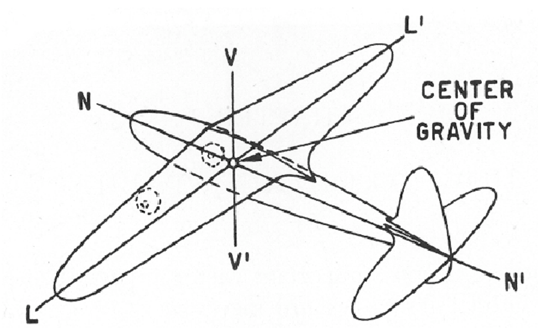
GRANT ON LATERAL STABILITY

This is the first in a series of articles abstracting information concerning Stability from the 1941 book "Model Airplane Design and Theory of Flight," written by the famous Charles Hampson Grant. Let the reader understand that I'm going to be liberally using Grant's exact words and illustrations, condensing them, and for ease of reading the constant use of quotation marks is omitted.

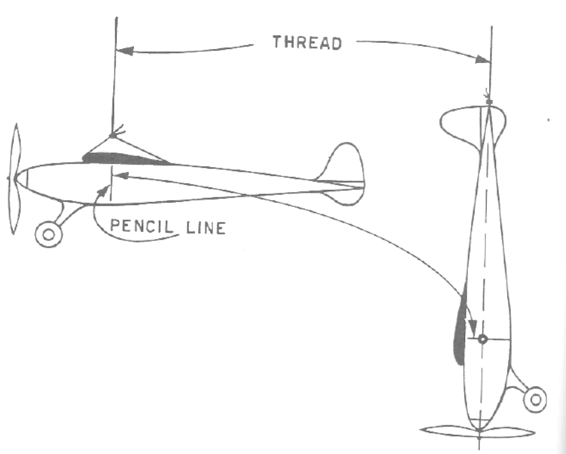
by George White

Kinds of Stability. This is surely well known, but I'll use Grant's diagram to help define his terms.



In the first place, stability is defined as the capacity of an airplane to overcome any tendency to displace or turn from normal flight — or to return to normal flight after displacement.

Critical to achieving stability in a model is the establishment of the center of gravity (c.g.). Many of us simply stick a couple of fingers under the wings and balance the model. That may more or less get the fore and aft location of the c.g., but many of us have no idea where the c.g. is above or below the wing. He proposes tying a string around the wing and suspending the model from a second string, moving it back and forth until the model is balanced. That establishes the fore and aft c.g. location and he recommends a mark on the fuselage. Then suspend the model from the tail and find the actual location of the c.g. by continuing the line from the tail until it crosses the line you made from above the wing.

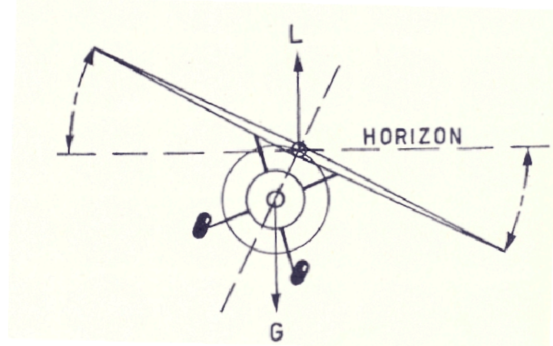


In his book Grant also provides a method for calculating the c.g. based upon weights and moments. That is the method used to calculate the c.g. of full scale aircraft, but is beyond the scope of this article.

As can be seen from the diagram above, there are three kinds of stability to deal with, i.e. **Longitudinal stability** which refers to the maintenance of normal flight about axis, L-L^1. **Directional stability** which refers to the maintenance of normal flight about the vertical axis, V-V^1. **Lateral stability** which refers to the maintenance of normal flight about the axis running through the center of gravity on axis N-N^1.

This first article on the subject will deal solely with **lateral stability.**

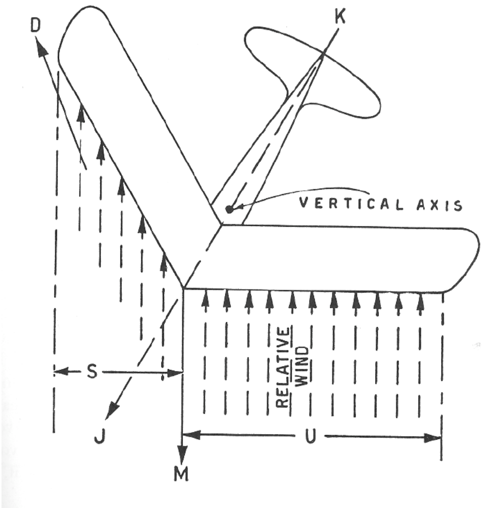
Grant states that the factors contributing to lateral stability of a model include **low center of gravity**, **sweepback of wing**, and **dihedral angl**e. Also, a combination of low center of gravity with either of the other two.



Low Center of Gravity. As seen in the diagram above, the lower the center of gravity relative to the center of lift (L), the greater the rotational force acting to correct any upset. This is relatively easy to accomplish with a high wing model. However, in many low-wing models the center of gravity gets very close to the center of lift, necessitating additional means of obtaining lateral stability. Low c.g. increases stability without loss of efficiency, and should be used in conjunction with sweepback or dihedral.

Sweepback Wing. The sweepback wing may be either constant chord or tapered — the sweepback angle on a tapered wing should be measured by a line equal to 1/3 the wing chord. He says that sweepback might vary between 10º and 30º, where 20º is average with a model with a high c.g. He defines a high c.g. as when the thrust line is close to the wing center section, and a low c.g when the c.g. is 6/100 or more of the wing span below the sweepback wing. With a c.g. being that much below the wing, only 10º sweepback is required and the spinning tendency is reduced. In addition to the method described above for determining the height of a c.g., an accurate check can be made of how high or low the c.g. is by balancing the model on its side, shifting the support point until the point of balance (the c.g.) is found.

Grant's proposal of sweepback to add lateral stability may at first be somewhat difficult to comprehend when he states that a sweepback wing is less efficient than a straight wing and also has a tendency to cause spinning. Insofar as a sweepback wing is less efficient, it should be obvious that in straight flight the air over the wing not only strikes the wing at an angle but also there is less wing presented to that air than would be the case for a straight wing of the same span. The tendency to spin requires further explanation.

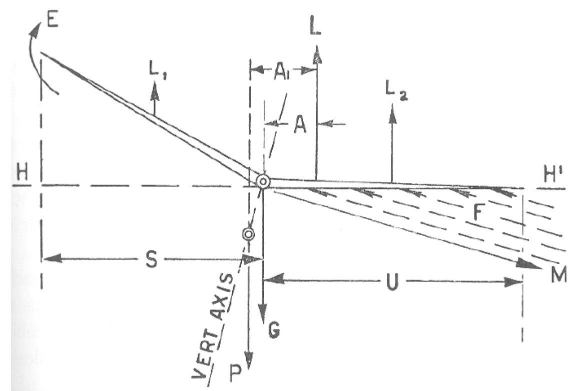


When the model becomes unbalanced laterally, it sideslips due to the force of gravity, at the same time it tries to move forward (J) due to propeller thrust. As a result, the airplane actually moves in a direction M. Consequently, air is moving against the wing in the direction of the arrows shown in the broken lines. The volume of air striking the low wing has a width equal to the length of line U, whereas the volume of air striking the upper wing is equal to the length of the line S. The volume of air striking the lower wing produces greater lift, not only because of its volume, but also because it is striking that portion of the wing squarely. The top wing is spilling much of the lower volume of air flowing over it. Thus, the greater the sweepback, the wider the air stream U compared to S, providing a stronger righting action.

The downside of the sweepback wing is the spinning tendency. That greater volume of air over the lower wing not only produces lift, but also drag, tending to shove the lower wing aft. That, combined with the center of weight forward of the vertical axis and propeller thrust at the nose, pulls forward at the center of the entire span. A sharp rotating couple is created , tending to spin the ship counter clockwise about the vertical axis. My aero engineer son comments that " Too much sweep and you loose the benefit to other bad low speed effects. Sweepback by itself for low speed model aircraft is a relatively weak lateral stability factor and so should be combined with dihedral and low CG or not used at all."

Dihedral Angle. Grant states that the best corrective action is through the application of dihedral alone or in combination with low c.g. or sweepback. Dihedral is the most efficient and practical method for securing lateral stability because it rights a banked plane without appreciable tendency to spin it. However he cautions that the less dihedral used to obtain the desired stability, the more efficient the wing. The theory behind the action of dihedral is illustrated below. In that illustration, which also includes information showing the effects of low c.g., the plane is banked and sideslipping in the direction of arrow M. The model here is also crabbing in the direction of arrow M in the sweepback wing illustration above as a result of propeller thrust, but with dihedral, air is also striking the the wing from the side as well as from the front. Arrows F indicate how this side draft (considerably exagerated here) strikes the dihedral of the lower wing. On the other hand, the higher wing spills the air as indicated by arrow E, decreasing its lift. There is also a blanking effect of the lower wing on the uplifted wing, something which is more pronounced on a low wing aircraft.

Interestingly, whether or not the center portion of the wing is horizontal with no dihedral is immaterial. The dihedral action provided by the upturned outer portion of the wing provides the same action as given here. In fact, the tips can be vertical and have a stabilizing effect, and by reducing wing end spill, can increase lift.



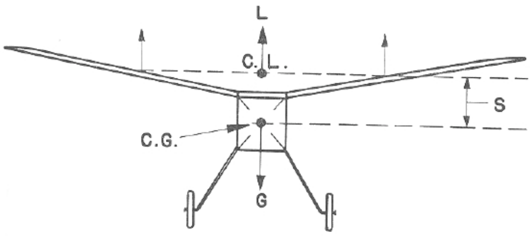
How much dihedral should a wing have to ensure proper performance? The following table provides the recommended wing tip elevation per foot of span for differing values of the c.g. below to the center of lift. Determination of the center of lift is illustrated in the diagram at the bottom of the page. Distances referred to in the table are represented by distance S in that diagram.

Distance from center of gravity to center of lift	Wing tip elevation per foot of span
0% or minus	1 1/2"
2 1/2% of span	1 1/4"
5% of span	1"
7 1/2% of span	3/4"
10% of span	1/2"
12% of span	3/8"

For the mathematically inclined, should you wish to determine the proper tip elevation for a wing which has a flat center section, Grant offers the following formula:

Multiply the above values by $1+4(S-2X / 2S)^2$ where:
S = total wing span and X = that part of the wing in inches which has no dihedral angle.

For a biplane , when the c.g. is at or above the halfway point between the wings, one inch of tip elevation per each foot of span is recommended.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C. L.
S
C.G.
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