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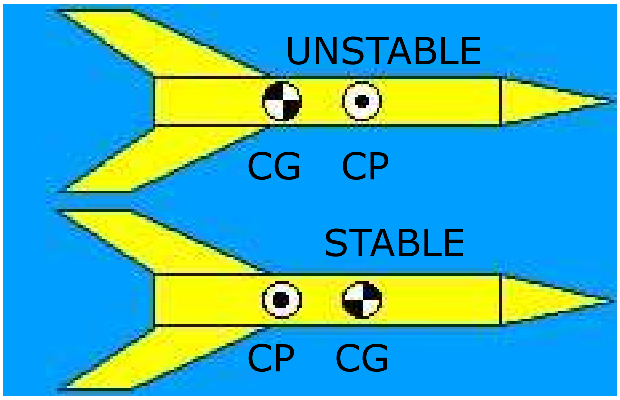
Understanding Model Rocket Stability

(By James F. Myres)

Model rockets are stable when they move under power in the direction that they are initially pointed. Similar to an arrow, a model rocket has fins on a long body. The fins add a large surface area to the rear of a model rocket that increases the air resistance and moves the center of this resistance towards the rear of the rocket. The center of all the resisting forces on a model rocket is called the center of pressure.

A model rocket or any object moving through the air will rotate around its axis at the center of the weight distribution. This is called the center of gravity. On a model rocket, the center of pressure (CP) needs to be behind the center of gravity (CG) for the rocket to be stable.



As a rocket is pushed through the air, the higher air resistance (CP), rotates behind the center of rotation (CG), causing the rocket to point forward. Because of this action, the rocket is pointed into the relative wind.

Generally, the distance the CG should be ahead of the CP is equal to 1 or 2 times the diameter of the body of the rocket. Being closer than this could cause the rocket to wobble or even try to reverse its direction by looping in flight. Being farther than this could cause the rocket to be overly stable and veer off into a moderate wind instead of going straight up. This behavior is called "weather-vaning." Of the two options, over stability is more desirable.

Finding the CG on a rocket, large or small, is relatively easy. Finding the CP is more difficult. One of the easiest methods for determining the stability of model rocket is to tie a loop of string around the CG of a model rocket and swing it around your head to see if the rocket is stable. This is called the "Swing Test". This method works on smaller rockets, but does not necessarily prove that a larger rocket is stable or unstable. This is due to practical limits on the length of a string you might be able to swing around your head. For example:

Example 1: At 10 feet of string length, a 24 inch rocket has the nose and tail moving through the relative wind at an angle of 2.9 degrees from ideal, or a total difference between the nose and the tail of 5.8 degrees. A rocket of this length will probably be able to be tested at this length.

Example 2: At 10 feet of string length, a 48 inch rocket has the nose and tail moving through the relative wind at an angle of 5.8 degrees from ideal, or a total difference between the nose and the tail of 11.6 degrees. A rocket of this length has too much angular distance between the nose and the tail relative to the forward motion in the wind and probably would not be able to be tested at this string length.

Large or heavy rockets are difficult to swing and could be damaged if the rocket hits a stationery object or person during the test. A better way of determining the stability of rocket is to determine the CP by calculation. One of the best known methods is called the Barrowman method.

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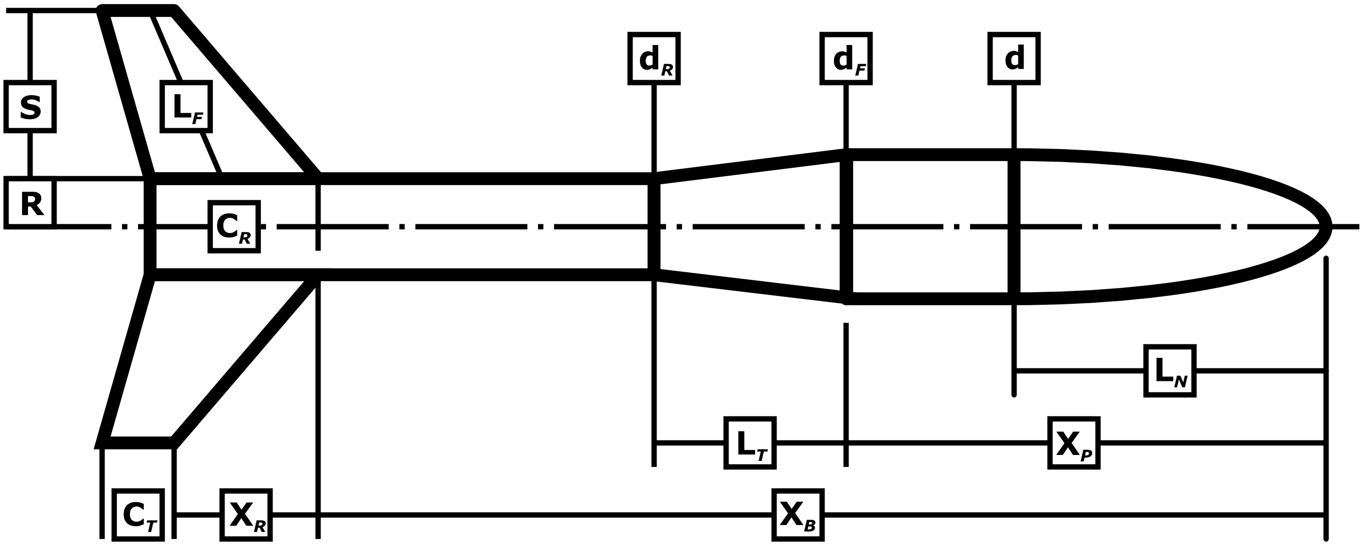

Barrowman Method of Predicting Stability

The Barrowman method calculates all the individual pressure changes along the rocket from nose to tip. After each change is calculated, the total of each element is added and a ratio is calculated from the same elements multiplied by the force value for each element.

To use the equations, the values measured from the rocket as illustrated above are substituted into the equation. Refer to the definitions below while taking measurements.

L_N	Length of Nose	d	Diam. of Base Nose
d_F	Diam. of Transition Front	d_R	Diam. of Rear Transition
L_T	Length of Transition	X_P	Distance to Transition
C_R	Fin Root Chord	C_T	Fin Tip Chord
S	Fin Span	L_F	Fin Mid-chord Line
R	Radius Body at End	X_R	Fin Sweep
X_B	Distance Nose to Fin	N	Number of Fins

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Barrowman Calculations

While this task seems daunting it can be done in stages using a calculator with square root capability. If you don't want to go to this trouble, you can download a free Windows software program the from our website at Scalerockets.com that can do this for you.

The following terms are substituted for general math symbols:

* = Multiplication Function
/ = Division Function
^ = Square Function
Sqr = Square Root Function

Barrowman Basic Equation

$CP = (C_{NN} * X_N + C_{NT} * X_T + C_{NF} * X_F) / (C_{NN} + C_{NT} + C_{NF})$

Calculating the Nosecone Values

All Shapes of Nosecones: $C_{NN} = 2$
For Conical Nosecones: $X_N = 0.666 * L_N$
For Ogive Nosecones: $X_N = 0.466 * L_N$
For Parabolic Nosecones: $X_N = 0.5 * L_N$
For Hack Nosecones: $X_N = 0.5 * L_N$
For Von Karmen Nosecones: $X_N = 0.563 * L_N$

Calculating the Transition Values

$C_{NT} = 2 * (((d_R / d) \wedge 2) - ((d_F / d) \wedge 2))$
$X_T = X_P + ((L_T / 3) * (1 + ((1 - (d_F / d_R)) / (1 - (d_F / d_R) \wedge 2))))$

Calculating Fin Values

The L_F value is needed for trapezoidal fins only. It can be measured or calculated with the following equation:

$$L_F = Sqr\ (S \wedge 2 + (X_R + (C_T / 2) - (C_R / 2)) \wedge 2)$$

Trapezoidal Fins

$$FT1 = 1 + (R / (S + R))$$
$$FT2 = 1 + Sqr(1 + ((2 * L_F) / (C_R + C_T)) \wedge 2)$$
$$C_{NF} = FT1 * (((N * 4) * (S / d) \wedge 2) / FT2)$$

$$FT3 = C_R + C_T$$
$$FT4 = (FT3 - ((C_R * C_T) / FT3)) / 6$$

$$X_F = X_B + ((X_R / 3) * ((FT3 + C_T) / FT3)) + FT4$$

Elliptical Fins

$$FT5 = (4 * N * (S / d) \wedge 2) / (1 + Sqr(1 + (1.623 * (S / C_R) \wedge 2)))$$

$$C_{NF} = FT5 * (1 + R / (S + R))$$
$$X_F\_cp = X_{\mathbf{B}} + 0.288 * C_R$$

Final Results

After calculating each element of the rocket. They are applied in the final equation:

$$CP = (C_{NN} * X_N + C_{NT} * X_T + C_{NF} * X_F) / (C_{NN} + C_{NT} + C_{NF})$$

The value of CP represents the center of pressure location measured from the nose of the rocket.

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