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NEWSLETTER



Feature Article

What is "Static Margin?"

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What is Static Margin?

By Tim Van Milligan

A question has come up from a user of RockSim. He had a rocket that had a static margin of "31," but when he flew it, the model went unstable. Shouldn't a rocket with such a huge static margin be stable?

The answer is that it depends...

"Static Margin" is not in the original Barrowman Equations. I'm pretty sure it was originally put forward by G. Harry Stine in his book *Handbook of Model Rocketry*, as a way of saying "HOW STABLE" a rocket is. In other words, a rocket with a high Static Margin is said to be more stable than one with a lower Static Margin number.

It is a dimensionless number found by dividing the distance between the Center of Gravity (CG) and the Center of Pressure (CP) by the body tube diameter. Most modelers call this "Caliber of Stability."

For example, if the distance of the CG and the CP is 0.976 inches, and the tube diameter is 0.976 inches, the rocket is said to have "one caliber Stability." On the same rocket, if the distance between the CG and the CP is 1.962 inches, then the rocket is said to have two calibers of stability.

The Estes Alpha, which most modelers have seen at one time or another has a Static Margin of 1.2. This means the CG is 1.2 times the tube diameter ahead of the CP (see figure 1 below). Since the tube diameter is .976 inches, the exact distance would be 1.17 inches ahead of the CP.

Here is where it starts getting confusing.

If the rocket doesn't have a constant diameter, what "reference diameter" do you use? For example, take a look at Figure 2. Here we have a really fat nose cone, that is followed by a transition which necks it down to a skinny tube. If we use the base of the nose cone (not the blue reducer portion that looks like it is part of the nose), then we're going to get

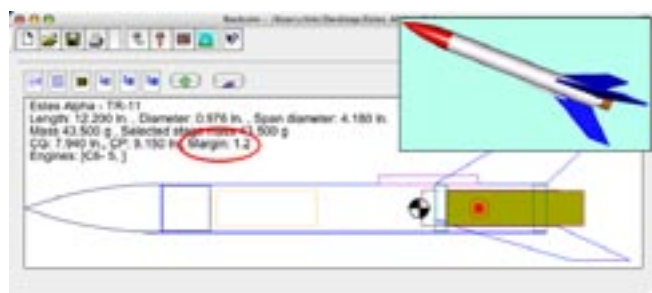


Figure 1: This rocket has a static margin of 1.2, which means the CG is 1.2 times the diameter ahead of the CP.

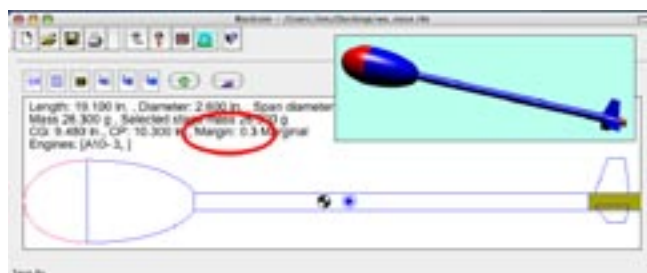


Figure 2: Some rockets with very small static margins would actually be highly stable.

really small Static Margins. Here, the Static Margin is only 0.3. Most rocketeers would tell you not to fly a rocket with such a small margin. But actually, this particular rocket would be highly stable.

Then, you have the case where the rocket starts out with a skinny nose cone, and transitions to a bigger diameter later on, such as shown in figure 3. Basically, this rocket isn't much different than the one shown above in figure 2. However, this time, the Static Margin is 0.8. While it isn't greater than "1.0," it is much larger than the 0.3 caliber value shown in figure 2.



Figure 3: While not much different than the rocket shown in Figure 2, this rocket has a much higher static stability value (0.8 versus 0.3).

As you can see, it is a bit confusing. Two rockets that are fairly similar can have drastically different Static Stability margins. Which one should you use?

Before we answer that, we'll go back to a little history. In his book: *Handbook of Model Rocketry*, G. Harry Stine didn't really tell us which diameter to use for the caliber reference. We assumed it was the diameter at the base of the nose cone.

But actually, the worst case scenario is to use the largest diameter of the rocket. This will give us the smallest Static Margins (or *caliber of stability*). This is the reference area

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used by several others, including Gordon Mandell in the book *Topics in Advanced Model Rocketry*.

The first time this scenario hit me was when I was working on the Saturn 1B (http://www.ApogeeRockets.com/Saturn_1B.asp) and the Saturn V (<http://www.ApogeeRockets.com/Saturn5.asp>) kits.

The escape tower on these kits throws the static margin way off. As seen from figure 4 below, the Static Margin with the escape tower in place is 11.9 calibers.

Compare this with figure 5, where the escape tower is removed from the design. Here the Static Margin is reduced to 1.87 Calibers.

That is why the picture in Figure 6 doesn't have the escape tower in place. This image was generated from the RockSim design file that you can download from the Apogee web site at: http://www.ApogeeRockets.com/education/downloads/Apogee_Saturn_1B.RKT. (I cheated to make this image. I took a 3D image from RockSim, and placed it

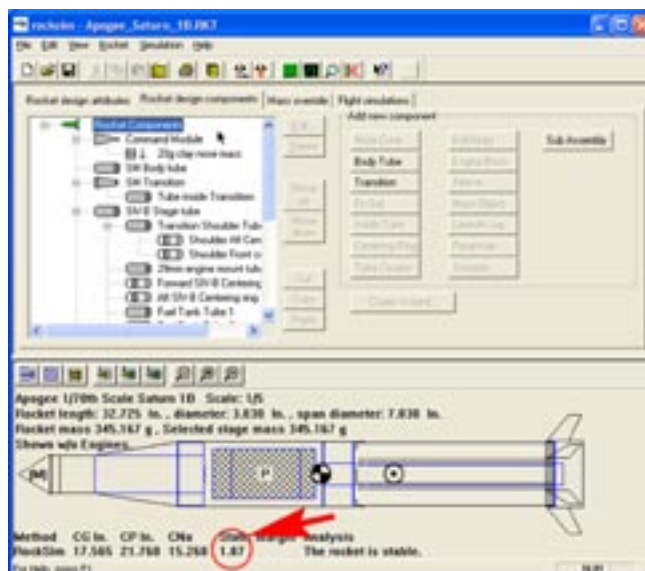


Figure 5: With the tower removed, the Static Margin goes way down. Here it is: 1.87.

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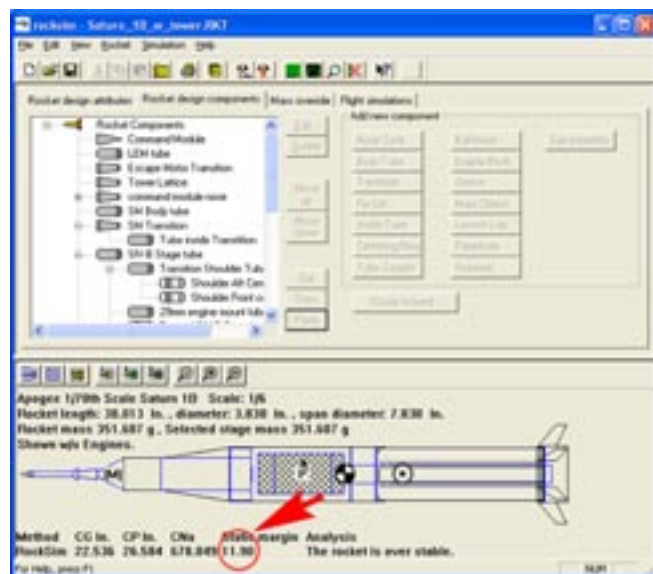


Figure 4: The Saturn 1B has a huge static margin when the escape tower is in the design.



Figure 6: With or without the escape tower, the Saturn 1B is still a cool looking rocket!

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on the landscape background. I then added fire using Adobe Photoshop).

Because of the different values for Static Margin, one change we will make in RockSim v8 is to allow the user to select the "Maximum Frontal Area" to give the smallest Static Margin. See figure 7.

As mentioned, this is most conservative value, because it indicates that the rocket is "least stable." As seen in Figure 7, when the maximum diameter is used, the Static Margin drops to 1.1 Calibers. Compare this to Figure 6 on the previous page which has a value of 1.87 Calibers.

However, *least stable* is a very arbitrary statement. As we saw in figure 2 and figure 3, rockets can have very similar shapes and yet have drastically different Static Margins.

Another example is shown in Figure 8 below. The relative distances between the CG and the CP is about the same, with or without the escape tower installed.

What is important is that these models will fly the same, no matter what the Static Margin says.

Did you see the importance of that last statement?

The static margin doesn't tell us how well the rocket will fly. It only gives us an indication of how stable the rocket is. And even that is relative. Because it depends on which

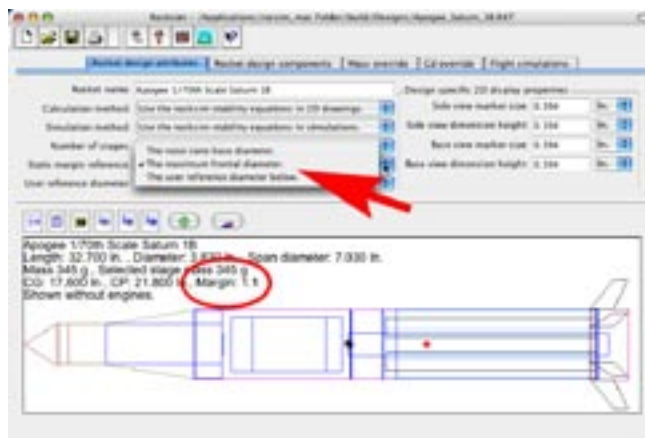


Figure 7: In this "sneak-peak" screen shot from the next version of RockSim, you'll be able to change the reference diameter that controls the Static Margin. By using the Maximum Diameter, the Static Margin drops to 1.1 Calibers.

reference diameter is used in the calculations. Use a small reference diameter, and you'll get a huge static margin. Use a big reference diameter, and you'll get a small (conservative) static margin.

But we still do not really know how well the rocket will fly, or whether or not it will be stable when flow.

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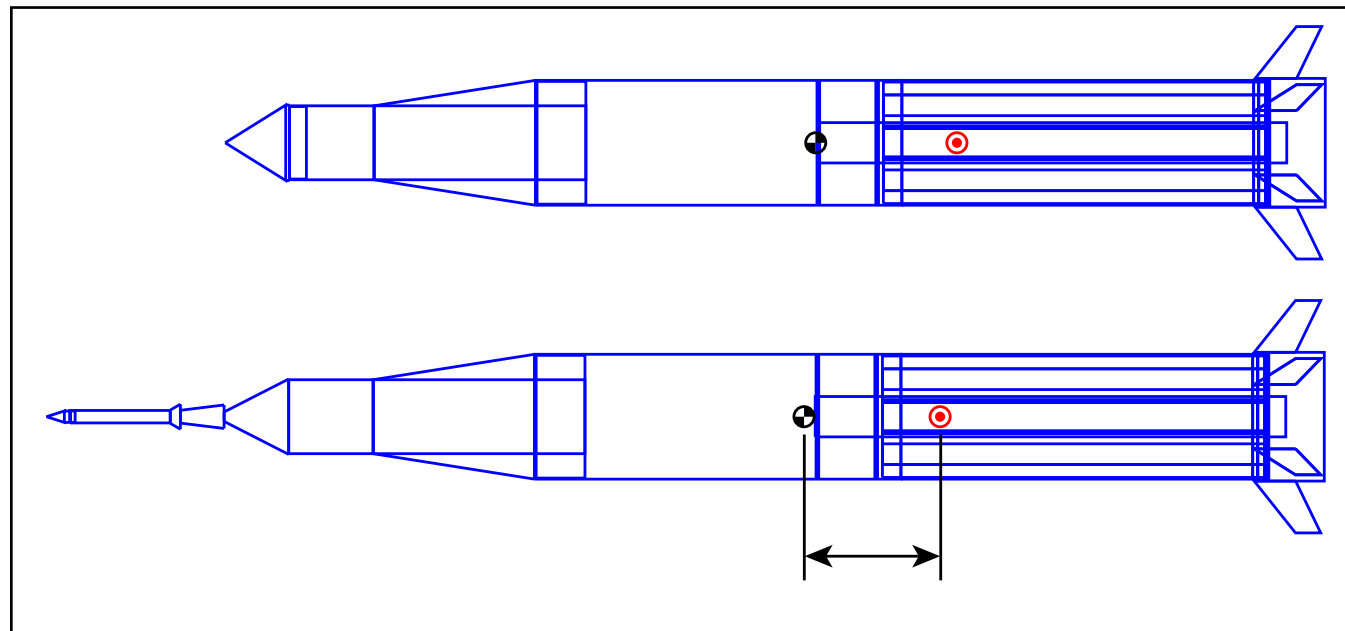


Figure 8: No matter what reference diameter is used to compute the Static Margin, it doesn't change the distance between the CG and the CP. This is what is actually important.

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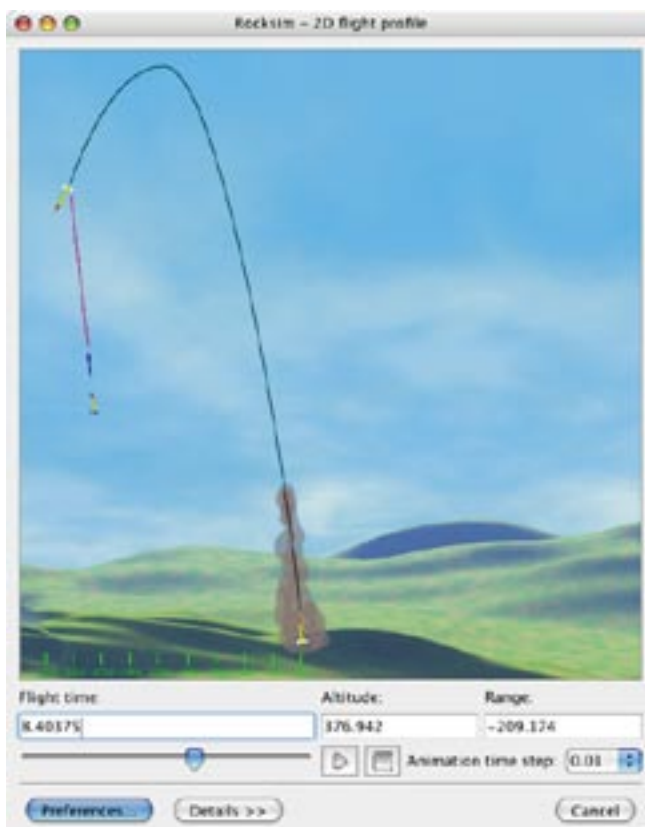


Figure 9: The only reliable indication of the flight and its trajectory is from the 2D flight profile.

There is a better way. Look at the 2D Flight Profile of RockSim!

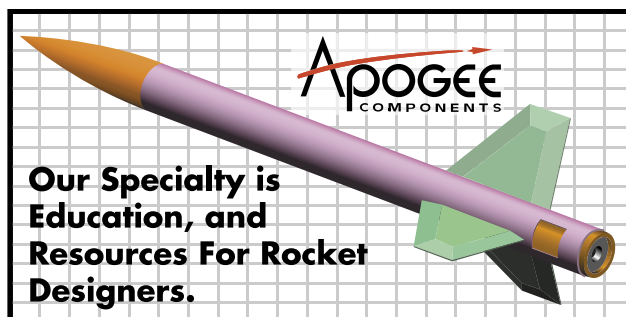
The 2D Flight Profile takes into account the actual distance between the CG and the CP, as well as the wind in the simulation. You'll get a much better indication of the trajectory of the rocket, and how stable it will really be.

Conclusion

The Static Margin number can be misleading, as well as confusing. You still have to look at the rocket with a calibrated eyeball. Unfortunately, when you are just starting out in rocketry, you don't have much experience to base your judgements. Fortunately, you have the RockSim 2D flight profile to give you a clear picture of how the rocket will actually behave.

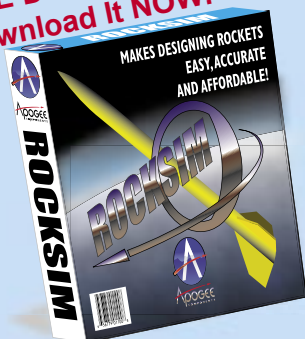
About the Author:

Tim Van Milligan is the owner of Apogee Components (<http://www.apogeerockets.com>) and the curator of the rocketry education web site: <http://www.apogeerockets.com/education>. He is also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.



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