W. The size selected should be judged by the area A_S of the horizontal stabilizer; the shorter the distance l, the larger A should be. Conversely, as l increases, stability

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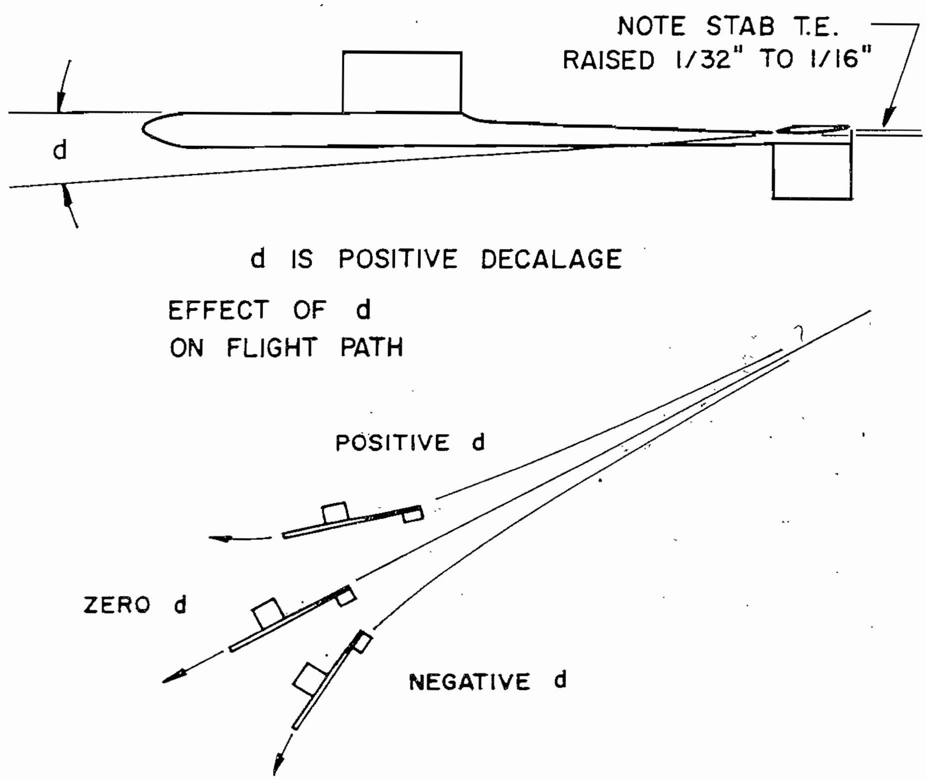

Figure 3—Definition of decalage

may be maintained with a smaller stabilizer area.

Correct nose length n falls between 1 and 2 times the wing width (or wing chord) C_W. This is not too critical a dimension except that the nose length should be long enough to hold the slip pod for the rocket, but not so long as to create excessive weight.

In general, the body length will be a little larger than the wing span, S_W. It is the sum of n, l and the wing and stabilizer widths, C_W and C_S. Typical values are shown in Table 1 for BB/G, but these can be altered according to the above rules as you design your own bird.

CONSTRUCTION TIPS

Sheet balsa 1/16 inch to 3/16 inch thick may be used for B/G wings. Birds powered by 1/2 A and A rocket engines can use the 1/16 inch sheet wings. Boost/gliders powered by B engines reach speeds sufficient to strip the 1/16 inch sheet wings from the glider, so use thicker wings for this category.

The 1/16 inch sheet may be used flat, but a higher lift wing can be obtained if the sheet wing is rounded in front and tapered to a sharp trailing edge. This "airfoil" shape reduces the weight of the wing, and decreases the drag, as well as increasing the lift. To take better advantage of the airfoil, 1/8 inch sheet wings are recommended for the A- and B-powered B/Gs. (Some of the larger wings can even use 3/16 inch sheet).

Figure 4 shows how the airfoil can be carved. First lay out light lines at 1/4 and 1/2 of the wing chord, then carve as shown, finishing with fine sandpaper to produce the airfoil.

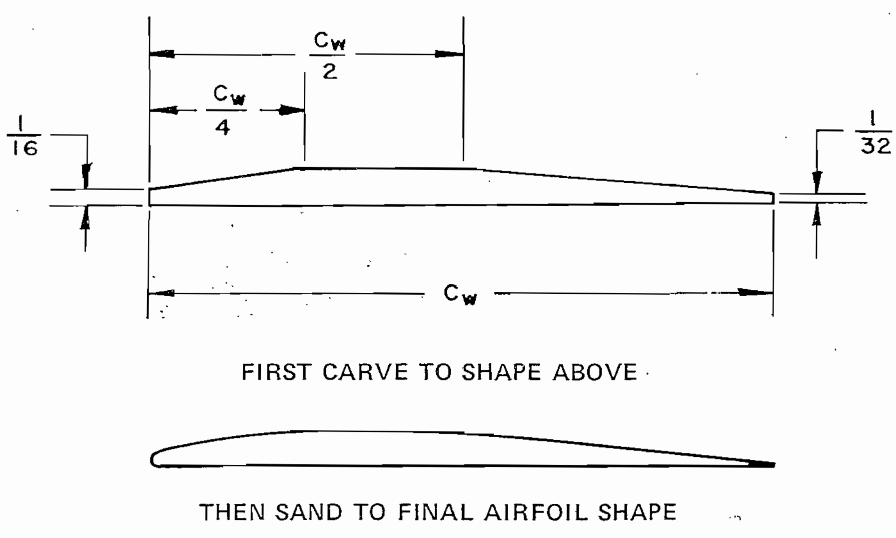

Figure 4—Shaping an airfoil on a wing

An airfoil with its peak thickness located at 30% of the distance from the leading edge is an efficient shape for gliders. The same procedure, incidentally, can be followed to increase the lift from the horizontal stabilizer.

The body of the glider should be built of hard balsa or a hardwood, such as pine or spruce. A cross-section of 1/8 inch x 3/8 inch or 1/8 inch x 1/2 inch provides excellent strength; weight can be reduced by tapering the body from a point under the wing to 1/16 inch or 1/8 inch at the rear. It is usually necessary to add weight to the nose of a glider for proper balance. To avoid having to add excessive nose weight, therefore, the body should be tapered as shown and lightweight balsa should be used for the tail surfaces.

When assembling the glider, make sure the flying surfaces are correctly aligned and warp free. Allow plenty of time for the glue to dry, especially the wing dihedral joints and the wing to fuselage joint. These are points of stress which will fail. Pigment weighs quite a bit more than clear dope and weight is the enemy of gliders. A little color trim is O.K. after one or two coats of clear.

FLYING

First make sure your glider balances near the center of gravity position shown on the drawing of BB/G. Add a little clay if required. Launch the glider over grass and add or take away weight from the nose until a smooth descent is obtained. Most gliders will have a tendency to turn slightly during the glide; you can help this turn by adding a bit of clay to the wing tip on the inside of the turn. The vertical fin can also be warped slightly to help produce a turn. Tightening the turn will also allow you to remove a little nose weight (and keep you from chasing the bird too far). Too tight a turn will produce a spiral dive, so be careful and try to get to know how your glider wants to fly. Each glider has its own peculiar behavior, try to understand it and have it turn—either right or left—in circles about 50 feet to 100 feet in diameter.

For boost, any slip pod design can be used with BB/G. Two points must be made: 1) the center of gravity of the fully loaded bird with pod must be at least 1/2 inch ahead of the leading edge of the wing, and 2) the center line of the engine thrust must be 3/4 inch to 1 inch above the wing. Of course, make sure your slip pod comes off freely when the ejection charge fires. If the pod sticks, the forward balance point will cause the glider to come straight in (no matter what decalage is used).

For rocket/gliders, the CG must be located in the same positions as for boost gliders; that is, forward of wing for boost and at wing mid-chord for glide. This makes trimming rocket/gliders difficult and may require some type of varying geometry, such as shifting the engine or wing.

SUMMARY

These few design rules have been used for years to build successful gliders. The BB/G is a simple design which will give good performance; but don't forget that it was used as an illustration for the aerodynamic concepts. The rules give you a sound technical base, now try different wing planforms—tapered, rounded, elliptical—different airfoil sections, multiple fins, etc. Design your *own* bird, and help improve the breed of boost and rocket/gliders.