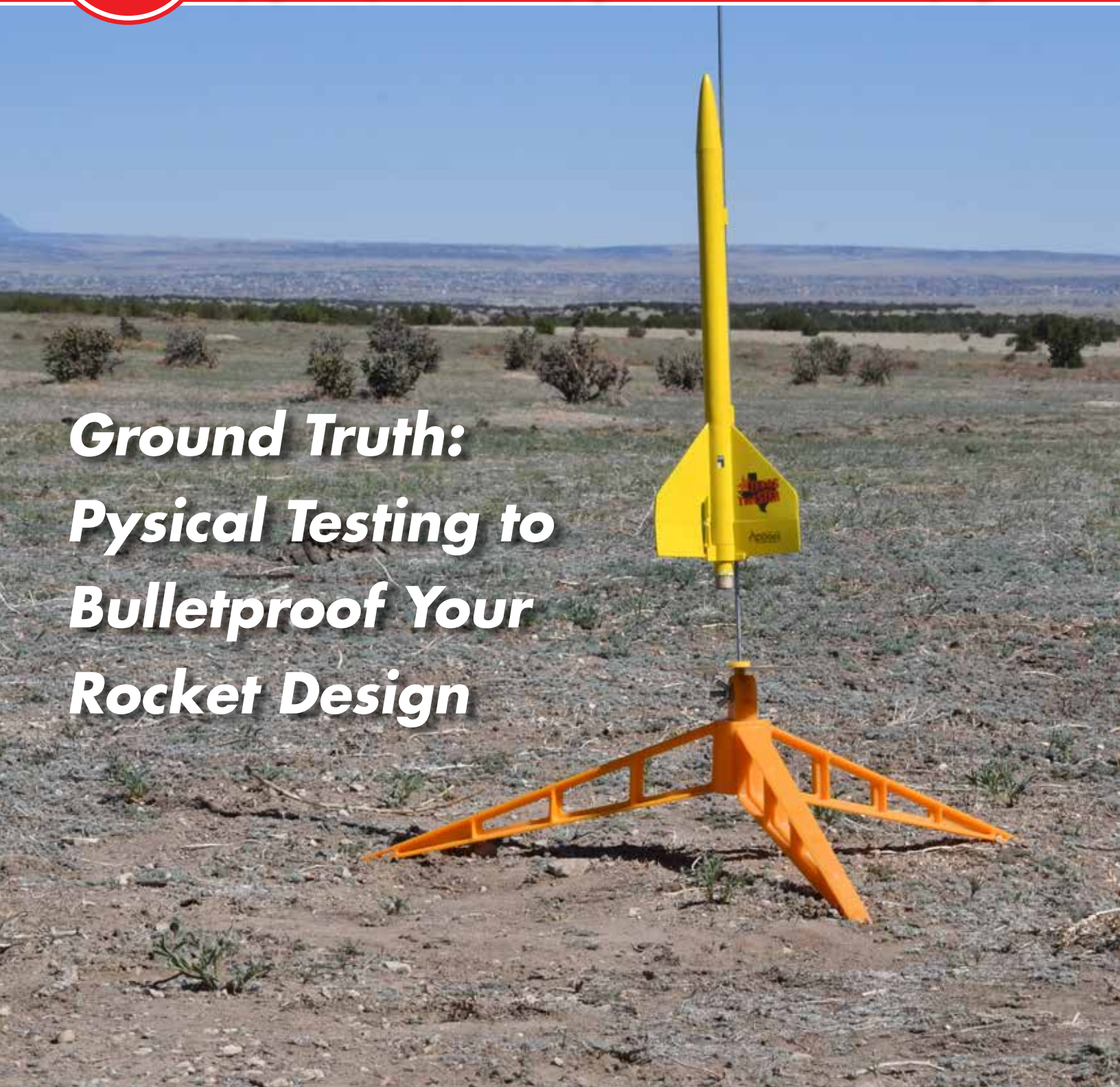
Issue 677 / April 28th, 2026

# PEAK OF FLIGHT NEWSLETTER

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



## Ground Truth: Pysical Testing to Bulletproof Your Rocket Design

PEAK OF FLIGHT NEWSLETTER

Issue 677 / April 28th, 2026

## COVER PHOTO



### Apogee Texas Twister

The Texas Twister is a unique helicopter recovery rocket that is enjoyable to build and exciting to fly. The kit features precut kraft paper tubes, die-cut balsa fins, an injection molded high-impact polystyrene nose cone. It is truly worthy of joining your rocketry fleet. Check it out!

## FEATURED ARTICLES



### Ground Truth: Physical Testing to Bulletproof your Rocket Design

When equations fall short on parachutes, 3D prints, and custom composites, hands-on experiments prove your design's mettle. This guide walks rocketeers through the scientific method—from observing failures to crunching stats on shear pins and drag coefficients—ensuring safer flights and fewer lawn darts..

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PEAK OF FLIGHT NEWSLETTER
Ground Truth: Physical Testing to Bulletproof Your Rocket Design
by Alex Magee
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# Ground Truth: Physical Testing to Bulletproof Your Rocket Design

By Alex Magee

This is part the continuation of my article from *Peak-of-Flight Newsletter #676* (https://www.apogeerockets.com/Peak-of-Flight/Newsletter676). For those of you who didn't read the first part, called *"Forces Inside Your Rocket"*, in that article we covered how to apply mathematical tests—like shear, compression, tension, and bending loads using the Johnson-Euler buckling formula—to verify if your rocket design was safe for a given motor, complete with factors of safety and real-world examples from L1 attempts. However, sometimes there are things you can't do the math for, such as parachutes, homemade composites, 3D prints, and electronics. For the physical parts I mentioned, the strength values change wildly based on construction practices, printer settings, and extraneous factors. Even for less complicated components, reliable material properties may be difficult to obtain. Other times you or other stakeholders (your certification officers or RSO) may question the math. For electronics, they are just complicated and often need troubleshooting. In all of these cases, you need some demonstrable test to show that something actually works, like ground testing. Since many reading this will know how to do ground testing, it provides a good example to illustrate the basics of experimental design and the scientific method.

## From Calculations to Crash Tests: When Math Isn't Enough

Experimental design comes from the scientific method. In the scientific method, we observe something, ask a question, form a hypothesis, design and perform an experiment, analyze the results of the experiment, then report a conclusion/take action. A long time ago, when dinosaurs like your grandfather roamed the earth, someone observed one too many lawn darts. They asked a question, why did the parachute not deploy? They formed a hypothesis that there was not enough black powder to pop the rocket open. They designed a test where they put the rocket on its side and test fired the deployment charges. The rocket didn't open and they then found that they did, in fact, not use a large enough deployment charge, so they decided to put more in when they flew the rocket.

Now that we have seen the steps of a good test like ground testing, let's see how we can apply it to other parts of your rocket design.

## Step One: Observe Something

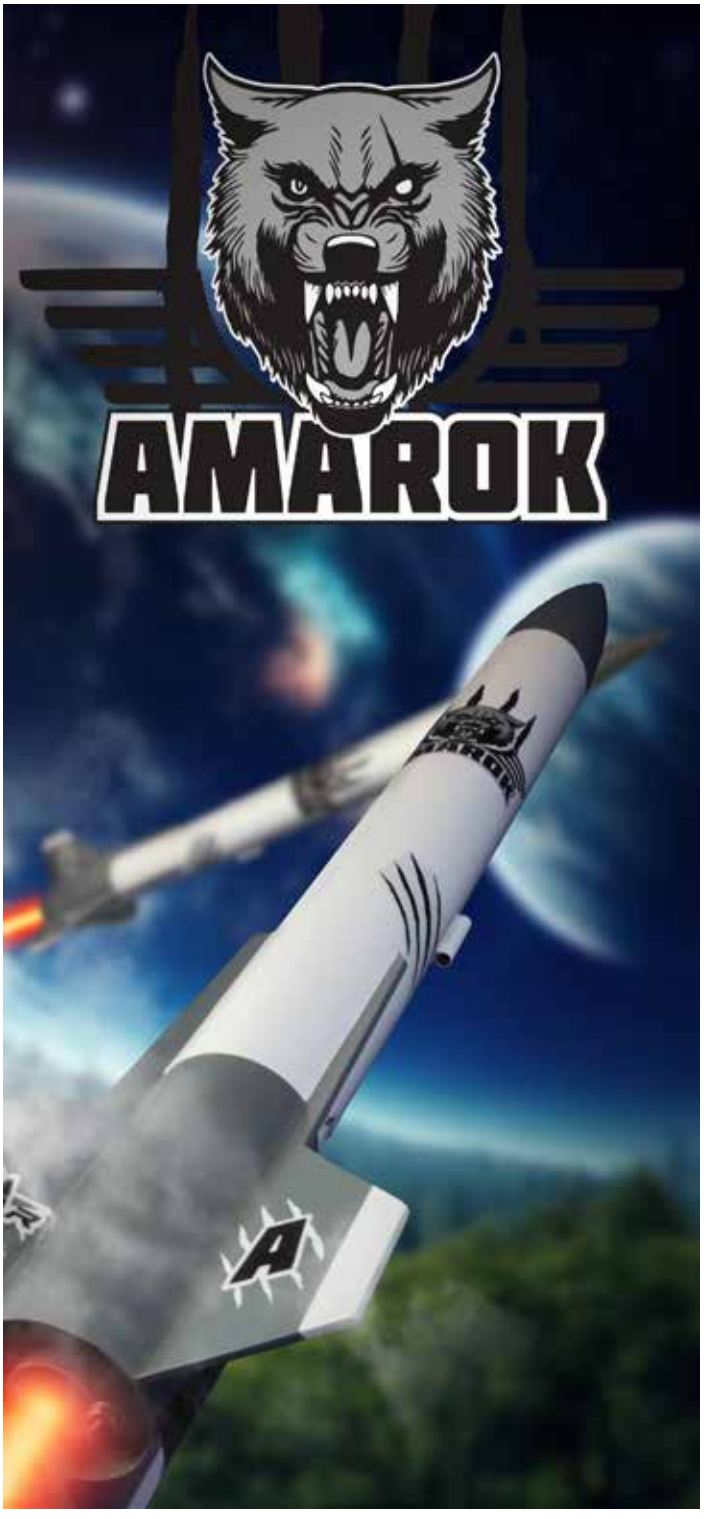




**Figure 1 - Top: My L3 cert rocket, the Proton, set up for ground testing. Bottom: The rocket after I tested the main charge. This test was successful because the parachute came out.**

This step is pretty easy. Find something that doesn't consistently go right in your rockets. But, as a proverb goes, "A smart man learns from his mistakes, a wise man learns from the mistakes of others", so look at other people's flights to find things that might go wrong in your rocket.

To practice, let's look at figure 2. There is a missing fin and cracked body tube. Looking even closer, it appears that the tail cone is warped. We also don't see a nose cone or parachute, so it's possible the shock cord snapped. Each of these things could have caused the demise of this rocket and may be worth experimenting with.

## Step Two: Ask a question and form a hypothesis

I put these two things together because a hypothesis is your guess answer to your question. This step is a little harder than step one because some questions will lead you down the correct path to finding the solution and reveal more than you thought about the issue observed, while others won't help at all. For example, let's



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# Ground Truth: Physical Testing to Bulletproof Your Rocket Design

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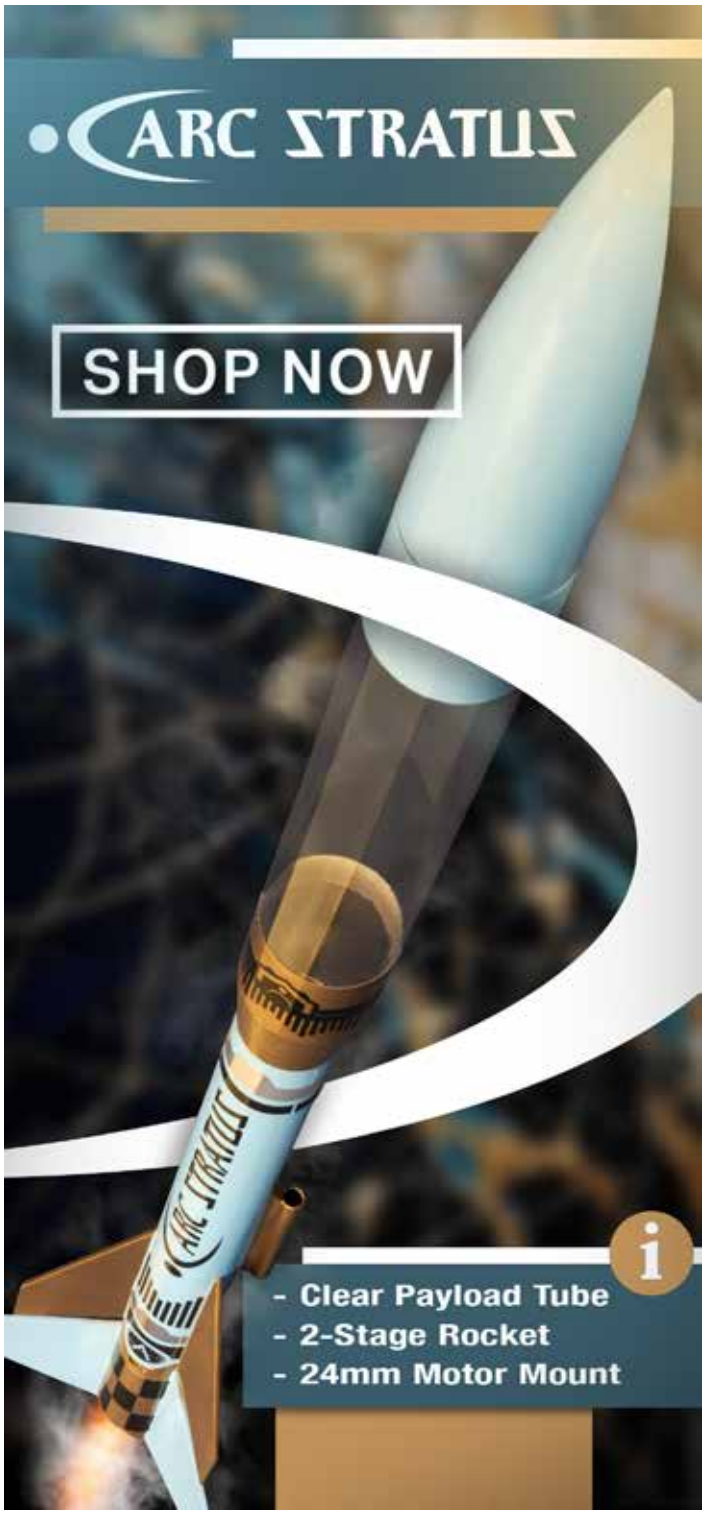





**Figure - A failed rocket launch.**

say you find your rocket in three or four pieces when it hits the ground. You ask the question, “If I glue the bulkhead on better, will it stay together on the next flight?” This leads to the hypothesis, yes, a better attachment for the bulkhead will in fact keep your rocket safe and sound. (This may or may not have happened to me once). This might have been a problem, but the real issue was that you used double the amount of black powder that you should have. (Once again, may or may not have happened to me). In this scenario, you will expend a lot of effort working on finding ways to fix your bulkhead when in reality something else will break with the amount of black powder you used, regardless of how you improve the bulkhead.

## Step Three: Design an Experiment/Test

This is a tricky step. Flying your rocket is obviously testing it, but it is not very helpful to test all of the parts at once. Doing this will not isolate your hypothesis and could lead to some confounding of results. Ground testing is closer to “good” experiment/test. In a ground test, you test if your electronics coupled to the charges can break the shear pins. However, the problem can be with the computers, the charges, with how you tried to set off the charges, or the shear pins. With all these confounding effects, it can be difficult to isolate the true problem. An example of a very good test is testing to see if your shock cord is strong enough for your rocket. This isolates one component, the shock cord, and therefore any

issues that arrive in testing are very easy to identify and correct.

Once we have isolated the thing we want to test, we need to make a test that mimics the conditions that part will experience. This step brings us back to the math and some simulation data that we discussed in part one of this series. Let's say I have decided to test if my parachute will survive deployment one or two seconds early. I could do that by attaching a 50 lb weight to the parachute and throwing it off a deck. But is that reasonable? Maybe, maybe not. If it is an Estes kit, this is a little overkill. If it is an L3 attempt, it may not be sufficient. So, we need to look at the simulation data. (Just a side note on this, I speak from experience testing parachutes by attaching a weight to them and throwing them off high things like decks. I once ruined a parachute by using the wrong weight.)



**Figure 3 - A parachute test. If you time the drop and weight the set up, you can get a drag coefficient for the parachute.**

Let's say the kit you are flying the parachute on is a scratch-built rocket designed for mid power flights. From your RockSim file, you see that it will be going about 11 m/s or 25 MPH at about 1 s before apogee. Now you know when you test your parachute for this condition, it should be going about 25 MPH. Going back to the idea where you throw the parachute off your deck with a weight attached, this will only get your parachute to 9.5 m/s if your deck






is about 12-15 ft off the ground. Therefore, this is not a realistic testing condition and will not help you know if your parachute is going to survive coming out 1 s too early.

An alternative option to testing the parachute at the appropriate speed is tying it to the roof rack of your car, finding an empty stretch of road, and driving at 25 MPH for a few seconds. This could reasonably recreate the speeds and forces the parachute will experience and, if timed properly, will also provide those forces for the same amount of time in flight.

### Here are some ideas for testing other rocket components:

For nose cones, drop them from an appropriate height onto the ground (pick either thin carpet of dirt). This can help simulate the impact it will have when it lands. I did this for the 3D printed nose cone I used for my L3. The first one shattered to pieces so I knew I had to go back to the drawing board.



**Figure 4 - This is my first nose cone attempt after it was "tested" by which I mean I accidentally knocked it off my rocket and it fell onto concrete. It shattered (notice the tip is missing too), so I had to print a new one, but I'm glad it didn't happen during my cert flight.**

For testing body tubes and tail cones, stack dumbbells on them until an appropriate weight is reached. To test for zippering, lay your body tube on a table with about 1 inch of the tube over the edge. Run your shock cord through your body tube so about 1 ft of it is dangling out of the body tube (see Figure 6 on page 9). Tie weights to the shock cord until you have reached the same amount of force your parachute will provide. If the tube tears, then you probably need to reinforce the area where the shock cord contacts the body tube, possibly using an Apogee Zipper Shield.

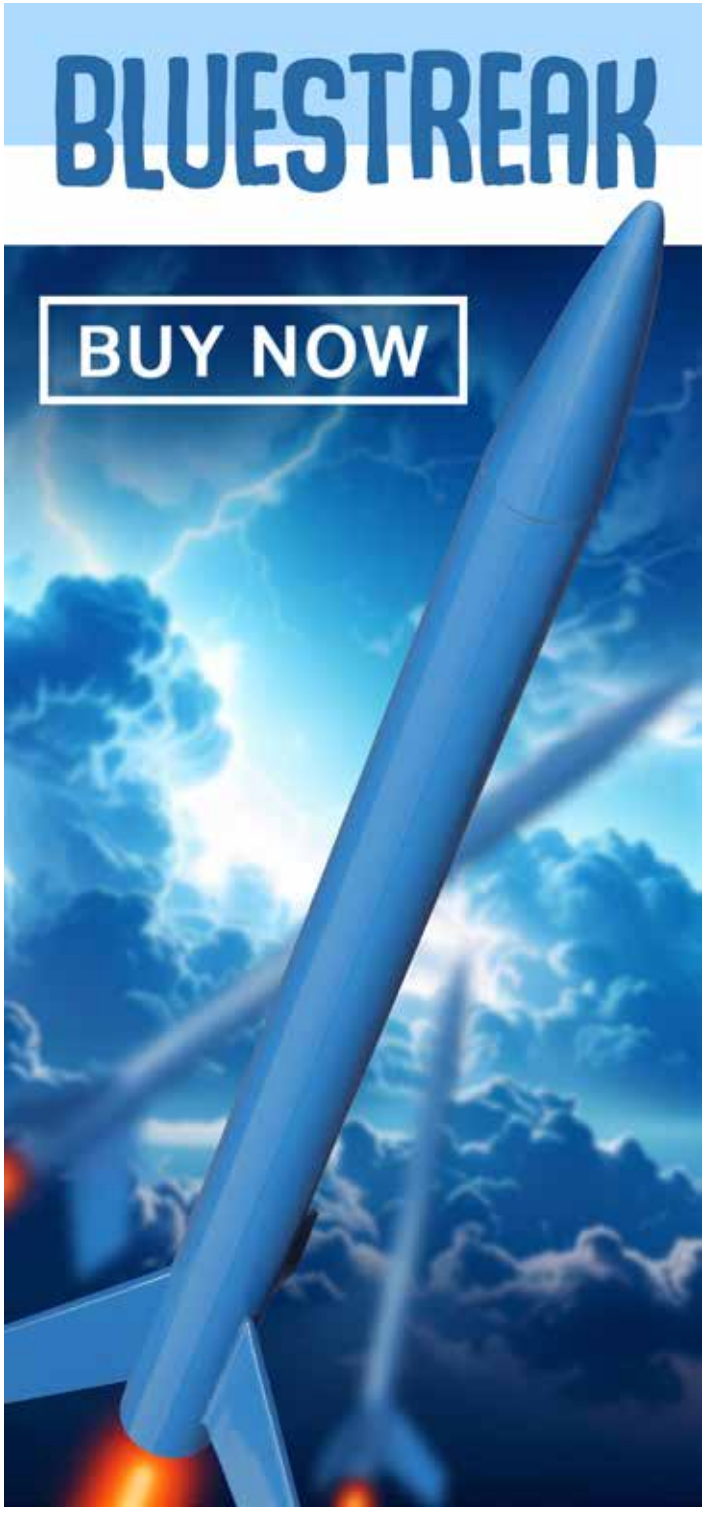
### Step Four: Analyzing Results



**Figure 5 - After that rough experience breaking my nose cone, I decided I would test the new version.**

Analyzing the results of your tests can be anywhere from extremely easy to somewhat difficult and misleading. Going back to the parachute test, if your parachute doesn't break when you deploy it, you know it will do the job and that's that. Questions start to arise when you repeat the experiment and on the second or third trial something fails. This fact alone is why it is important to do repeated tests because you never really know if your component passed the test due to dumb luck or if it is really resilient to the conditions it will experience in flight. The good news is that there are some nice statistical methods to help you make the most of whatever results you get from your tests.





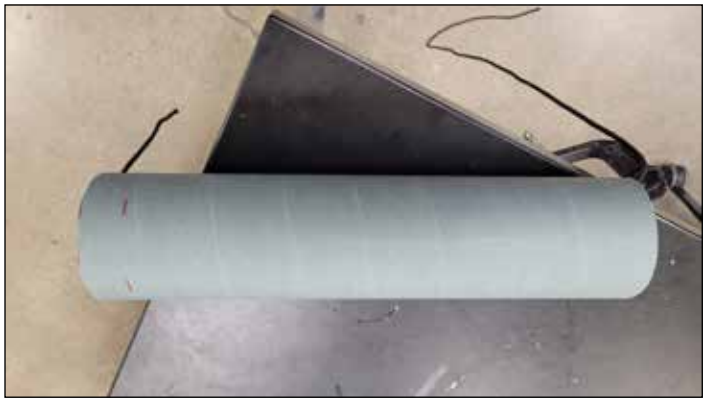



**Figure 6 - A zipper test set up without the weight. The body tube section and shock cord are secured by the clamp on the right, so they don't move.**

## Numerical Analysis

The first thing you probably want to know about your tests, especially if you choose to test a component to failure, is the uncertainty of your tests. This tells you the range of values you can expect from similar components under the same testing conditions. One personal example is when I started printing my own shear pins from PLA to use for my L3 cert flight. My certification advisors as well as some of my friends were rightfully suspicious if they would actually work, especially because the bonding between layers in a 3d print is very dependent on printer settings. So, I designed a test for these shear pins by putting them through two plates and using the pin to suspend some weights by putting a Kevlar cord over the pin in the space between the plates. I then progressively increased the suspended weight in 5 lb increments until the pins failed. The pins would break with 25 lbs but not with 20 lbs.

In this case, because the pin had two sides experiencing the load, the actual shearing would take place somewhere between 10 and 12.5 lbs. So, the uncertainty was +/- 1.125 lbs. Due to this resolution limit, even if I did 100 more tests, I wouldn't learn much more because most of the pins I would test would fall in this band, making it hard to create a good statistical distribution. The +/- 1.125 lbs was good enough for my certification advisors, but not good enough for one of my friends who still decries the use of 3d printed shear pins.

Uncertainty gets more dicey when there are multiple contributing factors. Going back to the shear pin example, let's pretend that 5% strength of the shear pins depended on how quickly they were loaded and another 5% depended on how long they had been holding the load. Our original uncertainty based on the resolution was +/-10% (1.125/11.25 = 10%). To combine the uncertainty,

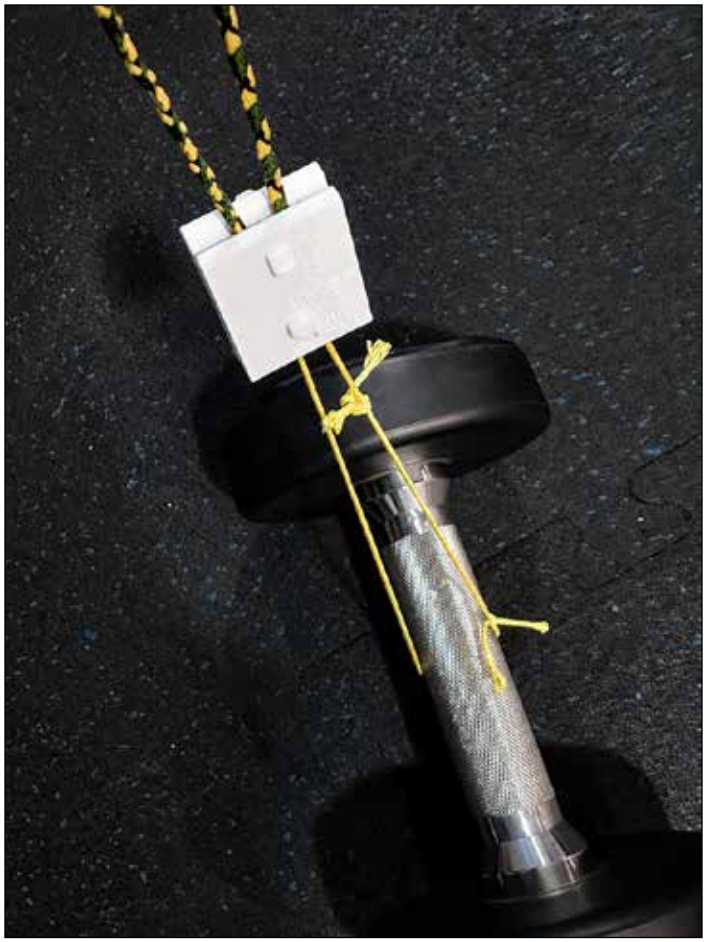


**Figure 7 - A shear pin test for my 3d printed shear pins.**

we take the square root of the sum of the squares of each factor contributing to uncertainty. In this case, the uncertainty comes out to 12.2%, or +/-1.38 lbs. This is still low enough that with good ground testing there won't be a problem with using these pins, but for more sensitive components this can be risky.

Now let's suppose we had much lower uncertainty in our tests and we were trying to determine the drag coefficient of a new parachute. The Peak of Flight Newsletter No. 662 goes into great detail of how to do this, although simpler means are possible using a small weight attached to a parachute, dropping it from a fixed height, and recording how long it takes to hit the ground. After 5 tests, we get drag coefficient values of 0.6, 0.8, 0.63. 0.75, and 0.66. It can quickly be determined that the mean and standard deviation of the drag coefficient are 0.688 and 0.084 respectively.





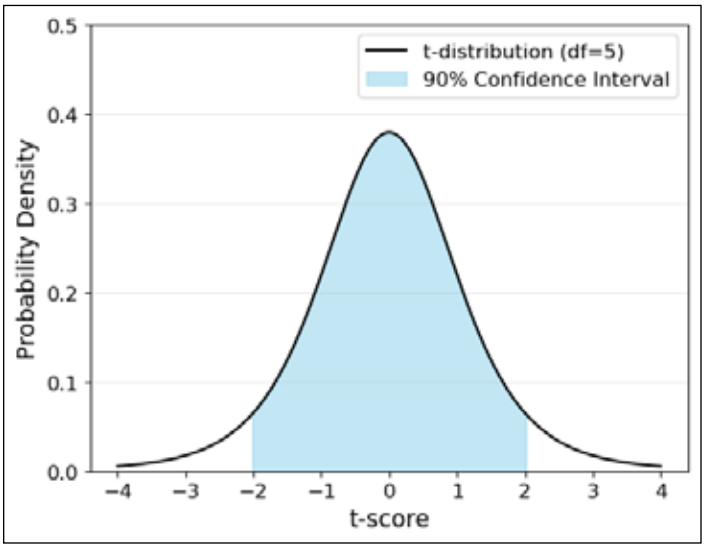




**Figure 8. A basic t-distribution. The t-score corresponds to standard deviations from the mean of the sample, and the mean of the sample always has a t-score of 0.**

But what does this actually mean? This is where the t-distribution comes in. The t-distribution is a statistical model that can help us determine what range of drag coefficients we should prepare for when using the rocket. It works for small sample sizes, helping us deal with the inherent uncertainty that comes with limited testing.

The t-distribution has three input parameters: the mean, the standard deviation, and the degrees of freedom. When we are creating a t-distribution for a mean, the degrees of freedom is always one less than the number of tests, in this case, 4. To find the range of drag coefficient values our parachute may have, we look for the two-sided t-score for the relevant probability. For 90%, this value is 2.13 and for 95%, this value is 2.78. We multiply the t-score by the standard deviation and then subtract and add this value from the mean to get the bounds for the value of interest. In this case, there is a 90% probability that the drag coefficient of our new parachute is between 0.509 and 0.867 and there is a 95% probability that it is between 0.454 and .922. Clearly, that is a wide range for the drag coefficient! If we want tighter bands, we can lower the t-scores used by doing more tests. In this case, if we do a 6th test and find a drag coefficient of 0.73, with the new t-scores and standard deviation, the 90% range becomes 0.540 to 0.850 and the 95% range becomes 0.497 to 0.893. This is a bit better than the previous ranges.

## Physical Analysis

The physical analysis after testing can also tell you a great

deal about how the test item broke and how the design can be fixed. It can sometimes require a better understanding of different material failure modes but other times can be pretty simple. When my nose cone broke (the one in figure 4), it was pretty clear that the weakest spot was at the shoulder. It was also clear that it suffered a brittle failure from the jagged edges of the cracks and absence of whitening. This was shocking because PETG is generally ductile even with carbon fiber reinforcement. This physical analysis revealed I should choose a tougher material and reinforce the region surrounding the shoulder.

Another example of doing a physical analysis came from a parachute test. The parachute came down mostly okay, but further analysis showed that the stitching of the shroud lines was coming apart. This showed that the issue was in a different location than I expected, normally my parachutes have had the fabric tear and not the stitching.

### Step 5: Taking Action

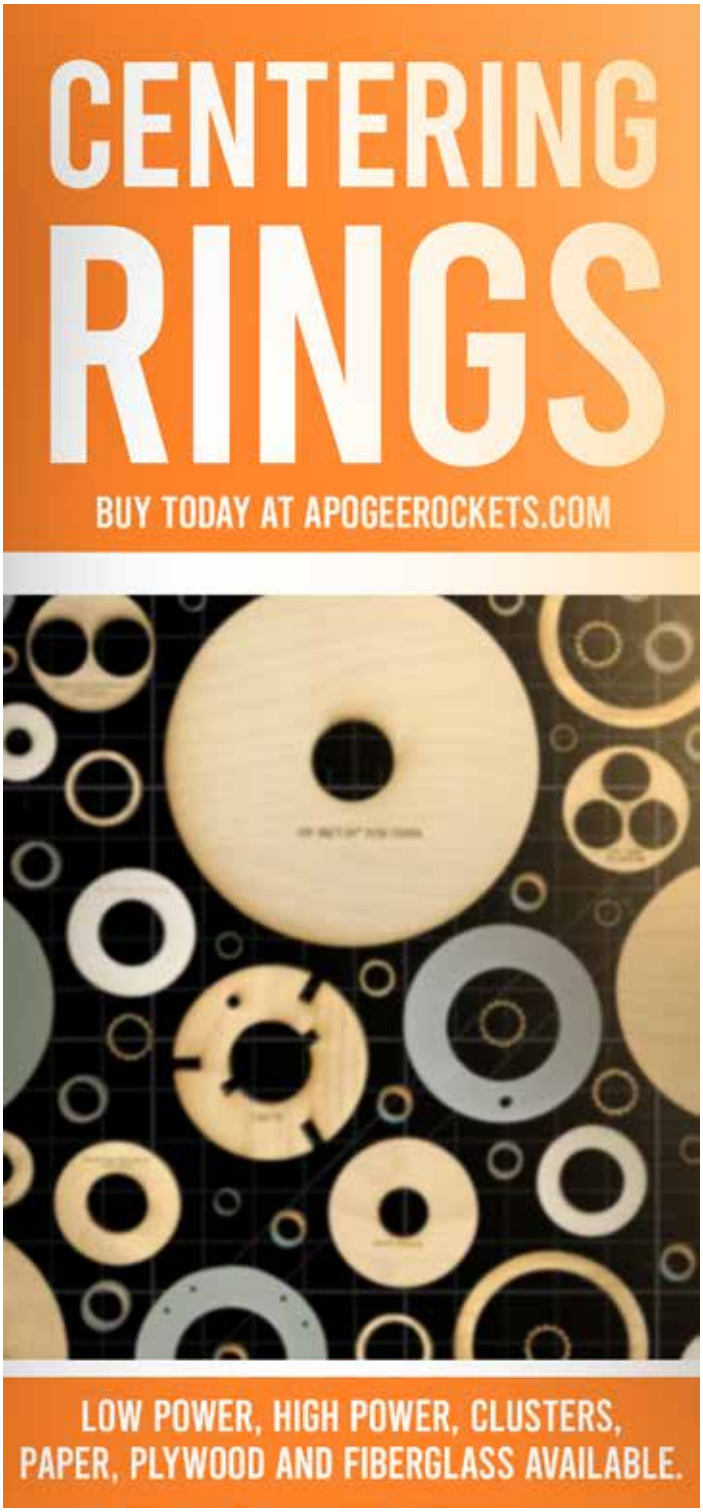
Taking action is simply applying what you have learned from your test. This can be as simple as adding some reinforcement to weak areas or can go as far as completely changing your design. From the results of my accidental nose cone test, I decided to remake the nose cone out of an entirely different material, Nylon GF, and I made the shoulder a bit thicker to avoid future failures. The key here is to do something. If you know something won't work, it is most definitely worth the work to fix it.



**Figure 9 - My first L3 cert attempt unfortunately ended with a zipper. Looking at it as a test flight, I concluded that I should wrap it in fiberglass to prevent future zippers.**

### Conclusion:

We all want to have successful rocket flights. Unfortunately,






there is a lot of uncertainty, especially in our homemade parts. To have success with these parts requires a bit of experimentation and testing the components before we put them into our rockets. By doing effective tests that target previous failures you have observed, or you think may happen, you can limit the extent of the damage when something goes wrong. This keeps the hobby safe and saves your rockets, so you can keep pushing the limits of what's possible.

## About the Author

Alex Magee, has been flying model rockets ever since his parents gave him one when he was six. He currently lives in Provo, Utah and attends Brigham Young University where he is studying mechanical engineering. He has a part time job researching heat transfer in ablative materials and when he is not working on his next rocketry project he is out riding his bike or swimming.



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# Article Submission Guidelines

## 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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