Issue 675 / March 31st, 2026

PEAK OF FLIGHT NEWSLETTER

Apogee Components, Inc. / ApogeeRockets.com / Colorado Springs, CO

The Science of the "Snug" Fit: Mastering Proper Nose Cone Fit



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FEATURED ARTICLES



The Science of the "Snug" Fit: Mastering Proper Nose Con Fit

This article explains how to make sure a rocket's nose cone fits just right. It shows how to test whether the cone is too loose or too tight so the rocket can launch safely and the parachute can come out when it should.

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A blue-painted Apogee Katana descends gracefully under an Apogee 48" diameter nylon parachute.



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The Science of the “Snug” Fit: Mastering Proper Nose Cone Fit

By Tim Van Milligan

In the world of model rocketry, we often talk about “feel.” We talk about a nose cone feeling “right” or “snug.” But if you’ve been in this hobby as long as I have, you know that “feel” is an unreliable metric to rely on when you’re talking to someone that has no way to compare feelings. A nose cone that is too loose can drag-separate during boost, leading to a high-speed deployment that shreds your parachute. Conversely, a nose cone that is too tight can resist the ejection charge entirely, turning your rocket into a ballistic lawn dart.

Since we deal with many newcomers to rocketry, I thought I’d write an article about this topic, and try to share some of my insights that may be able to help them. For years, I approached this as a problem of "friction." The problem is that it is hard to talk about friction, because it is something you have to “feel.” Newcomers to rocketry haven’t yet had the opportunity to feel what a good nose cone fit should be, and there isn’t a good way to describe it to them.

I want to move away from the abstract concept of friction and move toward a measurable, repeatable engineering standard. We’ll call it: **Breakout Force**. And it can be measured easily, which makes it something we can then use to train newbies to the rocketry hobby what a good fit should feel like—even when we aren’t physically there to hand them a rocket and say: “feel this nose fit into the tube.”

Why Friction Equations Aren’t Enough

When we learn about the physics of two objects sliding against each other, we are introduced to the classic static friction equation:

$$F_f = \mu_s N$$

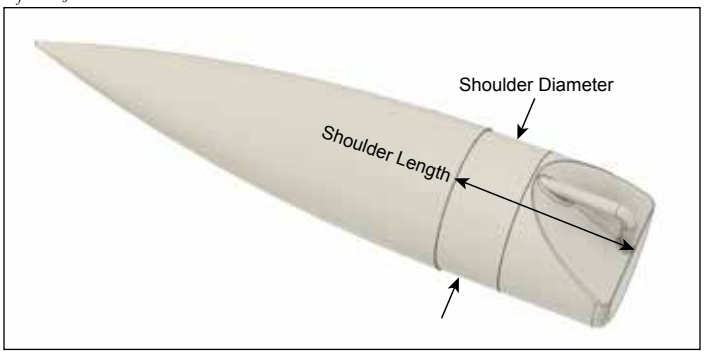


Figure 1. The typical rocket nose cone.





Figure 2 - Couple discussing rocketry.

In this formula, F_f is the force of friction, μ_s is the coefficient of static friction (determined by the materials, like plastic against cardboard), and N is the normal force—the force pressing the two surfaces together.

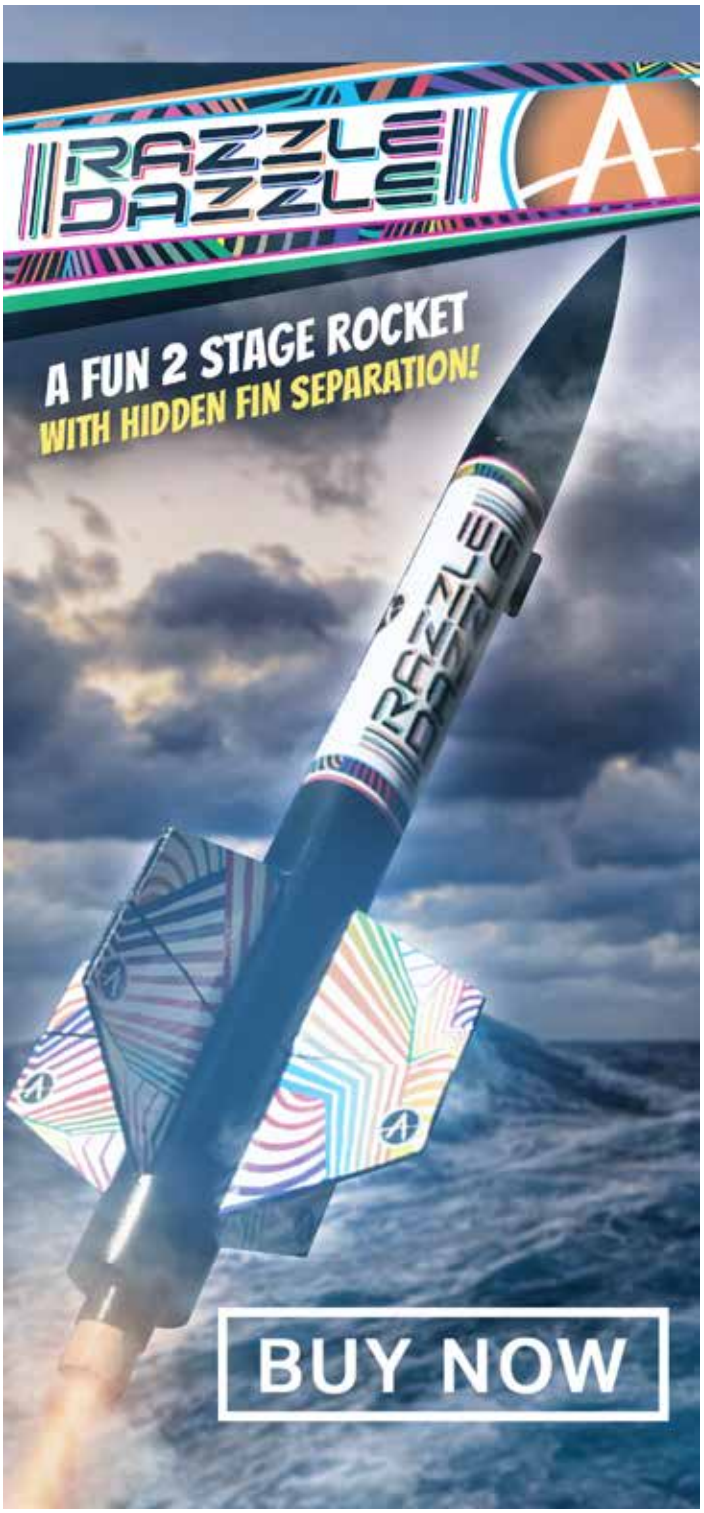
On paper, this looks like the answer. If I want more friction, I either need a "stickier" material (increase μ_s) or I need to press the shoulder harder against the inside of the tube (increase N). This is exactly what we do when we add masking tape. The tape increases the effective diameter of the shoulder, creating an interference fit that spikes the normal force.

However, applying this equation to a rocket in the workshop is nearly impossible. How do you measure the normal force N inside a cardboard tube? The tube isn't perfectly rigid; it flexes. The nose cone shoulder isn't a perfect cylinder; it has mold seams and slight tapers. The contact isn't uniform; it's a series of high points and low points.

Because we can't easily calculate N, the friction equation remains a theoretical ghost. This is why I shifted my focus to **Breakout Force**. Breakout force is the total axial force required to overcome all internal resistance—friction, interference, and surface irregularities—to initiate motion. It is the real-world "sum" of the friction equation, and most importantly, it is something I can measure with a pile of hardware and a scale.

The BT-80 Experiment: Putting Numbers to the "Feel"

To settle this once and for all, I took a standard BT-80 build off my bench. The measurements were typical for a mid-sized kit. The body tube inner diameter (ID) was 2.558 inches, and the nose cone shoulder diameter was 2.552 inches. Mathematically, that leaves a diametral clearance of:





2.558 - 2.552 = 0.006 inches

While six-thousandths of an inch sounds small, in the world of slip-fits, it's a canyon. When I put the nose cone in the tube and turned it over, the cone didn't just slide; it practically fell out. Gravity alone was almost enough to overcome the negligible friction present.

I decided to tune the fit using my go-to method: masking tape. I applied a single strip of tape to the shoulder. The specs of the tape were as follows:

- **Width:** 1.0 inch
- **Length:** 6.0 inches
- **Thickness:** Approximately 0.005 inches

By adding that 0.005-inch layer to one side of the 2.552-inch shoulder, I effectively closed the gap. But the fit now felt "right" by my old subjective standards. This is where experience comes in, and what I consider a good fit of the nose in the tube may be a little different from other modellers. I'll go with it anyway. The purpose of this experiment was that I wanted to know exactly what "right" looked like in a measurable way where someone else could repeat my experiment.

The Measurement Process

I inverted the body tube and supported it so the nose cone was pointing toward the floor. I then used a collection of heavy-duty metal nuts as my "test weights." I dropped them into the open end of the body tube so they rested on the internal base of the nose cone shoulder.



Figure 3 - Using metal nuts for weight, we can perform a simple experiment to measure how much force it takes to push off a nose cone

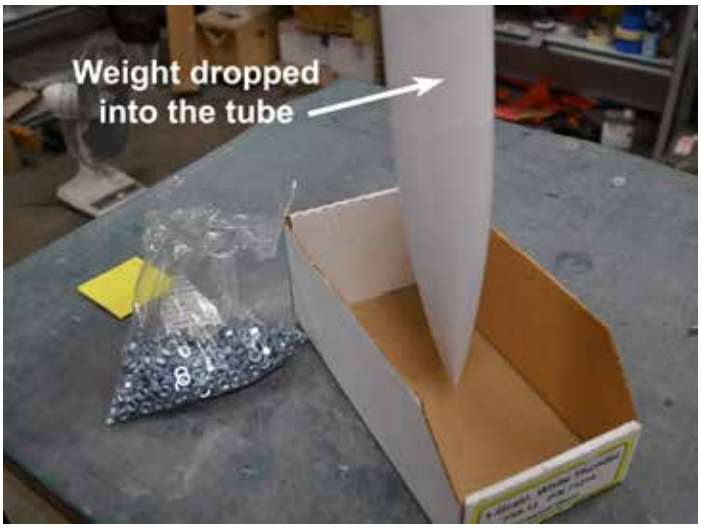


Figure 4 - Gently place the weights into the inverted rocket until the nose breaks free. Do it over a box to keep the weights from going all over the floor when they fall out.

I added the nuts one by one, watching for the moment the static friction broke. At 100 nuts, the nose cone finally began its descent. I took those 100 nuts to my digital scale and found they had a total mass of 315.8 grams.

Accounting for the Nose Cone Mass:

It is important that we don't neglect the mass of the nose cone itself. The nose cone with the masking tape had a mass of 65.94 grams. Therefore, the actual breakout mass is:

$$315.8\ g + 65.94\ g = 381.74\ g$$

To find the actual force in Newtons, I used the standard gravity calculation:

$$F = m \times g$$

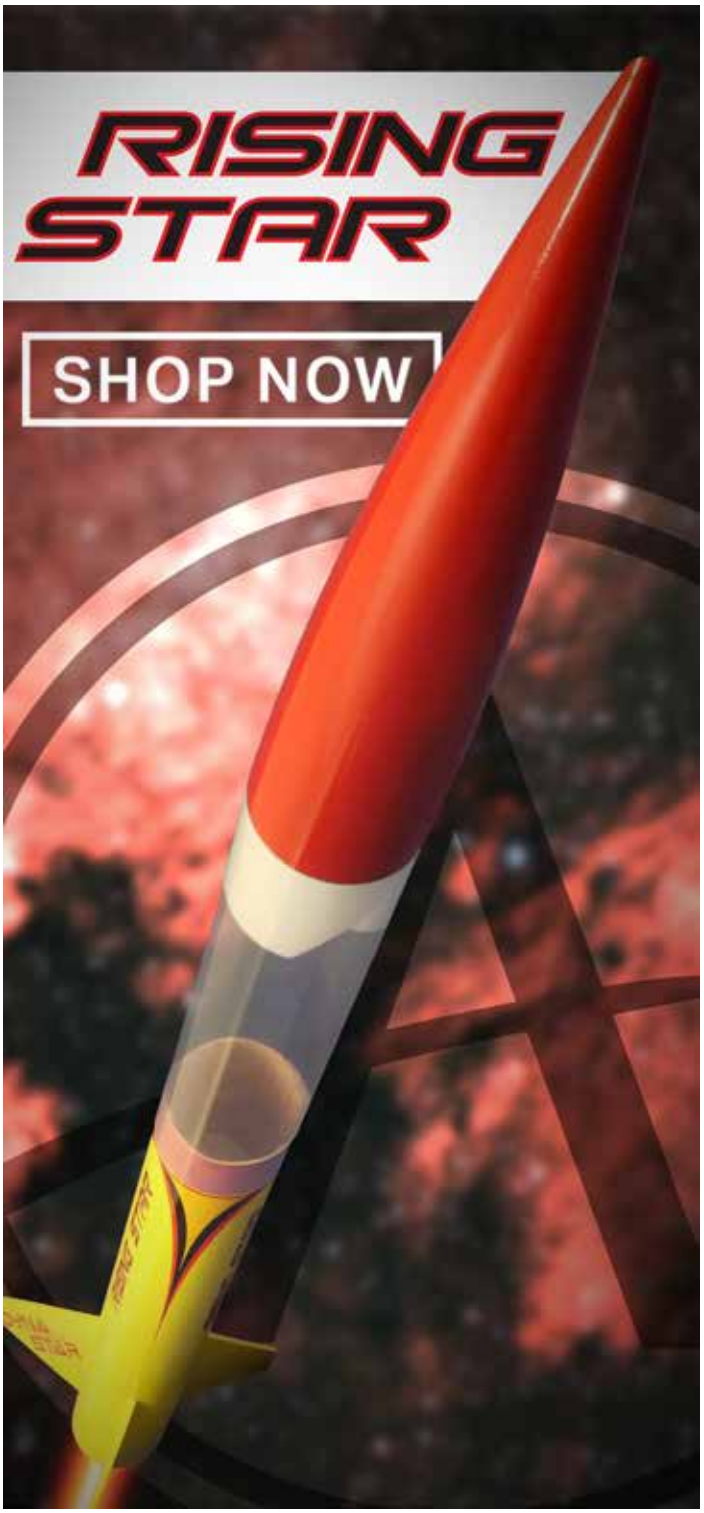
$$F = 0.38174\ kg \times 9.81\ m/s^2 \approx 3.74\ N$$

In imperial units, this is approximately **0.84 pounds-force (lbf)**.

This was my baseline. For a BT-80 rocket, a breakout force of 3.74 Newtons felt perfect. In my experienced opinion, this would be secure enough to handle a typical mid-power motor ascent, but loose enough that the standard black powder ejection charge in the motor would have no trouble clearing it.

Narrowing the Target

If the breakout mass is too low—say, under 200 grams for a BT-80—you are flirting with what a lot of people call "drag separa-



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tion." If it's over 600 grams, you are putting unnecessary stress on your shock cord anchor points and risking a no-deploy scenario if your motor's ejection charge is slightly weak. For a medium-sized rocket like our BT-80 example, I would suggest a target range of **340 grams to 425 grams**. If my test shows 381.74 grams, I am right in the sweet spot.

Scaling the Logic: Why Diameter Changes Everything

What do you do if the tube is smaller or larger in diameter? Do you still want in the range of 340 to 425 grams? No. The amount of test weight will be different. To understand why, we have to look at the relationship between the surface area of the nose cone base and the internal pressure generated by the motor.

Think of the nose cone like a piston in a car engine. The force pushing that piston out is the internal pressure multiplied by the surface area of the piston head $(F = P \times A)$. In a small BT-20 tube (0.71-inch diameter), the surface area is only about 0.40 square inches. In a large BT-80 (2.56-inch diameter), the area is over 5.1 square inches—nearly 13 times larger. A chart showing surface area of common tubes is shown in Table 1.

If you set both rockets to have a breakout force of 380 grams, the BT-20 would require a massive internal pressure of about 2.1 psi to move the cone. Meanwhile, the BT-80 would only need 0.16 psi. This is why a "one-size-fits-all" feel doesn't work.

How to Use the Reference Table: A Step-by-Step Guide

On the next page is a table of common body tube sizes and the approximate total mass (nose cone + added weight) that should move it out of the tube.

The "Custom Tube" Formula

If you are using a non-standard tube, you can calculate your own target breakout mass in grams using this simple formula based on our corrected BT-80 baseline:

$$M_{target} \approx 74 \times Area\ (in^2)$$

Example: If you have a 3-inch tube with an area of 7.06 in², your target mass would be: 74 × 7.06 ≈ 522 grams

The Altitude Factor: Quantifying the "Internal Push"

As any rocket climbs, the atmospheric pressure around it drops, but the air trapped inside the airframe remains at the pressure of the launch site. This creates a pressure differential—a lit-

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Tube Size	Apogee Name	Nominal ID (in)	Area (in^2)	Target Breakout Mass (Total g)	Target Force (N)
BT-20	18mm	0.710	0.396	25 – 35 g	0.25 – 0.34 N
BT-50	24mm	0.950	0.708	45 – 60 g	0.44 – 0.59 N
BT-55	33mm	1.325	1.380	90 – 115 g	0.88 – 1.13 N
BT-60	41.6mm	1.637	2.100	140 – 170 g	1.37 – 1.67 N
BT-70	56mm	2.180	3.732	250 – 300 g	2.45 – 2.94 N
BT-80	66mm	2.558	5.139	340 – 425 g	3.33 – 4.17 N
AT-74	74mm	2.930	6.743	450 – 550 g	4.41 – 5.40 N

Table 1 - Approximate mass that you could drop into the inverted rocket to that would be needed to push the nose cone off.

eral internal force pushing against the base of the nose cone. To master the "snug" fit, you have to understand exactly how much force this differential exerts at various altitudes.

Concrete Examples of Pressure Drop

In the lower atmosphere, air pressure decreases in a relatively predictable way. For every 1,000 feet of ascent, the ambient pressure drops by approximately 0.49 pounds per square inch (psi). Let's look at what happens to a rocket sealed at sea level (14.7 psi) as it gains altitude:

- **At 1,000 feet:** The outside pressure is about 14.21 psi. The internal pressure is still 14.7 psi. The differential is 0.49 psi.
- **At 3,000 feet:** The outside pressure is about 13.23 psi. The differential is 1.47 psi.
- **At 5,000 feet:** The outside pressure is about 12.25 psi. The differential is 2.45 psi.

While a 2.45 psi difference might sound negligible, we have to remember our physics: $Force = Pressure \times Area$. If we take my BT-80 experiment (Area = 5.139 in^2) and fly it to just 1,000 feet without a vent hole, the internal air is pushing on the nose cone with:

$F = 0.49\ psi \times 5.139\ in^2 \approx 2.52\ lbf$



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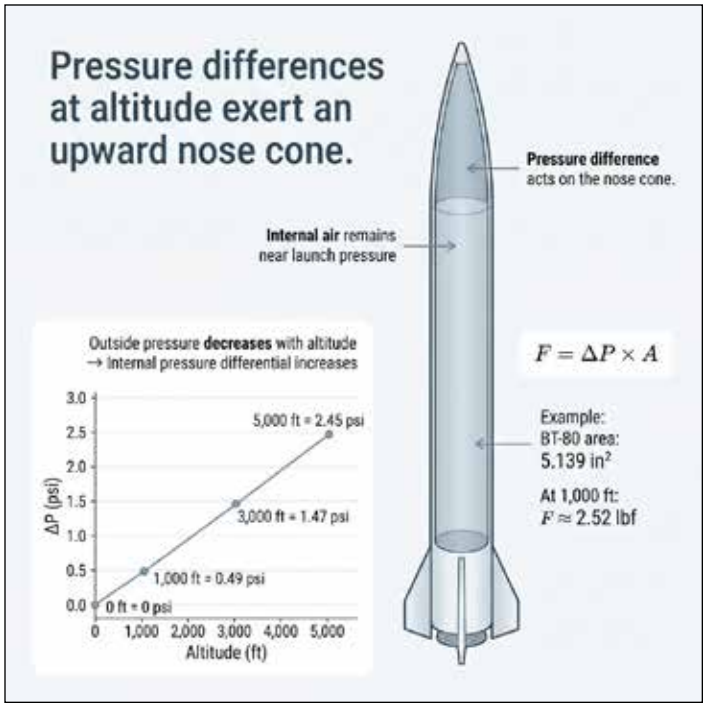


Figure 5 - Air pressure outside the rocket drops as the rocket goes up. This creates a pressure difference that increases the higher the rocket flies, which wants to push the nose off.

Convert that to grams (1 lb≈453.6g), and you get **1,143 grams of force**.

Compare that to my measured breakout mass of **381.74 grams**. At only 1,000 feet, the internal air is pushing with nearly **three times** the force required to pop the nose cone. We'll talk about why the nose doesn't pop off in the situation a little later. But for now, we're just looking at forces acting on the rocket.

How You Can Calculate This

You don't need a degree in meteorology to predict these forces for your own rocket. You can use a simplified linear approximation for any flight staying below 10,000 feet.

Step 1: Calculate the Pressure Differential (ΔP)

Use the standard "rule of thumb" for atmospheric pressure drop:

$\Delta P \approx 0.00049 \times \text{Altitude (ft)}$

Example: For a 2,500-foot flight, $\Delta P = 0.00049 \times 2500 = 1.225$ psi

Step 2: Calculate the Internal Force (F_{int})

Multiply that pressure by the cross-sectional area of your body tube:

$F_{int} = \Delta P \times A$

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Step 3: Convert to Breakout Mass (Grams)

To compare this directly to the weights you used on your workbench, convert the force to grams:

$$M_{equiv} = F_{int} \times 453.6$$

If your calculated M_{equiv} is higher than the breakout mass you measured in the shop, your nose cone will pop off during ascent unless you add a vent hole.

The Speed Factor: Compounding the Problem

Velocity adds another layer of complexity. As the rocket speeds up, except at the very tip, the air moving over the nose cone creates a “suction” effect (low pressure) on the exterior surface. This is Bernoulli's principle, and is why wings produce lift (see Figure 6). This low pressure area effectively increases the pressure differential. If the internal pressure is pushing out with 0.5 psi due to altitude, and the high-speed airflow is “pulling” from the outside with another 0.3 psi of suction, the total effective differential is now 0.8 psi. This is why high-speed, high-altitude flights are the most common victims of what most people call *drag separation*—which is often actually **pressure separation.**

The Velocity Factor: When Speed Meets Suction

While the physics of "aerodynamic suction" sounds like a major threat to your rocket, I want to put your mind at ease: for the vast majority of mid-power flights, like our BT-80 example, a standard "good fit" is more than enough to keep everything together. If you've followed the breakout force ranges in the table above, you are already likely protected against the typical forces of a standard flight.

Here's why your OK... First of all, you have another force working in your favor. The thrust of the rocket motor is making the nose cone heavier. While the rocket engine is burning, say it it produc-

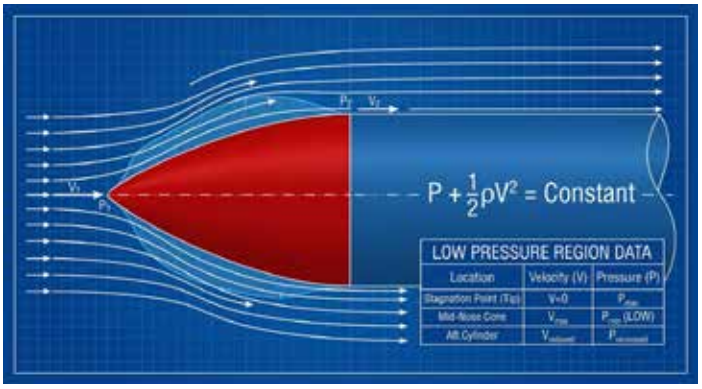
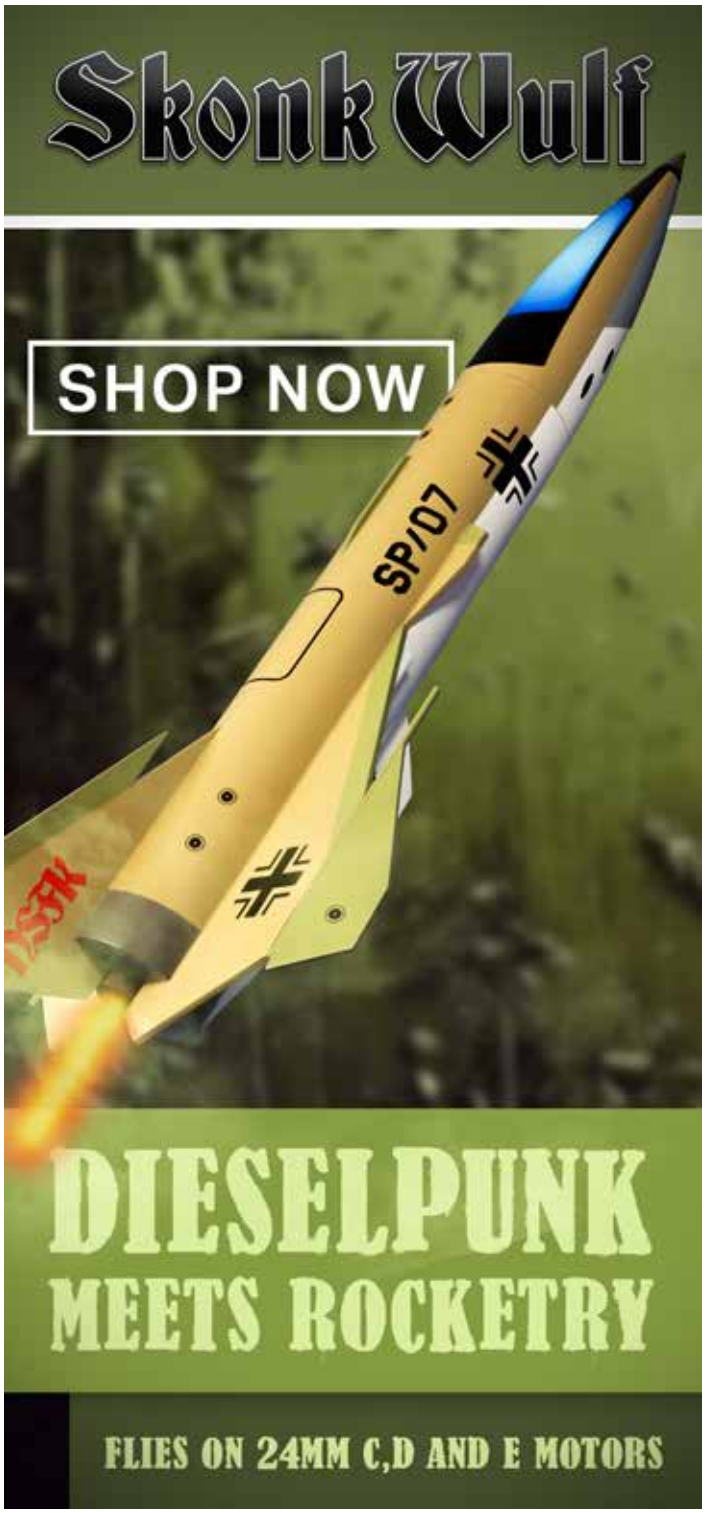


Figure 6- There is a low pressure region on the nose cone that increases the faster the rocket flies.





ing 5 Gee's off acceleration, the nose cone weighs 5 times its orignal weight, which is pressing it down harder into the tube.

And in reality, most model rockets are not airtight. Even without a dedicated vent hole, air naturally "leaks" out through the gap around the motor casing and mount tube and even through the tiny gap where the nose cone meets the airframe. This natural ventilation usually handles the pressure changes of a typical ascent quite well.

So the longer the motor burns, the more time you have for the air pressure to leak out and that really helps keep the nose on.

So, Why Talk About Suction at All?

We discuss these forces because they represent the "hidden" side of rocketry that becomes critical as you move into High Power Rocketry (HPR) or high-performance flight. As a rocket approaches higher speeds—specifically as it nears the speed of sound—the air moving over the curved portion of the nose cone creates a low-pressure zone (seen in Figure 6). This acts like a mild vacuum, trying to pull the nose cone forward. As mentioned, in most mid-power rockets, this force is negligible. However, it becomes a factor you must account for in two specific scenarios:

- **Transonic Flights:** If your rocket is designed to fly exceptionally fast (Mach 0.8 or higher), the suction force increas-



Figure 7 - A properly deployed parachute from the Flame Thrower rocket.

es significantly.

- **Large Diameter Rockets:** In rockets with 4-inch diameters or larger, the surface area is so great that even a small amount of suction can add up to several pounds of pull.

The Burnout Risk: When the Situation Gets Worse

The real danger zone isn't during the climb; it's the exact millisecond the motor stops firing. This is known as Motor Burnout, and it is where the physics shift from being your friend to being your enemy.

1. **Negative Acceleration (Deceleration) Begins:** See Figure 8 for an acceleration plot from a typical rocket) As soon as the motor goes quiet, drag starts hitting the back end of the rocket hard (while the nose is streamlined and low drag, the back has lots of protruberances as well as high base drag). The rocket begins to slow down. In the rocket's frame of reference, this creates an inertial force pulling the nose cone out of the tube.
2. **Pressure is at its Peak:** At burnout, the rocket is at its highest velocity and likely a high altitude. The internal pressure is at its maximum differential compared to the thin outside air.

If the internal air hasn't leaked out fast enough during the burn, this combination of internal pressure and "forward-pulling" deceleration can pop the nose cone prematurely.

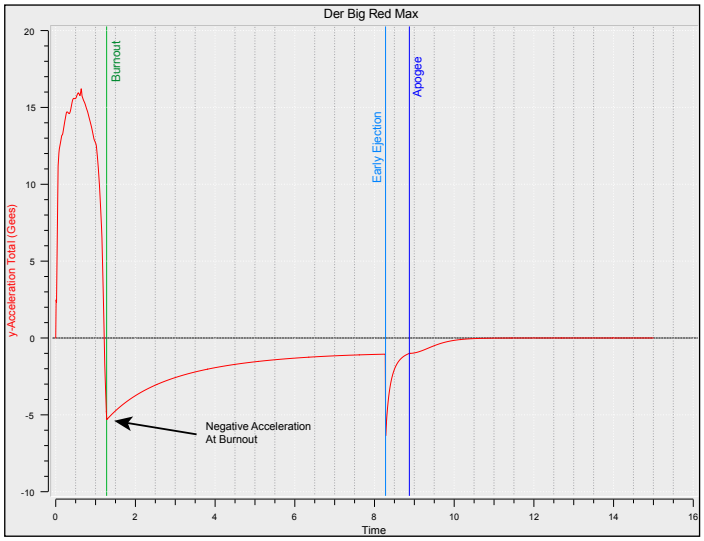


Figure 7 - Graph from RockSim showning acceleration on the rocket. At burnout, there is a negative acceleration that tries to separate the nose cone from the tube.





The High-Power Hazard: The Weighted Nose Cone

This problem becomes critical in High Power Rocketry (HPR), particularly when nose weight is added for stability.

If you have added 8 ounces of lead shot to your nose cone to move the Center-of-Gravity forward (to make the rocket stable), you have inadvertently compounded the problem. During the boost, that weight helps keep the cone seated. But at burnout, that same 8 ounces of lead wants to keep moving forward at the rocket's top speed while the airframe is being slowed down by drag.

In a high-performance HPR build, the "forward pull" of a weighted nose cone at burnout can easily exceed several pounds of force. This is why high-power flyers don't just rely on a "snug fit." They use:

- **Pressure Relief Holes:** A small 1/16" or 1/8" hole drilled in the airframe to ensure the internal and external pressure equalize instantly.
- **Shear Pins:** Tiny plastic screws that mechanically lock the nose cone to the airframe, designed to break only when the high-pressure ejection charge fires.

The Practical Takeaway

For 95% of the model rockets we fly on a Saturday morning, you don’t need to overthink the aerodynamics. If your nose cone passes the good fit as defined by the Inversion Test and falls within the target breakout mass, you are in great shape. As mentioned, Pressure Relief Holes and shear pins are best practices for high-power flyers pushing the limits of speed and size. For everything else, a calibrated, snug fit is good enough. You don’t need to fear the vacuum—you just need to be aware that as your rockets get bigger and faster, the way they interact with the air becomes a bit more sophisticated.

By keeping your fit within the recommended ranges, you ensure that the only thing popping that nose cone is the ejection charge at apogee.

Conclusion

In conclusion, mastering the "snug fit" is about transitioning from subjective guesswork to repeatable science. By using the Breakout Mass method, you provide yourself and your fellow modelers with a concrete way to ensure flight safety. Whether you are adding a sliver of masking tape or lightly sanding a shoulder, you are now tuning your rocket to handle the complex interplay of friction, internal pressure, and external aerodynamics.

Remember that while the math helps us understand the "why," the goal is to build an intuitive sense of quality. Use the weights and the table to calibrate your hands; eventually, you’ll know ex-



actly what a good-fit for proper breakout feels like. Fly safe, test your fits, and enjoy the peace of mind that comes with knowing your recovery system is ready for the ride.

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 (www.apogeerockets.com) and the author of the books Model Rocket Design and Construction and 69 Simple Science Fair Projects with Model Rockets: Aeronautics, as well as the publisher of the "Peak-of-Flight" newsletter. You can reach him through the contact form at www.apogeerockets.com/Contact.



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Article Submission Guidelines

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SUBMITTING ARTICLES TO APOGEE

We are always looking for quality articles to publish in the *Peak-of-Flight* newsletter. Please submit the "idea" first before you write your article. It will need to be approved first.

When you have an idea for an article you'd like to submit, please use our contact form at **https://www.apogeerockets.com/Contact**. After review, we will be able to tell you if your article idea will be appropriate for our publication.

Always include your name, address, and contact information with all submissions. Including best contact information allows us to conduct correspondence faster. If you have questions about the current disposition of a submission, contact the editor via email or phone.

CONTENT WE ARE LOOKING FOR

We prefer articles that have at least one photo or diagram for every 500 words of text. Total article length should be between 2000-4000 words and no shorter than 1750 words. Articles of a "how-to" nature are preferred (though other types of articles will be considered) and can be on any rocketry topic: design, construction, manufacture, decoration, contest organization, etc. Both model rocket and high-power rocket articles are accepted.

CONTENT WE ARE NOT LOOKING FOR

We don't publish articles like "launch reports." They are nice to read, but if you don't learn anything new from them, then they can get boring pretty quick... Example: "Bob flew a blue rocket on a H120 motor for his certification flight." As mentioned above, we're looking for articles that have an educational component to them, which is why we like "how-to" articles.

You can see what articles and topics we've published before at: **https://www.apogeerockets.com/Peak-of-Flight?pof_list=archives&m=education**. You might use this list to give you an idea or two for your topic.

Here are some of the common articles that we reject all the time, because we've published on these topics before:

- How to get a L1, L2, or L3 Cert
- Building cheap rockets and equipment (pads & controllers)
- How to 3D print parts, or a Rocket Kit
- How to Build a cheap Rocket Kit
- Getting Back Into Rocketry After a Long Hiatus

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format, or as plain-text. Graphics should be sent in either a vector format (Adobe Illustrator, SVG, etc.) or a raster format (such as jpg or png) with a width of at least 600 pixels for single column images or 1200 pixels for two-column images. It is preferable for images to be simple enough to be readable in a two-column layout, but special layouts can be used.

Send the images separately via email as well as show where they go by placing them in the word processor document.

ACCEPTANCE

Submitted articles will be evaluated against a rubric (available here on our website). All articles will be evaluated and the results will be sent to the author. In the evaluation process, our goal is to ensure the quality of the content in *Peak-of-Flight*, but we want to publish your article! Resubmission of articles that do not meet the required standard are heavily encouraged.

ORIGINALITY

All articles submitted to Peak-of-Flight must not run in another publication before inclusion in the *POF* newsletter, but it may be based on another work such as a prior article, R&D report, etc. After we have published and paid for an article, you are free to submit them to other publications.

RATES

Apogee Components offers **$300** for a quality-written article over 2,000 words in length. Payment is pro-rated for shorter articles.

WHERE WILL IT APPEAR?

These articles will mainly be published in our free newsletter, *Peak-of-Flight*. Occasionally some of the higher-quality articles could potentially appear in one of Tim Van Milligan's books that he publishes from time to time.





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