PEAK OF FLIGHT

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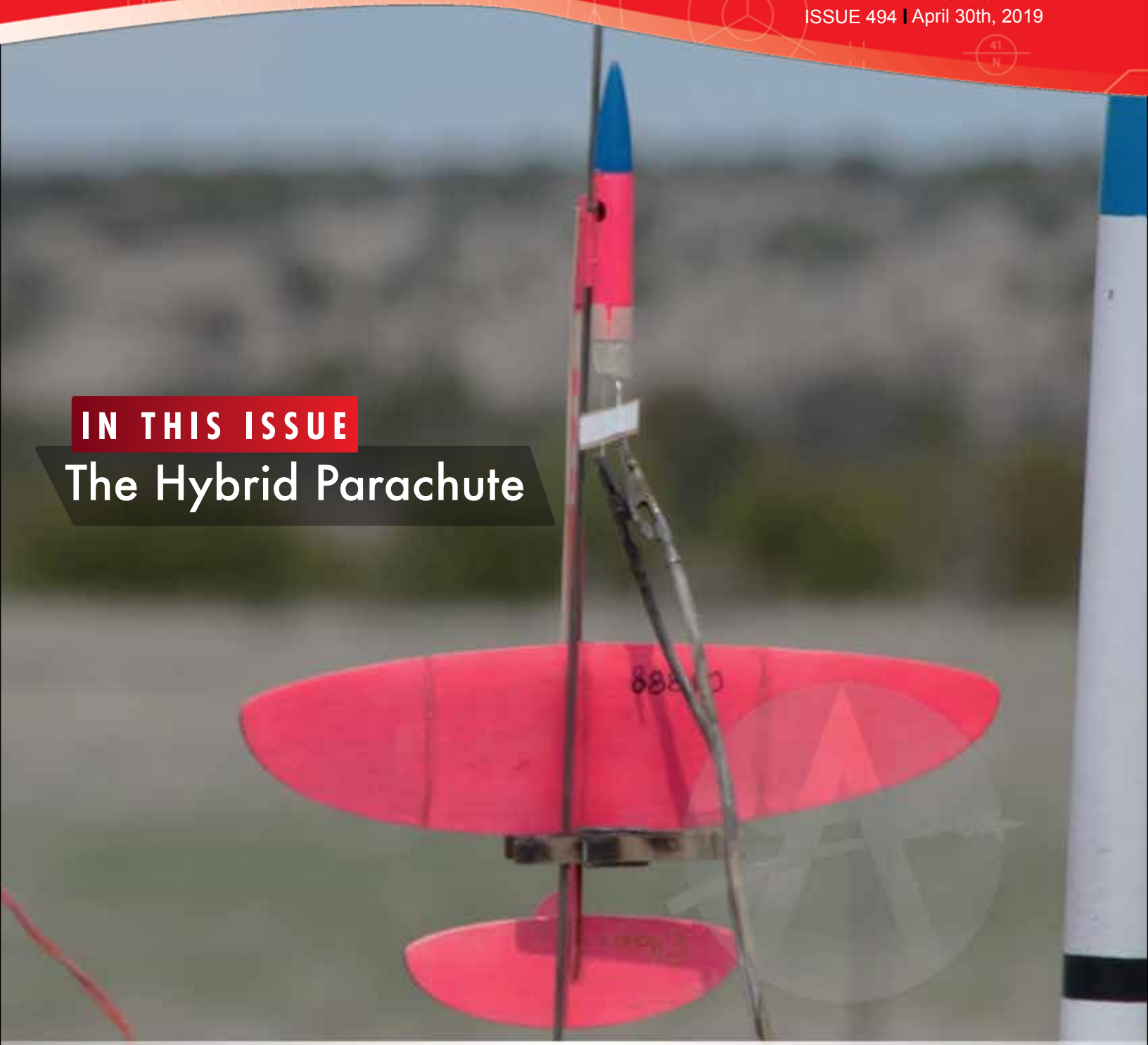

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4960 Northpark Drive Colorado Springs, Colorado 80918 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com Phone: 719-535-9335 Fax: 719-534-9050

PEAK OF FLIGHT

The Hybrid Parachute

By Dave Flanagan

Introduction

In the classic "The Handbook of Model Rocketry", the late G. Harry Stine talks about lightly loaded parachutes gliding and producing lift as well as drag. Stine noted that one study reported drag coefficients as high as 2.25 when large canopies with light loads were drop tested. These values were clearly apparent drag coefficients that ignore the production of lift. **[1]** Normally model rocket chutes have drag coefficients of about 1.0.

Parachute technology at the model level has advanced. Modelers can research and build small models of parachutes with impressive names like LeMoigne parasails, single and twin keel Rogallo parawings, and even Jalbert parafoils, and achieve amazingly high apparent drag coefficients. However the construction and use of these "deployable aerodynamic decelerators" (as NASA sometimes refers to parachutes) is complicated and tedious. Any modeler who has tried to trim a parawing for straight flight can attest to this.

A simpler approach is to cut small "drive" vents in regular model parachutes or possibly adjust the length of certain suspension lines hoping that forward speed will result in significant lift. But does it? Does the lift produced by the forward speed help more than the loss of drag hurts? No one knows.

Is there a parachute design that uses standard construction materials and techniques, that doesn't need special vents or suspension lines of different lengths, and yet would glide and thus produce lift regardless of how lightly or heavily loaded?

The Hybrid Parachute – The "Half and Half Chute"

The parachutes used to recover small rockets are regular polygons ("n-gons") such as the hexagon (6-gon) and octagon (8-gon). They have 'n' sides and 'n' triangular gores and 'n' suspension lines. Such parachutes are symmetrical. Each half of such parachutes is the same as the other half. However, a "half and half" Hybrid Parachute can be built using half of one parachute and half of another, and the resulting combination, if the two halves are well chosen, does glide and does produce lift.

Figure 1 shows a pattern for making a parachute from half of a hexagon and half of an octagon – shapes that are familiar to most modelers. It is presented only by way of example – the author discovered (the hard way) that this combination of parachute halves is extreme. With heavier payloads the parachute built from this pattern tends to dive more than glide.

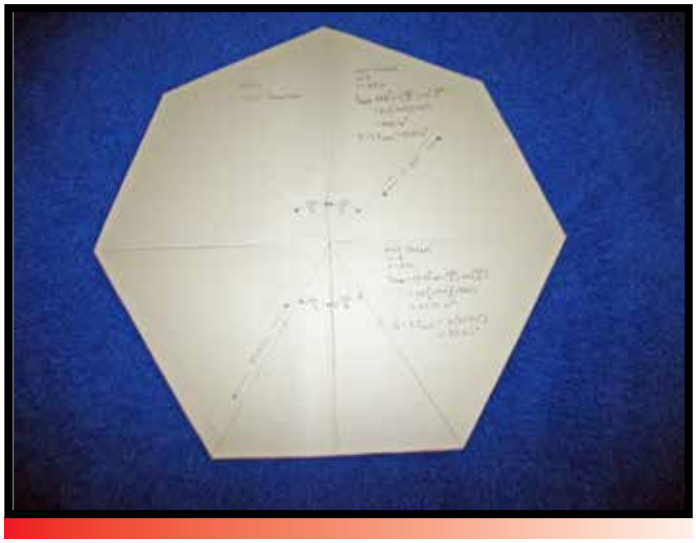

Figure 1. Patterns for half of an octagon (top) and half of a hexagon (bottom) are united to form the pattern for a "half and half chute". The circumscribed radius (outer radius) of both "source" polygons must be the same for both halves.

Building a Hybrid Parachute

In the "build" that follows, a more benign half octagon (8-gon), half decagon (10-gon) Hybrid Parachute will be constructed. This is just one possible combination.

Since the halves of the parachute meet at the "corners" where the suspension lines attach, the logical dimension to use for designing and sizing the parachute is the circumscribed (outer) radius symbolized by 'r'. For a first hybrid chute the modeler might try the half decagon (10-gon) and half octagon (8-gon) Hybrid Parachute constructed here. It should have a radius of about r=25 cm (~10"). This size pattern will fit easily on a canopy from a DynaStar 32" chute kit or an Estes 24" chute kit.

With the design complete, the next step is making the "half patterns". The author uses old file folders (or cheap ones from the local dollar store) taped together as stock material for patterns.

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Newsletter Staff

Writer: Dave Flanagan
Layout/Cover Artist: Chris Duran
Proofreader: Michelle Mason

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Begin by drawing a line at the edge of the pattern twice the length of the chosen radius 'r'. Then place a protractor on the middle of that line and mark off the angles needed to draw the gores for the half parachute. The angular increments are found by dividing 360 by the 'n' of the chosen "source" n-gon. For example, to make half of an octagon (an 8-gon), the angular increments would be 360/8 = 45. Draw the gores by extending lines through the marks and out to the value of the chosen radius 'r'. Any high school geometry book or math teacher can help with the characteristics of regular polygons, or just Google "regular polygons". See **Figure 2**.

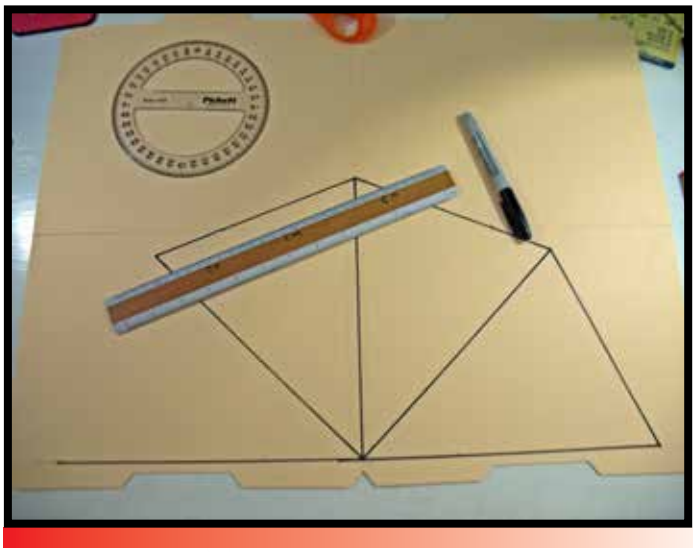

Figure 2. The pattern for the octagon half of the Hybrid Parachute is in progress.

Once the two "half patterns" are ready, cut them out and tape them together **(Figure 3)**.

Once the pattern is traced on to the canopy stock material and the canopy is cut from that material, the rest of the assembly process is exactly that which is used for any other parachute (**Figure 4**). Line lengths should be no more than twice the length of the radius 'r'. Be extra careful with line lengths. When building a regular parachute line lengths can be off a bit without causing problems. However, a Hybrid Parachute will tend spiral rather than glide if there is too much mismatch in line lengths, especially with a heavy payload.

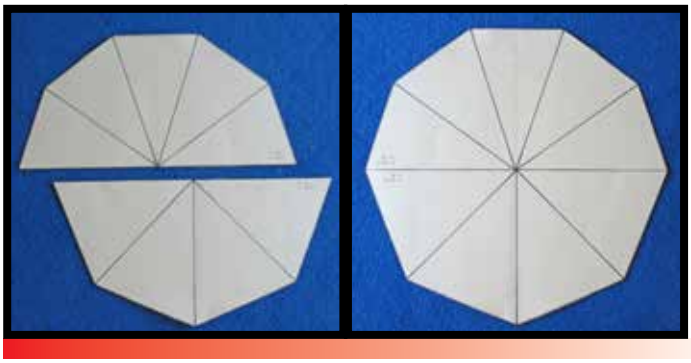

Figure 3 (a). The completed half patterns are shown. The top half pattern is sourced from a decagon (10-gon). The bottom half pattern is sourced from an octagon (8-gon). (b) The half patterns are joined to create the pattern for the Hybrid Parachute.

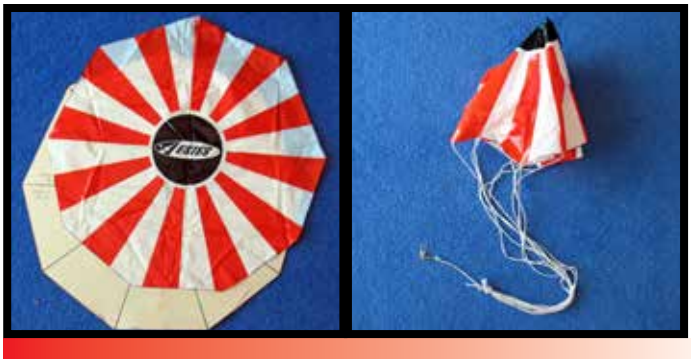

Figure 4. (a) The canopy is cut from the stock material. (b) The suspension lines are attached in the same manner as any other parachute.

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When making a new parachute, especially one of a new design, it never hurts to "toss test" it. Find a dummy payload that weighs about as much as the rocket in which it will be used and try the parachute out. Pack the Hybrid Parachute for toss testing or for use in a rocket exactly as any other parachute.

Figure 5 (a&b) The Hybrid Parachute looks much like a regular parachute in flight.

For a normal "n-gon" parachute like hexagons and octagons, the question "which direction will it fly" is meaningless. However the Hybrid Parachute will always fly in the direction of the half that has the most gores. In the case of the decagon/octagon Hybrid Parachute discussed here, the decagon half will be the "leading half" and the octagon half will be the "trailing half".

Why Does It Fly?

Where does the forward speed of a Hybrid Parachute come from? It appears that a Hybrid Parachute will always fly in the direction of the greatest "gore density", i.e. "half and half" chutes fly in the direction of the half having more gores. This is likely because this half also has the most suspension lines. The greater number of suspension lines keeps the edge (periphery) of the canopy pulled down lower in the front, while the rear, with its fewer suspension lines, lets the gores balloon up to the point where they can vent air. This air venting from the rear of the canopy likely provides the forward thrust. See **Figure 6.**

Figure 6. A Hybrid Parachute is hard to distinguish from a regular parachute in flight. In this picture the parachute is gliding away from the camera in the direction of the black arrow. The trailing half (four gores sourced from an octagon) and the leading half (five gores sourced from a decagon) are evident.

Other combinations of "n-gon halves" can be combined to form a Hybrid Parachute. A dodecagon (12-gon)/ decagon (10-gon) combination can be tried. Or perhaps half of an 18-gon can be combined with half of a 16-gon. It is up to the modeler.

The parts of a Hybrid Parachute do not have to be "sourced" half from one n-gon and half from another. Any combination of any number of triangular gores can be used provided that the sum of all the central angles (gore angles at the apex of the chute) is 360 degrees.

An Alternate Method

Like the vast majority of full scale and model parachutes, the Hybrid Parachute is based on regular polygons. By selecting various gores from different source polygons, a variety of parachute designs can be created that distribute the suspension lines in various ways. However it is not necessary to deal with polygons.

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A truly circular parachute (almost unheard of in the full scale parachute world) can also be used, and may provide a faster way of "prototyping" a true polygon-based Hybrid Parachute since patterns are not required. Suspension lines may be placed anywhere on the circumference of a truly circular canopy. Some commercial parachute kits have "gores" printed on them that might make choosing the line locations easier. For example, the canopy from an old Estes PK-24 kit has 24 gores printed on it, as does the current "checkerboard" pattern. Each gore has an apex angle (central angle) of 15°, a useful increment for experimental suspension line distributions (see Figure 7). There are 36 gores printed on the canopy in the 32" Dynastar parachute kit – one every 10° - this could also provide useful increments for experimenting.

Figure 7. The circular canopy has been cut from a parachute kit. The upper half of the canopy has lines attached every 30 degrees (every two gores). The bottom half has lines attached every 45 degrees (every three gores). This is a circular version of a dodecagon/octagon (12-gon and 8-gon) Hybrid Parachute – a fairly extreme combination. It glides in the direction of the dodecagon half.

The Hybrid Parachutes built for this article and all the others discussed above have something called "bilateral symmetry" with respect to the direction of flight. This means the left half is a mirror image of the right half. It is a good idea for the modeler to keep this in mind when designing custom Hybrid Parachutes, at least at first.

Extra for Experts

So far there is no known way to predict the amount of lift produced by a polygonal Hybrid Parachute. There are two possible ways of mathematically quantifying the physical difference between the forward and rear halves – but neither has been correlated with actual model performance. One way is to compare the areas of the forward half of the parachute with the rear half. The other is to compare the length of the peripheries of the front half and the rear half. For example in the case of the half decagon, half octagon Hybrid Parachute constructed for this article, the forward half (five gores sourced from a decagon) has about 3.9% more area than the rear half (four gores sourced from an octagon), and the periphery of the front half is not quite 1% longer than the periphery of the rear half. Does either of these things correlate to model performance? If so, to what degree? No one knows.

Determining the apparent drag coefficient through drop tests would also be interesting. Is a tower or building or maybe the catwalk around a high school gym basketball court available for timed "drop tests"? Can a Hybrid Parachute and a regular parachute of the same area be dropped at the same time from the same height with the same amount of weight?

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Or perhaps a recording altimeter can be used to record the rate of descent during flight. (Note: Make sure any such altimeter has sufficient precision!) Hybrid Parachutes offer many opportunities for research

A few formulas useful to researchers may be:

The apex angle 'α' (or central angle) of any single gore of a regular polygon of 'n' sides.

$$z\alpha = \frac{360}{n}$$

Area of a single gore based on the circumscribed radius 'r' of the regular n-gon from which it is taken (its "source polygon").

$$S_{single\ gore} = r^2 \sin sin\ \left(\frac{180}{n}\right)\ \cos cos\ \left(\frac{180}{n}\right)$$

Edge length (along the periphery of an n-gon) of a single gore based on the circumscribed radius 'r' of the regular n-gon from which it is taken (its "source" polygon)

$$e_{single\ gore} = 2r\ sin\left(\frac{180}{n}\right)$$

The formulas for truly circular parachutes are well known.

Historical Note

To the best of the author's knowledge there is no such thing as a full scale Hybrid Parachute. The design of the Hybrid Parachute presented here was inspired by a technique once in common use with emergency personnel parachutes (and still used by the military) called a "four line release". Many of the early round emergency parachutes used by pilots and skydivers were not steerable and they did not glide. However, after opening the parachute the user could release the four lines in the very back of the parachute, two on the left rear riser and two on the right rear riser. This allows the five rearmost gores to "balloon up" and spill air out the back of the canopy. This provides forward thrust. The user can also (slowly) turn the parachute by pulling on the left rear or right rear riser as desired. This technique was developed to provide maneuverability rather than to reduce the rate of descent by creating lift. See **Figure 8**.

Have fun!

References

1. Stine, G. Harry, Handbook of Model Rocketry, 4th Ed, Follett Publishing Company, Chicago, 1976.

Figure 8. (a) Test jumper David Mattsson has activated the four line release system of a military C-9 canopy and the rear gores have "ballooned up". (Air to air photograph by Nick Halseth, used with permission.) (b) This mid-1980's skydiver is under his reserve (emergency) parachute following a malfunction of his main parachute. He has released the four lines in the rear of the chute and is starting a left turn (author photo.) Air venting from the rear gives both jumpers forward speed. They can also turn slowly using rear risers.

About the Author

Dave is a registered professional engineer with well over twenty years of aerospace experience at NASA's JSC and MSFC. He holds bachelors and masters degrees in engineering and a bachelors degree in science, and while at MSFC supported NASA's University Student Launch Initiative. Although no longer actively jumping, he holds an expert skydiver rating and is a former Army paratrooper. Dave is a master parachute rigger and has completed the AIAA Parachute Systems Technology Short Course. He is a licensed private pilot and a 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 weird parachutes.