ISSUE 53

APOGEE

PEAK OF FLIGHT

NEWSLETTER

Why Do Swing Tests Often Fail?

By Tim Van Milligan

This past week, there was a discussion on the newsgroup rec.models.rockets on the subject of swing testing. I'd like to review the information that was said, and go into depth on the subject a little bit.

To review: you will recall, that swing testing is a method of validating the stability of a rocket design. In this method, you attach a long string to a rocket (at the CG point - with an "unburnt" motor installed), and whirl it around your head and see if it flies straight. If if does fly straight (nose first), then you can be confident in the stability of the design when you actually go out and launch it.

The controversy arises when the rocket fails to fly straight as you whirl it about your head. Does this mean the rocket is unstable? Can you launch it? And if the rocket does launch straight, why did the string test fail?

You probably know from your past experiences that many rockets that have flown straight and true have failed the swing test. One that comes to mind is the Estes Alpha. But literally millions of Alpha's have taken to the air over the years. So why did the swing test fail to provide indication that the design is indeed stable?

Peter Alway made a great comment on R.M.R.. He said:

"There are two issues with the swing test that gan lead to false negatives, both having to do with angle of incidence.

The first, is that if the model isn't short compared to string length, then different parts of the rocket are at different angles of attack."

What this means is that those components furthest away from the CG of the rocket are flying at a higher angle of attack than those components near to the CG point (where the string attaches).

So if you have identical rockets, except for the body tube length, the fins on the longer rocket will be at a different angle of attack than the short rocket. To make the all the parts fly at a similar angle of attack, we need to make the string longer.

This leads us to the conclusion that we want a long string when we perform a string test. This will give us a rocket where the various components are flying at a near zero angle of attack.

In simple terms, the string test may be failing because the string is too short.

The problem is that it is difficult to swing test using a long string. You need to start the rocket while it is flying straight; because once it is unstable, it may never recover. This is a "catch 22" situation -- if it won't fly straight with a short string; then it won't ever recover once you let the string out. Ideally, you want to swing it with a long string...

So if your string isn't long enough, you may not get a "otherwise" stable rocket to swing properly.

Because the swing test can give us errors, we have other methods of determining the stability of a rocket. The most common way is to use the Barrowman Equations. This is particularly advantageous for really big rockets that are impossible to swing test anyway.

Peter's second argument really gets to the point of why the string test can fail. He continues:

*"The second is that some rockets are stable at a low angle of attack, but unstable at a high angle of attack. If you start the rocket going on the string with a good, straight, fast toss, along the circular path around you, it will have a low angle of attack. If you just dangle if from the string and start swinging, it starts at a high angle of attack, and some models that would be stable in flight will actually point sort of backwards. They won't go *straight* backwards, but they will go sort of backwards and they are draggy and hard to get going fast.*

It's not that the model will swing nose-first if you get it going fast enough, but rather, once you get it going nose-first, you can get it going faster."

But, you're probably asking yourself: "what difference

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does the angle-of-attack mean to stability?"

The answer to that question is that the CP of the rocket moves forward with increasing angle of attack. By definition, we have a stable rocket only when the CP location is behind the Center-of-Gravity location. So if the CP moves forward of the CG because of an increase in angle-of-attack; then the rocket will go unstable.

I need to repeat that; because it is the key to why the swing test can fail. "If the CP shifts forward of the CG position due to an increase in the angle-of-attack of the rocket, the model will go unstable."

So for your particular rocket, how do you find that critical angle-of-attack where the rocket will go unstable?

Let's take a look at what RockSim tells us.

Figure 1 shows us the stability analysis from RockSim . The Barrowman "static" CP location, and the CG location of the rocket with a motor installed:

CG = 7.828 inches from the tip of the nose when a Quest C6 motor is installed..

Barrowman CP location = 8.836 inches from the tip of the nose.

At this point, the rocket is stable -- because the CG is forward of the CP.

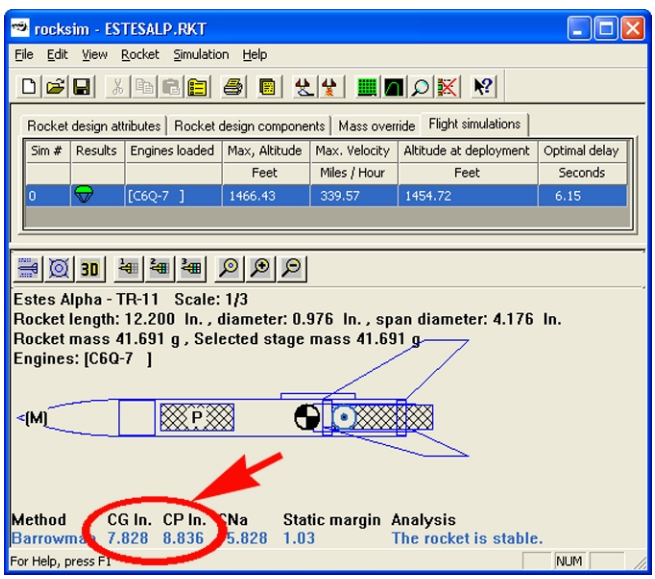
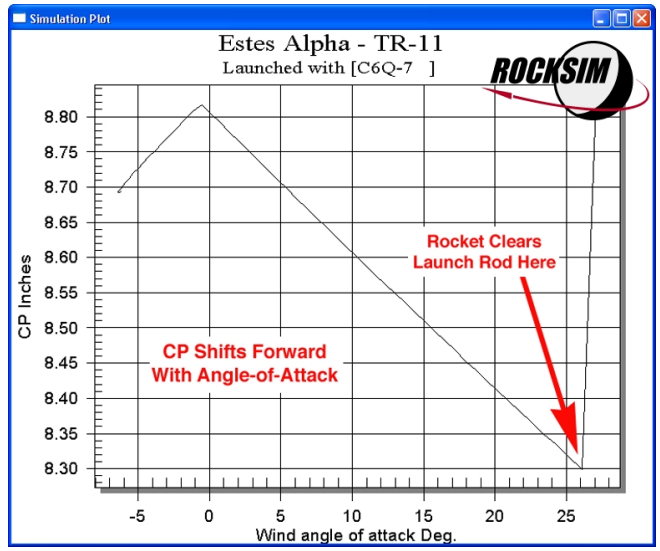


Figure 1: From RockSim, we can get the location of the CG and the CP of the rocket.



RockSim will allow us to plot the CP position as a function of angle-of-attack.

Now add a 15 mph wind, and run a simulation. We want to make a plot of the CP versus the Wind Angle of Attack. This is shown in Figure 2.

Do you see that the CP is moving forward when the model flies at an angle-of-attack? While this rocket never becomes unstable, there are many designs that can go unstable at high angles of attack.

In theory, we don't want the model to exceed 12-15 degrees angle of attack. Beyond this point, we'd expect the fins to stall, and become useless at keeping straight the path of the rocket. But if you had a design where the CP shifted forward of the CG at relatively low angles-of-attack (less than 10 degrees), you're going to be flying a really marginally stable rocket. A sudden gust of wind as the rocket leaves the launch pad could cause a shift in the CP location that makes the rocket go unstable.

There is somthing else that may not be obvious that the above simulations tell us. In a sense, the Barrowman method can also give us a false indication of the model's true stability. The reason is that it only gives the CP location at zero angle-of-attack. In real life, the situation is dynamic. As we just found

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out, the CP is constantly shifting due to the model flying at various angles-of-attack (which can be caused by wind).

Therefore, it should be noted that the "one-caliber" static stability recommendation is a pretty good rule-of-thumb to follow. By starting with the CP far enough back, we shouldn't get the condition where the CP shifts forward of the CG location.

How far back should the static CP position be moved? It depends. If you move it too far back, then the model may weathercock excessively when launched in windy conditions. See the related article in Newsletter 34.

In conclusion, the string swing test is just one method to check the stability of a rocket. If it works, you've got an excellent indication that the rocket will be stable when you launch it.

If the swing test fails, it doesn't necessarily mean the rocket is unstable. It may be proved stable using other methods: like the Barrowman Equations, or the RockSim proprietary method,. These other methods should be used when your swing test fails.

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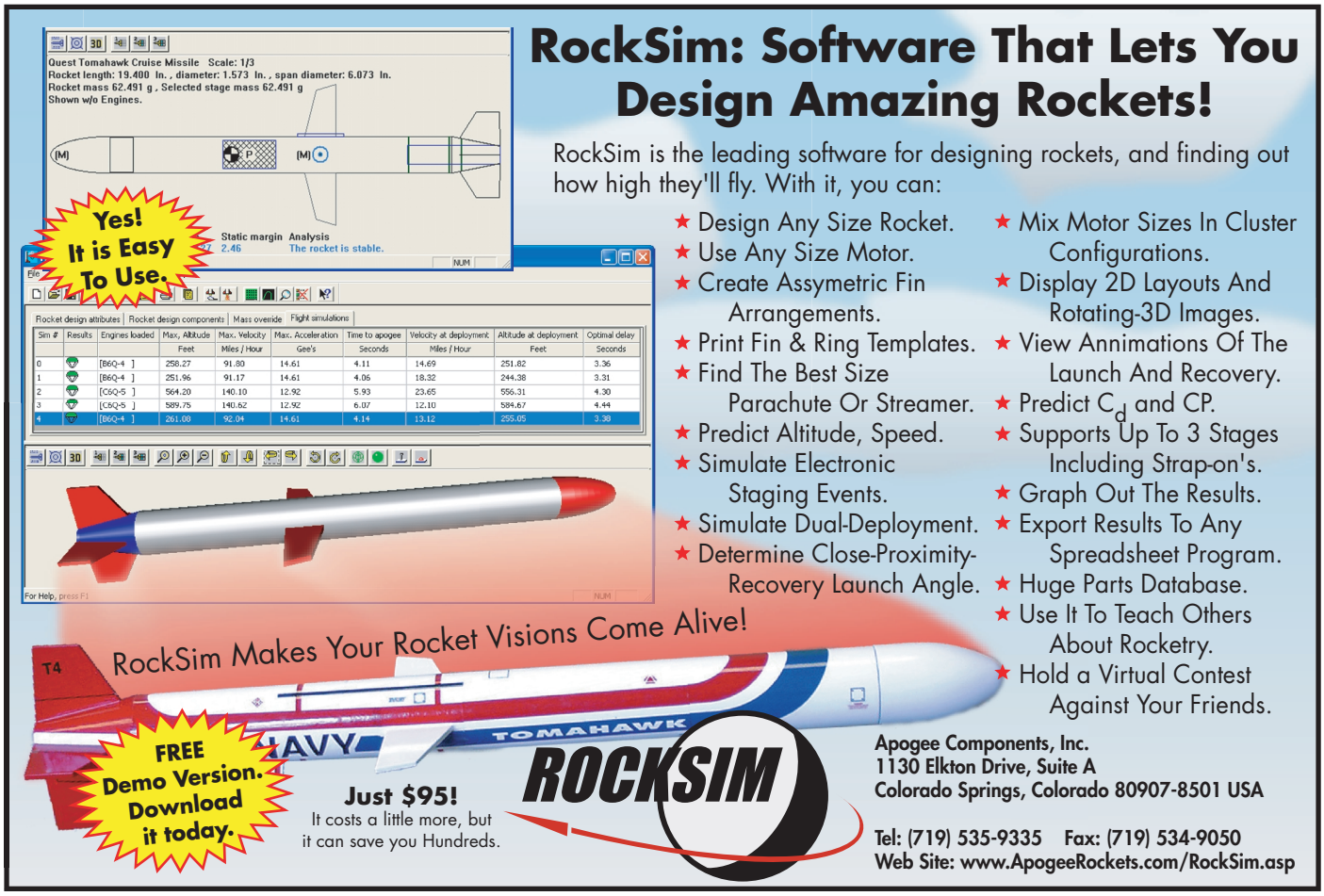
Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: "*Model Rocket Design and Construction*," "*69 Simple Science Fair Projects with Model Rockets: 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.