PEAK OF FLIGHT NEWSLETTER

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USING THE STABILITY GRAPH OVERLAY IN ROCKSIM

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APOGEE COMPONENTS

PEAK OF FLIGHT

Stability Graph Overlay

By Tim Van Milligan

One of the cool features of RockSim is that it allows asymmetric fin arrangements. What this means is that if you look at the rocket from different sides, it looks different. An example of this would be a glider. If you look at a top view of a glider, it looks completely different than if you looked at it from a side view.

FIGURE 1: THE DYNASTAR ORION (TOP) IS AN ASYMMETRIC FIN ARRANGEMENT, WHILE THE DYNASTAR STONEBREAKER (BOTTOM) IS A SYMMETRICAL DESIGN

In this article, I'll show you a little bit about the feature that makes asymmetric arrangements possible - the Stability Graph Overlay. With it, you can use it to create your own asymmetric arrangements. And you'll know from the get-go whether or not they will be stable when you hit the launch button to send them skyward.

The thing about asymmetric arrangements is that they are not accounted for in the traditional Barrowman stability equations. The reason that RockSim can do these types of configurations is that it breaks the fin sets apart and looks at the contributions to stability of each fin by itself. So RockSim not only looks at the rocket from one direction (like a side view), but in actuality looks at it from 360 different views (all the way around the outside) to see if the rocket is stable in every view angle.

RockSim has had the ability to create asymmetric fin arrangements since version 7, which was first released in 2003. Veteran users of the software have probably experimented around with it, but just didn't know that it was looking at a full 360° view of the rocket. In the normal 2D views (the top and the side views), the software just reports the 'worst case' situation, which would be the one view that has the CP (Center-of-Pressure) in the furthest forward location.

We can show a quick example of this by starting with an ordinary rocket, and look at how the CP changes location as we remove fins. In Figure 2, we see the rocket with three fins on it. Note that the CP is at 15.5233 inches from the tip of the nose.

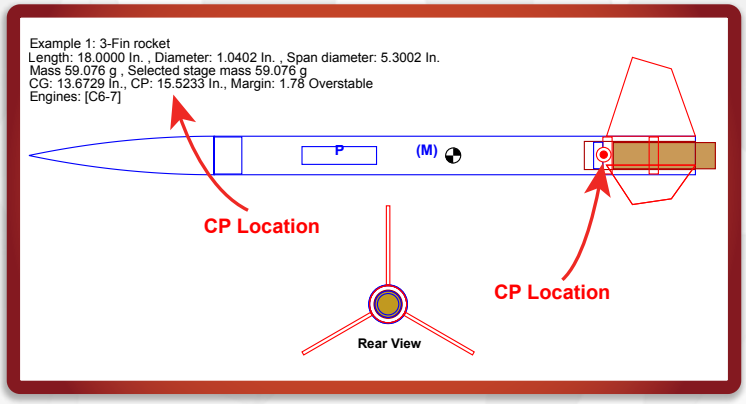

FIGURE 2: THE EXAMPLE ROCKET WITH THREE FINS NOTE THE LOCATION OF THE CP ON THE ROCKET

In Figure 3, we dropped one fin from the design. You can tell this by looking at the rear view of the rocket. Note that the CP of this design shifted forward on the model to 14.7877 inches as measured from the tip of the nose cone. Also note that the model is still "Statically Stable" with a margin of 1.17 calibers (a caliber is calculated as the distance apart the CG and CP are, divided by the body tube diameter - so it is a dimensionless number).

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Stability Graph Overlay

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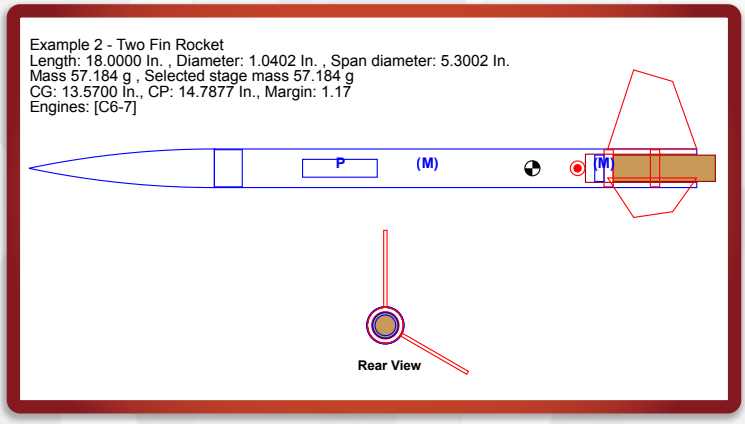

FIGURE 3: A TWO FIN ROCKET

We'll talk more about this design later, and why you probably shouldn't launch it, even if RockSim thinks it is statically stable.

In Figure 4 we take this design one step further and drop all but a single fin on the rocket. Note that the rocket is now statically unstable, because the CP has shifted in front of the CG (Center-of-Gravity). Not only did it shift in front of the CG, but the location shift was massive. Compare the shift of distance from Figure 2 to Figure 3 against the shift in distance from Figures 3 to Figure 4.

The reason is that this situation is the worst case of the rocket from a stability standpoint. In fact, if you eliminated all the fins completely, the CP would be in the same place (at 2.3251 inches). In other words, with just one fin on the rocket, from a perspective of looking at stability, it is as if the rocket didn't have any fins at all.

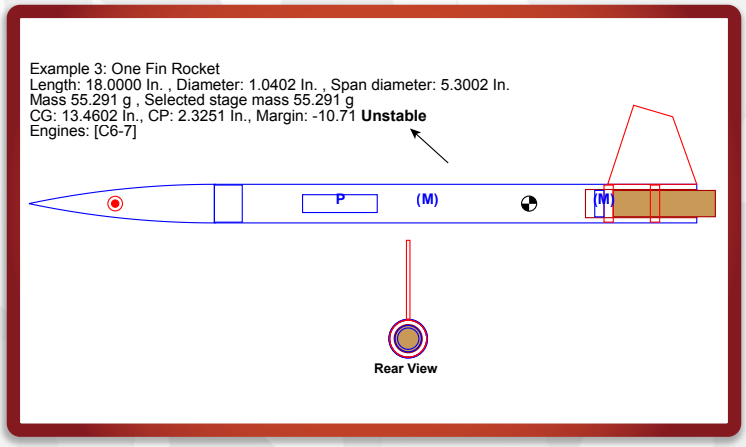

FIGURE 4: CP LOCATION OF A ONE-FIN ROCKET. NOTE THE ROCKET IS MASSIVELY UNSTABLE

The point of all this is just to demonstrate that RockSim is looking for the worst case for rocket stability, because it is looking at the rocket from all sides. What it is telling us in the case of Figure 4 is that from one view angle, it is not seeing any stability improvement by the single fin. So it is reporting that the rocket is wildly unstable.

You can kind of get an indication from which direction that RockSim sees the rocket being unstable by going into the preferences of the software and checking the boxes "Stability Graph Overlay," and "Show angle grid" on the 2D drawing tab as shown in Figure 5.

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Stability Graph Overlay

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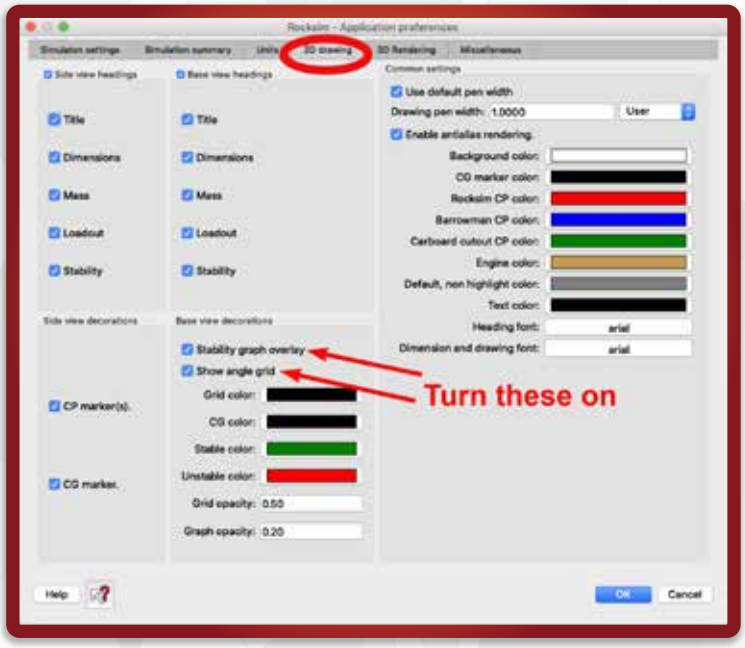

FIGURE 5 - THE CONTROLS TO TURN ON THE STABILITY GRAPH OVERLAY IN THE ROCKSIM APPLICATION PREFERENCES

Once you turn on the stability graph overlay, the base view of the rocket will show extra information, as shown in Figure 6.

What this overlay does is to summarize the general CP location of the rocket from all 360 views of the rocket. If you counted all the lines radiating from the center of the rocket, you'd count 360 of them.

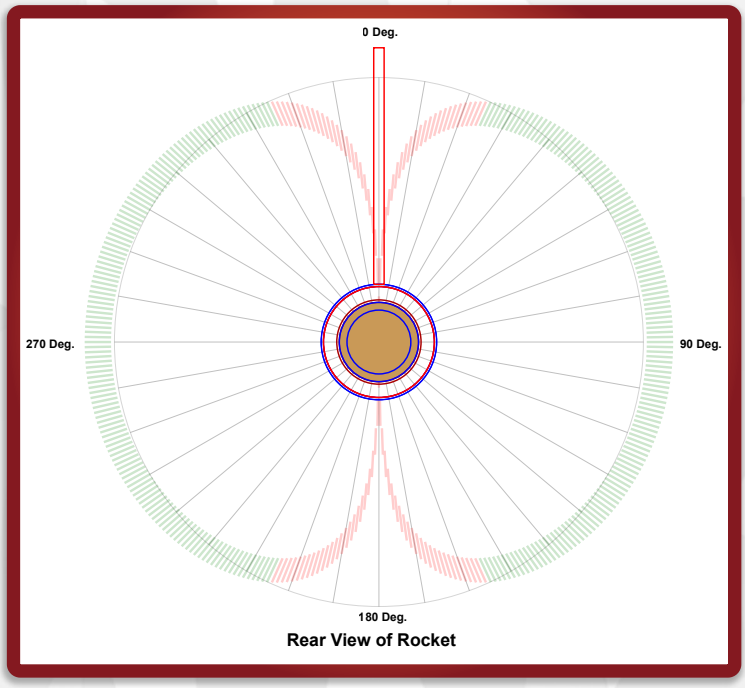

FIGURE 6: THE BASE VIEW OF THE ROCKET WITH THE STABILITY GRAPH OVERLAY AND THE ANGLE GRID DISPLAYED. COMPARE THIS TO THE REAR VIEW SHOWN IN FIGURE 4.

It is similar to looking at a cardboard cut-out view of the rocket from 306 views around the outside of the model as shown in Figure 7. Although it is more sophisticated than a simple cardboard cut-out of the rocket. The analogy is so you get the concept of what RockSim is doing when it figures out the CP location from all 360 views around the outside.

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Stability Graph Overlay

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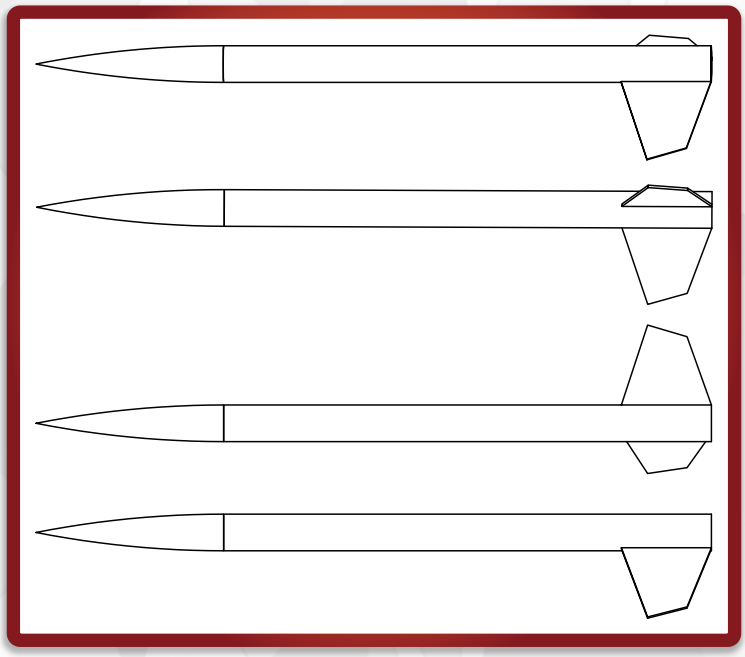

FIGURE 7: LOOKING AT A SIDE PROFILE OF THE 2-FIN ROCKET AT SOME RANDOM VIEW ANGLES, THE ROCKET LOOKS DIFFERENT

What we need to know is if the CP is behind the CG the rocket. This, by definition, is when the rocket is statically stable. In the graph, the outer circle is the CG location. The distance is fixed in the graph, so the circle will always be the same diameter no matter what rocket you're looking at. The green and the red lines are the CP location relative to the CG. If the lines are on the outside of the CG line, it is telling us that the CP from that view angle is behind the CG of the rocket. That is a "statically stable" condition, so the lines are colored green (for good). If the CP is in front of the CG on the rocket for a particular view angle, the lines will be colored red (for bad).

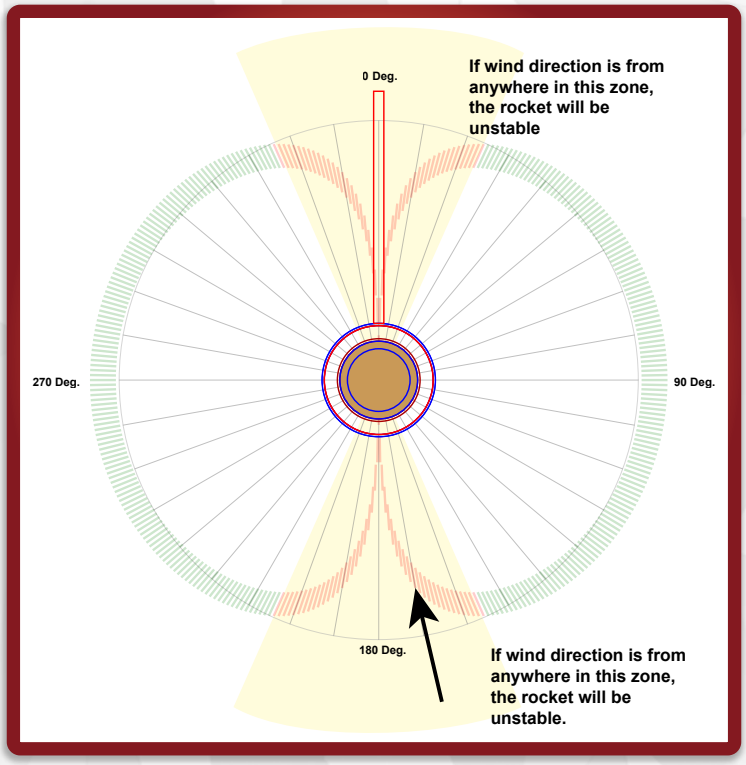

FIGURE 8: WHAT THE GRAPH IS TELLING US, IS THE VIEW ANGLES WHERE THE CP WOULD BE IN FRONT OF THE CG (WHICH WOULD BE UNSTABLE)

Before you fly the rocket, all the lines in the stability graph overlay should be green colored. That is the criteria you should be aiming for when you are designing asymmetric rockets.

It is important from a safety standpoint to design rockets with the assumption that you never want the CP to get forward of the CG (Center-of-Gravity) location. That is the very definition of an unstable rocket. It is only when the CP is behind the CG that we can say the rocket is statically stable.

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Stability Graph Overlay

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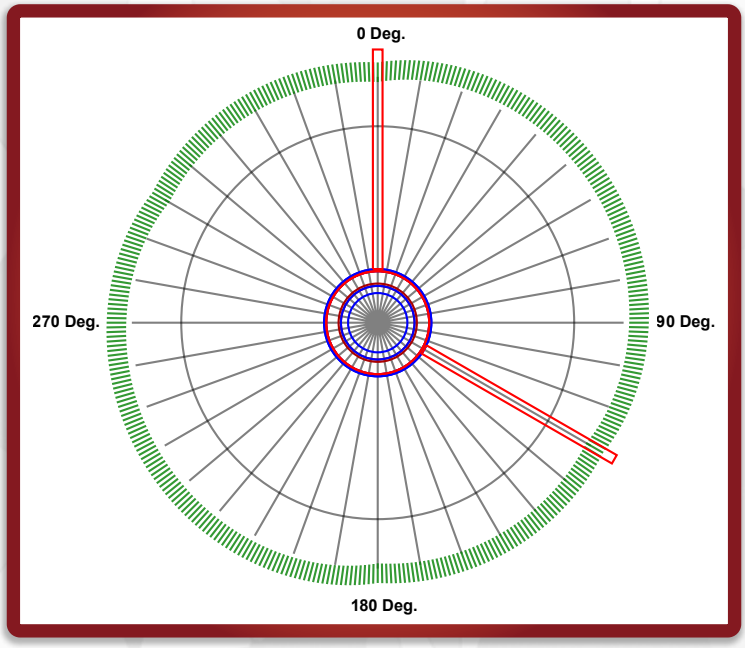

FIGURE 9: IN A TWO-FIN DESIGN, THE STATIC STABILITY OVERLAY IS SHOWING THE ROCKET AS BEING STABLE. BUT THIS DOESN'T MEAN IT WILL FLY STRAIGHT.

Unfortunately, "statically stable" doesn't define the full situation. When a rocket takes off, it is very dynamic. And even though the rocket might be statically stable, it may not be dynamically stable.

As a test to see whether RockSim is correct in determining if the 2-din rocket shown in Figures 3 and 8 is stable, I decided to go out and fly it. The launch was on a pleasant spring day, with winds under 5 mph. As you can see in Figure 10, the rocket did indeed fly straight.

FIGURE 10: THE LAUNCH OF A 2-FIN ROCKET TO VERIFY THAT WHAT ROCKSIM PREDICTED WILL WORK FINE.

You can see the full video on Youtube at: https://www.youtube.com/watch?v=0S7OEWBptoI.

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Stability Graph Overlay

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If you watch the video closely, you'll see that the rocket does a slow barrel-roll as it ascends into the sky. The reason for this is that there is more drag on one side of the rocket than on the other (due to the fins not being symmetrical). The offset drag causes the rocket to yaw to one side. But then this puts one fin at a higher angle of attack, and that fin creates more of a lift force that causes the rocket to rotate. This is an aerodynamics phenomena that is technically called "yaw-roll-coupling." It basically means that if a rocket yaws to one side, it is going to induce it to roll too.

The downside of yaw-roll-coupling is that it robs energy from the rocket. So it might not fly as high as a rocket that flies straight without a roll. But on the other hand, since the rocket has fewer fins, its static drag calculation is lower. So if you look in RockSim, it will show that a two fin rocket will fly higher than a three fin rocket. Unfortunately, RockSim doesn't know that the rocket is going to roll with just two fins, and therefore doesn't take into account the extra drag that a rolling rocket creates.

And it really depends on the configuration of the rocket as well. I think this would be great subject for a research paper, to figure out which two finned rockets would fly higher than their three-fin counterparts.

Conclusion

The Stability Overlay feature in RockSim is a really simple tool that isn't too hard to understand. And with it, you can check to see if your model that has an asymmetrical configuration would be stable. Just make sure that all the quadrants in the base view show "in the green."

www.ApogeeRockets.com/RockSim/RockSim_Information

Some other articles you might be interested in:

Creating Asymmetric Fin Arrangements in RockSim
https://www.apogeerockets.com/education/downloads/Newsletter105.pdf

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About the Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.

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