

## Why Do Spinning Rockets Fly Straighter?

And why don't they fly as high as a rocket with straight fins?

Your Questions Answered



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# PEAK OF FLIGHT

## Questions Answered About Spinning Rockets

By Tim Van Milligan

Devon Sinsley asks: *"I have seen it mentioned various places on your website that spinning a rocket will not fly as high as a non-spinning one. Why is that?"*

The reason a spinning rocket is not going to fly as high (in perfect conditions) is that it takes "energy" to spin it, and to keep it spinning. That energy has to come from somewhere, and it is stolen from the rocket's velocity.

But let's go back to basics. What might be the reason we want a rotating rocket? The answer is that it helps to make the rocket fly straighter.

Why is it that a rotating rocket flies straighter? That answer is found on page 183 of the book *Topics in Advanced Model Rocket* by Mandell, Caporaso, and Bengen ([www.apogeerockets.com/topics\\_advanced\\_model\\_rocketry.asp](http://www.apogeerockets.com/topics_advanced_model_rocketry.asp)). "A rapid roll rate makes a rocket "sluggish" in its rotational (pitch and yaw) behavior, allowing it to respond more nearly to the time average of disturbances than the individual disturbances themselves -- and since the time average is generally much less than any one individual disturbance, this is greatly to the rocket's advantage." The book goes on to say that when the rocket does react to the disturbance, that the amplitude of the oscillations are also lot lower.

In other words, a rotating rocket doesn't react very quickly to disturbances and it also doesn't swing very far in response to the disturbances. This means that it just keeps going straight, which is a good thing!

How can we induce rotation? The best way is to pre-spin the rocket prior to launch. A spinning launch platform (some kind of turn table) would be ideal. However, that isn't very practical. The second best alternative would be a helical launch tower. This kind of tower does exist, and is still used by NASA for launches of the Super Loki Dart rocket. Photos 1 and 2 show one at Cape Canaveral. As the rocket rises up through the tower, the guides induce a spin into the rocket. The faster the rocket leaves the tower, the higher the rotation rate.

According to Newton's first law of motion, a body in motion will remain in motion unless acted on by some outside force. This law is also known as the law of inertia. In our case, we're talking about the spinning motion. Once the



**Photo 1 and 2: Helical launch tower used to impart a spin to a rocket. Right: Front view looking down into the tower [Source: Florida Tech JAMSTAR report].**



rocket leaves the helical tower, the spinning will continue unless some outside force acts on it. But as we all know, even a spinning top will wind down and fall over after some time. So there must be some force acting on it that causes it to slow down. That force is mainly friction on the point where it touches a table. In the case of a spinning rocket, the force is aerodynamic drag.

But for the most part, as long as the rocket is spinning as it leaves the tower, we're probably going to get a good straight flight. The positive effects of spinning the rocket will probably be sufficient to keep it going straight during that time period when the rocket is most susceptible to disturbances. That period is when the rocket's speed is the slowest, which is right when it leaves the launcher. After it has built up enough speed, the fins will do a pretty good job keeping it going relatively straight even if it does slow down

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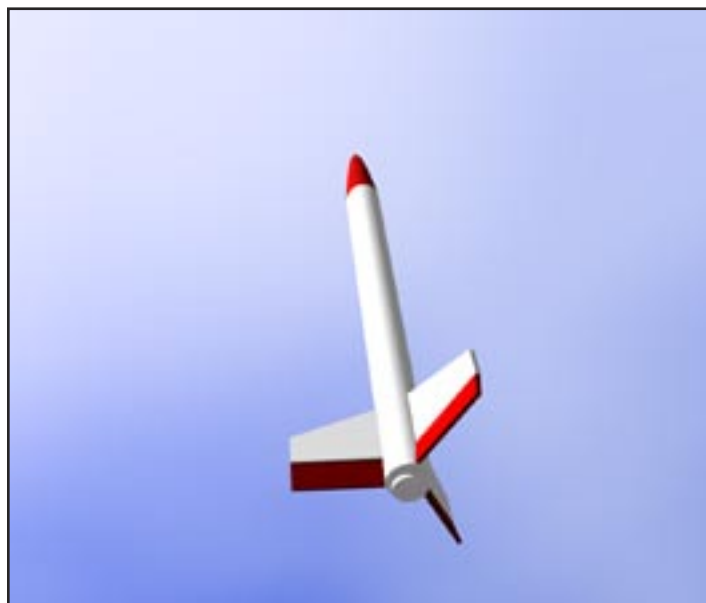
## Questions about Spinning Rockets

or stop its spinning.

But what if you don't have a helical launch tower? I don't. The way to induce a spin then is to either add spin tabs, angle the entire fin, or put a cambered airfoil on each of the fins (Fig 2). The lift force that is created by any of these methods would cause an unbalanced force that will cause the rocket to start to spin about its long axis. The result: we've spun up the rocket in order to get a straighter flight.

But there is a downside to this. It takes energy to start the rocket spinning using these methods. To start it spinning, and to keep it spinning, we need energy to pump into the system to spin it. Where does this energy come from? We have to rob it from somewhere else. We rob it from the speed (kinetic energy) of the rocket as it travels upward, in order to turn it into a lift force on the fin to cause rotation. It actually is worse than that, because whenever there is a lift force, there is also an induced drag force. Basically, we're slowing down the rocket throughout its flight, and hence when the motor burns out, it is starting its coast at a slower speed and therefore won't travel as high.

And since we can't turn off the lift force once the rocket is spun up to a sufficient angular speed, we're continuing to pump more energy in the rotation of the rocket. That means



**Figure 2: Spin tabs (also called spinerons) on the fins cause the rocket to rotate as it ascends.**

we can't reduce the drag force and the rocket isn't going to go as high as a non-spinning rocket. Why can't we turn off the spin once it is spun up? Because we can't reorient the fins while it is in flight. If we had some mechanism to sense

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## Questions About Spinning Rockets

that the rocket is spun up to the proper speed, and then reorient the fin tabs to a zero degree angle-of-attack, then it would be possible to limit the drag.

The rocket with spin tabs or canted fins is also going to be spinning at a high rate when it ejects the parachute. This could be a bad thing if you're not ready for it, as it could wind up the lines of the chute and cause it to collapse. That means the rocket is going to come down too fast and could be damaged by the hard landing. Keep this in the back of your mind as you are designing and prepping your rocket. You'll probably want to use a longer shock cord with a swivel at the parachute attachment point and use a method of folding or a deployment bag for the chute that makes it open more slowly (see Peak-of-Flight Newsletter #187). That way the rocket can have a chance to de-spin itself before the chute has time to fully open.

### **When is it desirable to spin throughout the entire flight?**

As noted above, for most model rockets, we'd like the model to start out spinning as it leaves the launch pad, so that it has the greatest effect at preventing weathercocking. Weathercocking usually begins when the rocket is traveling at a slow speed. Once the rocket gets past that critical point in the flight, then ideally it would be desirable to de-spin it so as to lower the drag. In rockets launched off a spin table or out of a helical tower, this will happen by itself.

But for rockets that are being designed for super high altitude flights (maybe greater than 30,000 feet), it may be desirable that they spin for a good portion of the flight to reduce the chances of weathercocking. In that case, canted fins or spin tabs would have to be used.

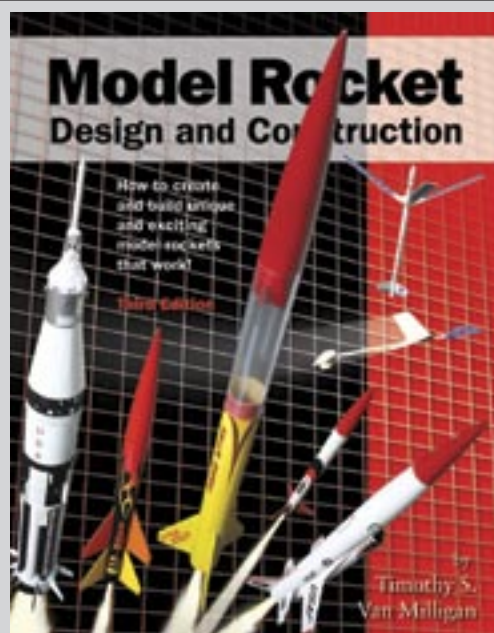
*"Would spinning a rocket to stabilize it allow a reduction in fin size? Say, like a bullet or a football maybe using very small fins that really only induce spin."*

It is possible to have spin stabilization without fins. But according to the book *Topics in Advanced Model Rocketry*, it is tricky. It works better on short, squat rockets than it does on long and slender rockets. Artillery shells and bullets are spin stabilized for less dispersion. But I can't think of any no-fin military rockets that use it.

*"So is there a happy medium between using a small canted fin that will provide lift and induce spin and the spin itself to stabilize the rocket with a net overall loss in drag and weight, thereby achieving higher altitude for the same effort?"*

I'm sure it can be optimized to some extent. But it will be rocket shape and motor dependent, much like optimum mass is dependant on the rocket shape and engine used. I don't have any rules of thumb to help guide you in this process. If you're really interested in optimizing the rocket, then I highly recommend the book *Topics in Advanced Model Rocketry*.

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## Model Rocket Design and Construction

By Timothy S. Van Milligan

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### References:

*Topics in Advanced Model Rocket* by Mandell, Caporaso, and Bengen. Can be purchased from Apogee Components at: [www.apogeerockets.com/topics\\_advanced\\_model\\_rocketry.asp](http://www.apogeerockets.com/topics_advanced_model_rocketry.asp).

Florida Tech JAMSTAR 2003 (Joint Aerospace & Meteorology STRatosphere Analysis Rocket) Final Report - May 2, 2003: [www.fit.edu/projects/jamstar/](http://www.fit.edu/projects/jamstar/)

Dynamic Stability Analysis. A series of six articles that explain how a rocket reacts to a disturbance in flight. Peak-of-Flight Newsletter 192 through 198. These can be downloaded at: [www.ApogeeRockets.com/education/newsletter\\_archive.asp](http://www.ApogeeRockets.com/education/newsletter_archive.asp)

Deployment Bag Assembly Instructions. Peak-of-Flight Newsletter 187: [www.ApogeeRockets.com/education/downloads/Newsletter187.pdf](http://www.ApogeeRockets.com/education/downloads/Newsletter187.pdf)

Parachute folding instructions for high speed deployments. Peak-of-Flight Newsletter 199: [www.ApogeeRockets.com/education/downloads/Newsletter199.pdf](http://www.ApogeeRockets.com/education/downloads/Newsletter199.pdf)

### About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket

scientist who likes helping out other rocketeers. 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 a 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 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 a FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site or by sending an e-mail to: [ezine@apogeerockets.com](mailto:ezine@apogeerockets.com) with "SUBSCRIBE" as the subject line of the message.



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## Your Questions and Comments

By Tim Van Milligan

Richard McDonald writes: *"I think the workshop videos are a great idea! As long as it doesn't end up replacing the Peak of Flight Newsletter; that would be a shame. Keep up the good work."*

I'm glad you like the videos. I enjoy making them because it is something vastly different from my usual routine. This newsletter is much harder to produce than making the videos. But I don't have any plans to stop just yet. I do get occasional writers block, so I appreciate ideas for the articles. Hint, hint.

I've also recently made a home-page on our web site where we have links to all our free how-to videos. You may want to let your friends know. It is: [www.apogeerockets.com/Rocketry\\_Video\\_tips.asp](http://www.apogeerockets.com/Rocketry_Video_tips.asp)

Troy Coverstone writes: *"Thank you for your concern with our order. I would like to add we are very grateful for the free gift, and the prompt response time. And it is rare today that companies give such personal attention to their customers."*

What can I say... Thank you for those kind comments. We're just happy to have great customers.

Oliver Arend writes: *"While you were writing about the forces acting on the fins of a rocket and stability in Newsletter #220, I was wondering again why the 1 caliber rule is held up so strongly. Wouldn't it make more sense to relate the "necessary" distance between CP and CG to the length of the rocket, say 10-15%, rather than its diameter?"*

Wow! What a great question.

In the world of airplanes, this is exactly how things are done. I'll quote from the section on balancing a glider,

which is on page 208 of my new book: "Model Rocket Design and Construction - 3rd Edition:"

"Ideally, the CG should be positioned to give your glider a 10% to 15% stability margin. What does this mean?

Like a model rocket, a glider's stability is defined by the relationship between the CG and the CP. There are just two small differences though. First, the CP on a glider is called the Neutral Point.

The second difference is the reference length used to define how far in front the CG is from the Neutral Point. On a cylindrical rocket, the diameter of the tube is used as the reference length. On a glider, the Mean Aerodynamic Chord (M.A.C.) length is used.

For example, if your glider had a M.A.C. length of 3.0 inches and you wanted a 10% stability margin for the glider, you would multiply 0.1 times 3.0 inches, for a distance of 0.3 inches. You would then balance the glider so the CG was 0.3 inches in FRONT of the Neutral Point position."

The one thing I don't like about the glider neutral point procedure is that you have to find the M.A.C. length. It isn't very easy to do. I prefer the simplicity of the caliber rule, and I wish that there was something similar for gliders.

But my own opinion's aside, could you do the same thing on a rocket (which is your question)? I guess you probably could.

The issue would then become how easy would it be for the rest of the world to adapt to this new standard? I think there would be quite some hesitation.

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## Your Questions and Comments

The nice thing about the caliber rule is that it is very “visual,” and not “cerebral.” You can look at a rocket and see the diameter of the tube. As long as the CG is ahead of the CP by one tube diameter, you’re likely to have a stable rocket. It is a simple one-to-one ratio that you can do with your eyeballs.

But if you used the overall length of the rocket and then had to define a percentage of that length, you lose a lot of simplicity. You would have to make a division in your mind to find a new length, and then apply that to the current location of the CP. In other words, you have to think about it a lot more than just the caliber system.

Maybe your next question might be: is “one caliber stability” sufficient, or is it overkill?

My answer to that question is that based on 50+ years of trial and error by rocketeers, it seems to work most of the time. Because of that, as a rule-of-thumb, it is a good one to go by.

I’m guessing here, but it is possible that the original 1-caliber rule came about because in the 1950’s and 60’s no one really knew an accurate way to determine where the CP was on the rocket without a wind-tunnel test. So they might have said, estimate your CP point, and then give it a

fudge factor just in case your actual position is not accurate. The fudge factor they used was “one body tube diameter” because it was easy for young modelers to visualize.

Why a fudge factor? Because of the potential for danger of an unstable rocket, we always err on the side of caution. One caliber stability may be overkill and thus making rockets more prone to weathercocking on breezy days. But I’d rather have that than the rocket go unstable and smash itself to bits.

If you were trying to extract every ounce of performance out of your rocket, then greater than one-caliber stability might be too much. For a discussion of that, I’ll refer you back to Peak-of-Flight Newsletters #192 through #198, where we dive deeply into the subject of dynamic stability and how to design your rockets to fly higher.

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Todd Brady writes: “How do you break down the ratio for nose cones? In a 4:1 or a 5:1 (or whatever the ratio is) ratio, do you add up the diameter of the nose cone four times to get the length of the nose cone?”

You’re right on the ratios. Take the maximum diameter and multiply it by the ratio. That will be the exposed length. For example, if you want a 3:1 ogive, and your tube is one inch in diameter, then the overall length of the nose will be 3 inches.

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