Issue 622 / March 26th, 2024

PEAK OF FLIGHT NEWSLETTER

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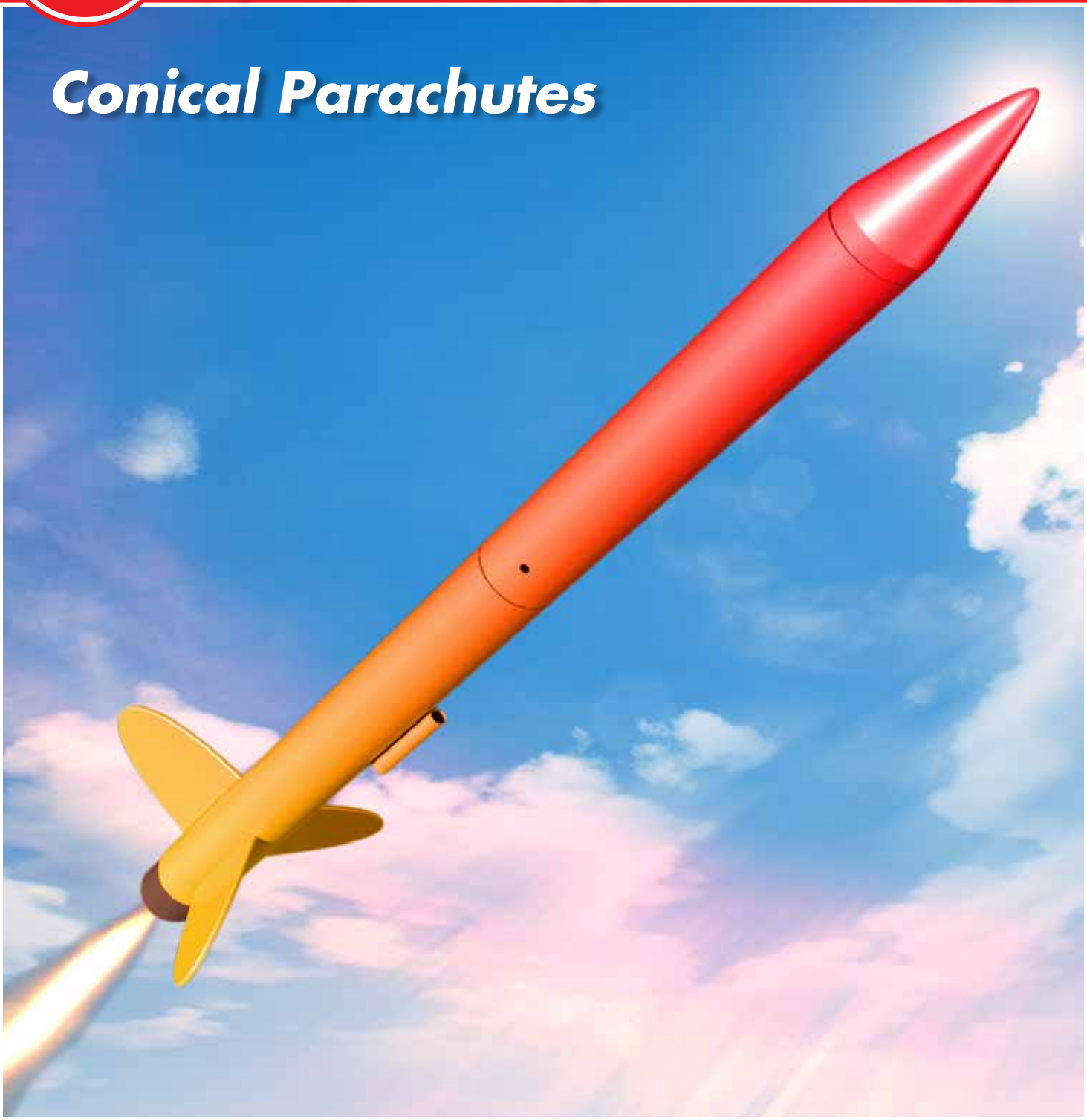
Conical Parachutes



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COVER PHOTO

Frit -single stage payload

The "Frit" rocket is a contest model designed for the Payload-Altitude event. It is a simple, single stage rocket that set an altitude record the first time it was launched in competition, shattering the old record by 180 meters. It is designed specifically for the NAR's competition event where the object is to boost a 1 ounce payload as high as possible. Use in "C" engine class for flights over 350m (1150 feet). Can also be used in "A" and "B" motor contests, especially when the day is breezy.

FEATURED ARTICLE

Conical Parachutes

by Dave Flanagan

Parachutes are vital components of rocket kits, yet many are still using outdated designs like the "flat circular" canopy. This article explores the transition from traditional flat circular parachutes to the more efficient conical design, providing insights into crafting model conical parachutes using readily available materials and simple techniques.

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The Hermes HLV rocket flying off the launch rail at the SCORE event in Pueblo, Colorado 11/18/2023.
photo credit: Martin Jay McKee

Would you like to see your launch photo featured in the *Peak-of-Flight* newsletter? To submit photo: https://www.apogeerockets.com/Contact

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Conical Parachutes

by Dave Flanagan

Introduction

The parachutes supplied with most low power and some medium power rocket kits (a.k.a. "kit chutes") belong to a class of parachutes called "flat circulars." This is the simplest type of parachute. In the full scale parachute world, with few exceptions such as some military cargo chutes, it is obsolete. Many parachutes are now based on a cone shaped canopy rather than a flat canopy.

The conical parachute was developed by the military from the common flat circular parachute shortly after WWII. The process involved removing pie shaped gores from a flat parachute canopy one at a time which created an increasingly conical shape. Each new configuration was tested to see if there were advantages in terms of drag or stability. It turned out that at a certain point the conical parachute did indeed have a higher drag coefficient than a standard flat circular parachute. Values greater than CD= 0.90 were reported whereas the drag coefficient of the original flat circular parachute topped out at CD=0.80. The conical parachute also oscillated less during descent. Conical parachutes weighed less, required less material to manufacture, and packed up smaller than their flat counterparts (1). As a result the United States Navy incorporated the design into a widely used emergency personnel parachute in the 1950's. Modern civilian manufacturers of emergency parachutes for aviators have also abandoned the old flat circular design in favor of the conical parachute. It is also common in aerospace applications. For example the Shuttle Solid Rocket Boosters were all recovered using conical parachutes of a particular type. The conical parachute is truly superior. I personally have had to use both flat circular and conical parachutes during emergencies and the conical parachute wins flat out.

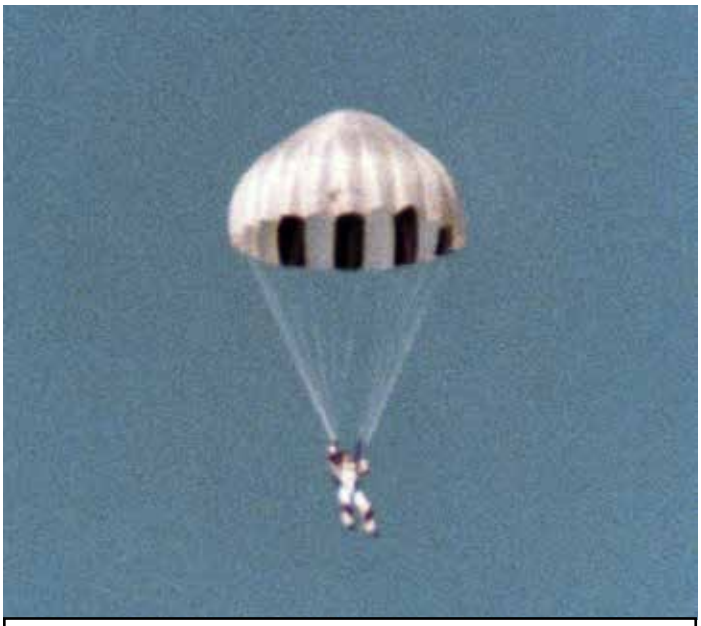

Figure 1. A modern conical parachute is shown in use. Photo C. A. Hitchens, used with permission

The Model Conical Parachute

There is no need to know anything about the geometry of cones to build a model conical parachute – there is a shortcut. Most modelers know how to make transition shrouds or boat tails that adapt a rocket airframe from one body tube diameter to another. (See reference 2 for a refresher if needed.) The model conical parachute shown here uses exactly the same approach. The main diameter of the parachute (D_O) corresponds to the larger airframe diameter, and the diameter of the parachute apex vent ("spill hole") corresponds to the diameter of the smaller airframe diameter.

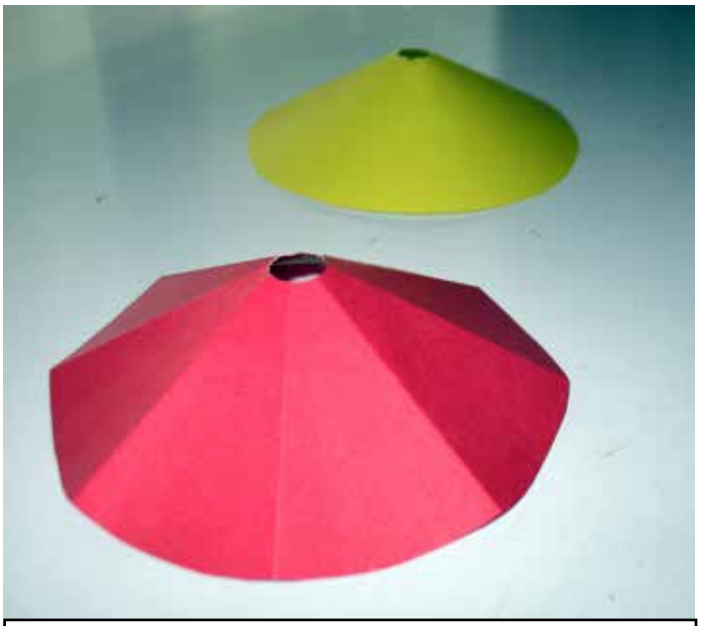

Figure 2. Cardboard models of a geometric cone or shroud (background) and a cone showing how the parachute gores can be developed from a geometric cone (foreground).

Scale data for the shroud (canopy) is provided in Table 1. The selected diameter (D_o) of the parachute (at the base of the cone) is the reference dimension for scaling. The value for ϕ (phi) is constant for this design, but can be varied (see the Extra for Experts section).

Scale Data	
r_1	$0.058D_o$
r_2	$0.577D_o$
ϕ	311°

Table 1. Scale data for a conical parachute.

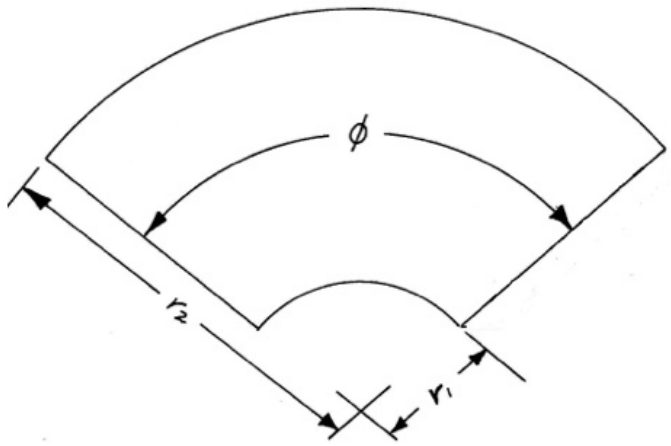

Figure 3. Canopy/shroud dimensions – see Table 1.

Making a Model Conical Parachute

Materials

Conical parachutes can be made from polyethylene material such as garbage bag plastic or canopies supplied with a kit chute. Joining the gores is done with "invisible" or "transparent" tape although this does make smaller parachutes a bit bulkier. Shroud lines made of fuzzy kite string can be taped into place, or lines may be tied to holes with adhesive reinforcements the same way it is done with some common kit chutes.

Regular parachute materials (nylon fabric and synthetic suspension line material) and standard parachute construction techniques may be used to make larger models. It is easier to sew together a conical parachute than a shaped parachute like an elliptical since there are usually fewer seams and most of them are straight. Reference 3 describes how to sew nylon parachutes used to recover amateur rockets.

Method

The first step is to create a gore pattern. The gore pattern is just part of a transition shroud. The value of phi shown in Table 1 is ϕ=311°. To make a complete shroud for a rocket airframe transition shroud all 311° would be required. But to make gore pattern for a conical parachute canopy of, for example, four gores the value of phi (ϕ) just needs to be one fourth of that 311°, or about 78°. Note:

The minimum recommended number of gores for a model conical parachute is four ($n \geq 4$).

Trace out the gores on the canopy material. Be sure to leave a "seam allowance" for taping or sewing the gores together.

Figure 4. The gore pattern (center) and the four gores used to make a D_O=30 cm conical canopy. The material is garbage bag plastic. Note the seam allowance at the edge of each gore. To make the pattern the value of phi (φ) from Table 1 was divided by four.

Figure 5. The canopy for a D_O=30 cm conical made from four polyethylene gores taped together with transparent tape. Notice how the canopy is a cone and cannot be laid flat.

Figure 6. A nylon conical canopy sewn from six gores is shown. Here D_O = 50 cm. To make the gore pattern (not shown) the value of phi (φ) from Table 1 was divided by six.

Once the canopy is done it is simple to add the suspension lines equidistantly around the circumference of the canopy. The more suspension lines the better (use at least eight). Using too few lines makes the canopy less conical. Line length is equal to the selected diameter, D_O.

Figure 7. Toss testing the D_O=30 cm conical canopy. When possible it is always good to toss test a new parachute design before flying it.

Figure 8. The completed D_O=30 cm conical canopy recovering an Apogee Wayfarer.

Figure 9. A D_O=50 cm conical parachute made from an Apogee kit chute canopy. Eight gores were used to make this canopy so the value of phi (φ) from Table 1 was divided by eight to make the gore pattern.

Figure 10. The D_o=50 cm conical parachute recovering a scratch built BT-80 model

Extra for Experts

The research described earlier that led to the Navy's parachute design was done with parachutes made from the materials available at the time. These fabrics were generally very permeable compared to modern parachute fabrics. In many cases the fabric was so permeable a person could actually breathe through it. Using modern impermeable material (polyethylene sheet or modern nylon fabrics) will very likely produce very different parachute performance.

There are two variables besides permeability that can also affect the performance of the conical parachute. One is called "geometric porosity." It is defined as the area of all the material removed from a canopy to the area of the entire original parachute. Geometric porosity is so important to parachute performance it is given its own symbol – a lower case Greek letter lambda (λ). The range of lambda is from zero to one. A value of λ=0 means none of the parachute canopy material is removed and a value of λ=1 would mean all the canopy material is removed.

The apex vent ("spill hole") is the only part of the canopy removed in the design of a conical parachute. Therefore the geometric porosity controls the diameter of the apex vent D_V. When the canopy and the apex vent are both circular as they are with the conical parachute the following equation holds.

$$D_v = \sqrt{\lambda} D_o$$

In the conical parachute described above the porosity is set at λ=0.01, or one percent. But is that the best value when modern parachute materials are used? No one knows.

Figure 11. An Apogee 12"/15"/18" canopy used to make an experimental D_O=30 cm conical parachute. Here the size of the apex vent is increased to give a geometric porosity of λ=0.025. Note the design data taped to the gore pattern. Keeping good notes and records is important in any research.

The other variable of interest is called the cone angle. It is the angle of the slope of the cone with respect to the horizontal. It too is given a special symbol – the lower case Greek letter "mu" (μ). See Figure 12.

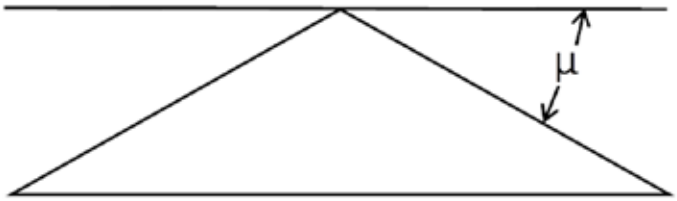

Figure 12. The cone angle as described in reference 1.

A value of 30° was used as the cone angle in the simple model described above (μ=30°). Based on the original WWII era tests this is roughly the cone angle giving the best performance. But again, those test parachutes were built with very permeable materials. A different value for cone angle might produce even better performance when parachutes are built with impermeable materials. Again, no one knows.

The shroud formulas in Table 1 can still be used to make gore patterns for test parachutes, but in slightly different forms to include the variables of interest, λ and μ.

$$r_1 = \frac{\sqrt{\lambda}\, D_o}{2\cos\mu}$$

$$r_2 = \frac{D_o}{2\cos\mu}$$

$$\varphi = 360 \cos\mu$$

Perhaps a model like the simple one described at the beginning of this article (μ=30°, λ=0.01) can serve as a baseline or "control" model. Then other identical models can be made but with different values for μ and λ. Simple tests may be done by dropping the control chute and the experimental chute side by side from a high (and safe!) place. (The total weight of the parachute systems must be equal for this type of testing.) Which one lands first? That is the less efficient one with a lower drag coefficient (CD). If there is a way to determine the rate of descent during this drop testing the drag coefficient can be estimated by using the drag equation. But the best way to determine the true performance of a test parachute is to actually fly it. Determining the drag coefficient of a parachute in several different ways is thoroughly covered in reference 4.

Can you do better than the U.S. Navy? Maybe!!!

REFERENCES

1. Knacke, T.W., Parachute recovery systems design manual, NWC-TP-6575, March 1991.

2. Van Milligan, T., *Model Rocket Design and Construction, 3rd Ed.*, 2008, pg. 116.

3. Riegel, S., Make a multi-gore Apollo style parachute cloth parachute, *Peak-of-Flight #491*, March 19, 2019.

4. Van Milligan, T., How to determine the drag coefficient of a parachute. *Peak-of-Flight #449*, August 8, 2017.

ABOUT THE AUTHOR

Dave is a registered professional engineer with over twenty years of aerospace experience at NASA's JSC and MSFC. He holds B.S. and M.S. degrees in engineering and a B.S. degree in science, and while at MSFC supported NASA's University Student Launch Initiative. He earned his airborne wings in the Army and holds an expert skydiver rating from the U.S. Parachute Association. Dave is an FAA master parachute rigger and has completed the AIAA Parachute Systems Technology Short Course. He is also a FAA licensed private pilot and an EAA certified ultralight pilot. Dave is retired and spends most of his time scuba diving and kayaking but does occasionally fly model rockets, usually ones recovered by really weird looking parachutes.

CROSSWORD ANSWERS

ACROSS
6. Zippering 8. Mid Power 10. Weathercocking 11. Drag Race
12. Rail Button 13. Rod Whip 17. Fin Canister 18. Airflow
20. Anemometer

DOWN
1. Landshark 2. Chuffing 3. Center of Pressure 4. Spillhole 5. Mylar
7. Hypersonic 9. Wingspan 14. Headwind 15. Burnout 16. Downdraft
19. No Joy

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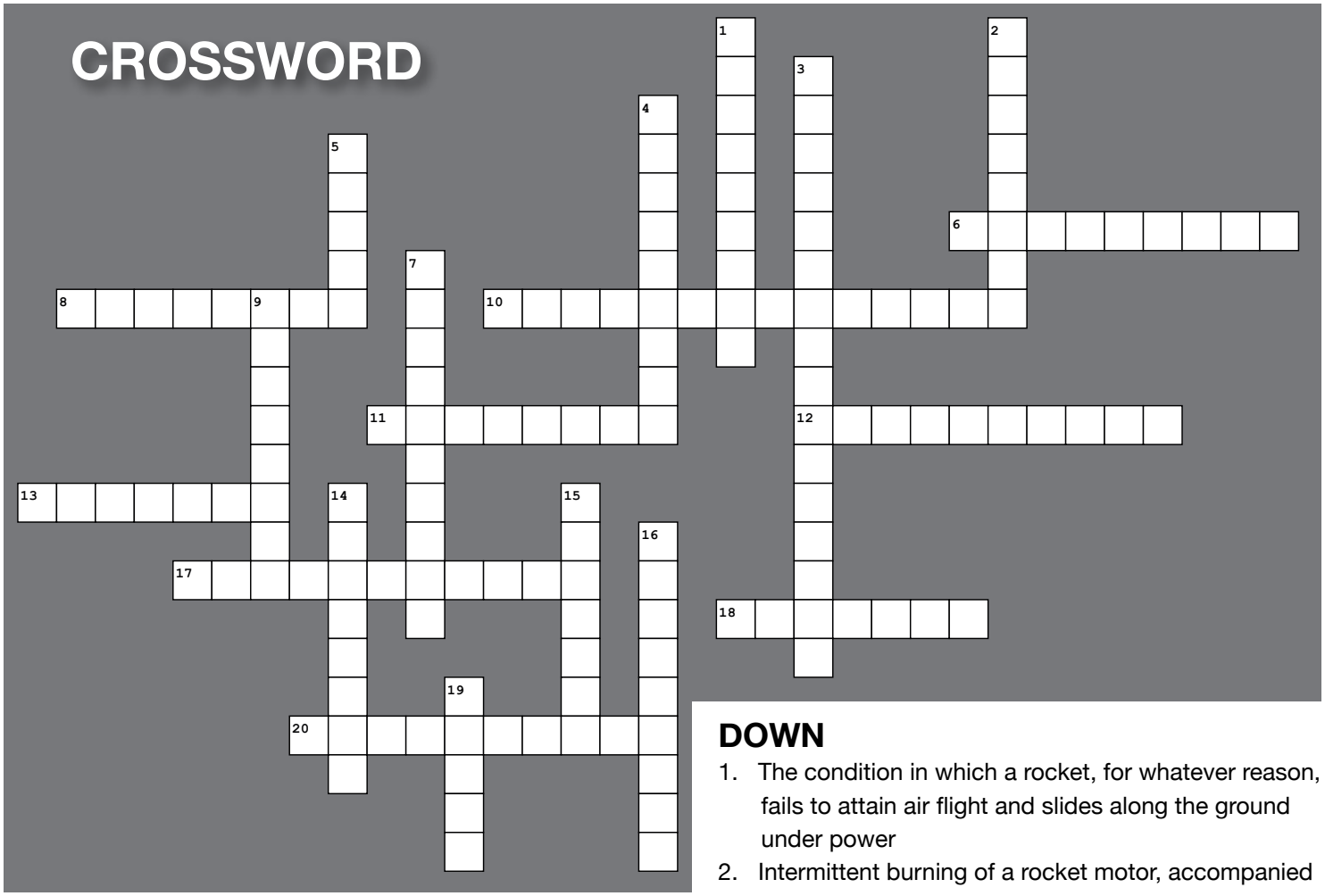
CROSSWORD



ACROSS

6. A condition in which a slot is cut in an airframe by a shock cord
8. Typically rockets flying on motors in the E to G range
10. The tendency of a rocket to fly into a breeze, altering the flight path from vertical
11. An event, usually informal, in which multiple rockets are launched simultaneously
12. A piece of plastic or metal that mates with a Launch Rail; forms a 'H' shape when viewed from the side
13. The flexing of a rod during lift-off, which may cause the rocket to head off at an undesireable angle
17. A section of tubing with fins mounted on it, intended to slide over the airframe
18. Motion of air past and around an object
20. An instrument used to measure the speed of an airflow

DOWN

1. The condition in which a rocket, for whatever reason, fails to attain air flight and slides along the ground under power
2. Intermittent burning of a rocket motor, accompanied by the sound of a steam engine starting
3. The point at which the aerodynamic lift on a rocket is centered
4. A hole in the center of the canopy of a hemispherical parachute
5. An extraordinarily strong polyester film made by DuPont; commonly used for parachutes
7. Vehicle exceeding Mach 5
9. The linear distance between the extremities of an air-foil; typically the distance between the wing tips of an airplane
14. Wind blowing generally into the front of an aircraft, thereby slowing its ground speed
15. The point at which propellant is exhausted in a motor
16. The movement of a column of cooler air downwards, opposite to a thermal
19. When a rocket motor fails to ignite

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 nice 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 more common articles that we reject all the time, because we've published on these topics before:

- How to get a L1 Cert
- How to get an L2 or L3 Cert
- Building cheap rockets
- How to 3D print parts
- Building Low Cost Launch Equipment (pads and controllers)
- Getting Back Into Rocketry After a Long Hiatus
- How to Build a Rocket Kit
- How to Build a Computer (too technical)

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format (MS Word, Libre Office, etc.) or as plain-text. Graphics, meanwhile, should be provided 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 a width of 1200 pixels for two-column images. If possible, it is generally preferable for images to be simple enough to be readable in a two-column layout, but special layouts can use the whole page width if required.

Send the images separately via email as well as showing 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 have been run in another publication before inclusion in the *Peak-of-Flight* newsletter, but it may be based on another work such as a prior article, R&D report, project 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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