PEAK OF FLIGHT

NEWSLETTER

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IN THIS ISSUE

Make a Multi-Gore, Apollo-Style Cloth Parachute

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Make a Multi-Gore, Apollo-Style Cloth Parachute

By Steve Riegel

Like many rocketeers, I'm building a Saturn V model for the 50th anniversary of the Apollo 11 launch. In February of 2019, I started seeing discussion of high gore-number orange and white NASA-style parachutes on the NAR Facebook page. While I certainly understand the cost-effectiveness of printed plastic chutes in my kit, I have to admit that the thought of a proper nylon canopy with narrow orange and white gores seemed so much more fitting for this majestic bird. Several vendors began advertising such chutes in a variety of sizes and gore numbers around that time. Although I would happily fly with their wares, I wanted to challenge myself to construct my own chutes. Now, I'm not a professional parachute rigger, nor have I studied the math of canopy design. Everything I'm presenting here is based either on advice I gleaned from others or a generous dollop of "TLAR" (That Looks About Right) design. I do have experience building kites from ripstop, and many of the techniques for the parachutes are similar.

I had previously built chutes using fabric store coated ripstop (approximately 1.9 oz) and made a 1.1 meter 12-gore canopy for my successful L2 flight (**Figure 1**).

Figure 1: 1.1 m 12-gore elliptical parachute used for L2 certification flight.

For these chutes, however, I know the heavier fabric wouldn't be suitable as it was too bulky and stiff, especially considering the number of gores I had in mind. I found a reasonable price at Ripstop by the Roll (https://ripstopbytheroll.com) on 1.1 oz calendared fabric. "Calendared" means the fabric was pressed with a hot roller to help close the porosity in the weave. I chose white and blaze orange for these chutes.

With the fabric in hand, I now needed a template with which to cut the gores. I wanted an elliptical canopy and found Richard Nakka's pattern generator (https://www.nakka-rocketry.net/paracon.html). Richard's pattern generator is an Excel spreadsheet that allows the user to enter the diameter of the chute and the number of gores. I played around with various numbers and eventually settled on 24 gores on a 24" canopy. While not as skinny proportionally as the true Apollo chutes, 24 gores was the limit for this small of a canopy before the gore tips became too congested for my sewing skills. Richard's spreadsheet provides both a table of x- and y-coordinates for the gore as well as a printable template (**Figure 2**).

Parachute Panel Scaled Coordinates 61 cm. Diameter			
x	y	x	y
7.89	0.00	0.00	0.00
7.97	1.52	0.01	1.52
7.95	3.04	0.04	3.04
7.90	4.56	0.09	4.56
7.83	6.06	0.15	6.06
7.75	7.55	0.24	7.55
7.65	9.02	0.33	9.02
7.54	10.47	0.44	10.47
7.42	11.90	0.57	11.90
7.29	13.31	0.70	13.31
7.15	14.70	0.83	14.70
7.01	16.06	0.98	16.06
6.86	17.40	1.12	17.40
6.71	18.72	1.27	18.72
6.56	20.01	1.43	20.01
6.41	21.28	1/58	21.28
6.25	22.53	1.73	22.53
6.10	23.76	1.89	23.76
5.95	24.97	2.04	24.97
5.79	26.26	2.19	26.16
5.64	27.34	2.34	27.34
5.49	28.50	2.49	28.50
5.34	29.64	2.64	29.64
5.20	30.78	2.79	30.78
5.05	31.90	2.93	31.90
4.91	33.01	3.08	33.01
4.76	34.11	3.22	34.11
4.62	35.20	3.37	35.20
4.48	36.29	3.51	36.29
4.33	37.38	3.65	37.38
4.19	38.46	3.79	38.46
4.05	39.54	3.93	39.54

Figure 2: X- and Y-coordinates for a 24" x 24 gore parachute canopy. These dimensions do *not* include hem allowance of ½" on all sides. Dimensions are in centimeters.

Continued on page 3

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Make a Multi-Gore, Apollo-Style Cloth Parachute

Continued from page 2

I had trouble convincing my printer to actually print the pattern at the proper size so I simply plotted the coordinates manually to form the gore. I elected to add a central vent of approximately 20% of the chute base diameter, so I lopped about 2.5" from the tip of the gore pattern. This resulted in a nominal central vent of 5". In actuality, I ended up with about 5.75" as the vent diameter, likely due to a slight mis-measurement in my side hem allowances. The vent provides a more stable canopy and also gave me some working room to roll over the gore hems. I added a ½" hem allowance all around. The top and bottom hems are ¼" rolled hems. The side seams were stitched with ½" hems then folded over and stitched down in a flat fell seam.

Having plotted the gore dimensions, I cut out the paper pattern and traced that onto thin plywood to make my cutting template (**Figure 3**).

Figure 3: Wooden template for gores. The template includes a ½" hem allowance.

Once cut out, I sanded the edges to minimize snagging and set to cutting. Although the seams would eventually be rolled with all raw edges protected, I chose to hot cut the gores to seal the edges while I worked. I took an old soldering iron, bent the tip slightly and filed it thinner. The effect was somewhat scimitar shaped (**Figure 4**).

Figures 4 & 5: (Left) Shaped soldering iron tip for cutting gores. (Right) Cutting the gores. The soldering iron glides cleanly through the ripstop, heat sealing the edges as it goes. You can only cut one gore at a time, however, to avoid melting layers together.

Once hot, the tip would cleanly melt through the fabric in a thin line (**Figure 5**). I cut 12 each orange and white gores using a piece of scrap "door skin" plywood as a cutting surface (**Figure 6**). The soldering iron tip leaves a bit of a burned line but the wood handles the brief heat surprisingly well. An alternative would be to get a sheet of plate glass as a cutting surface.

Figure 6: 12 each orange and white gores.

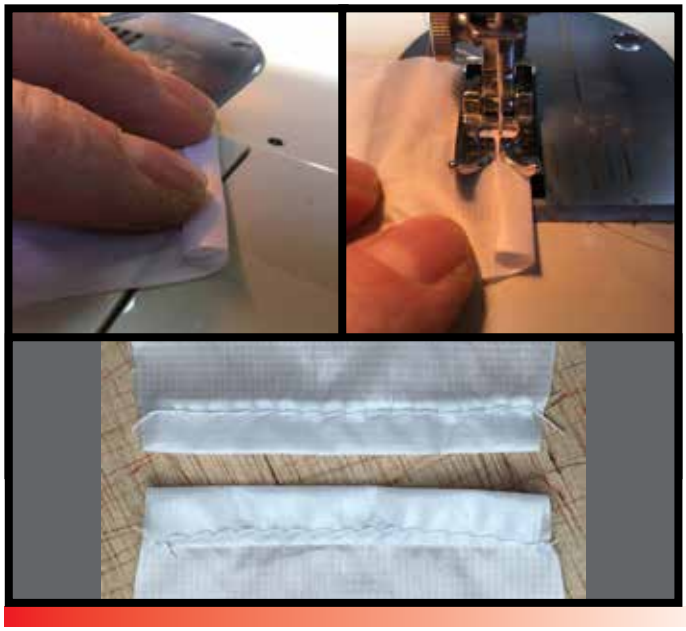
The next step was to sew the gores together. I elected to match the thread colors to the fabric on these chutes so found I needed to swap the top and bottom threads repeatedly throughout construction. While this did take a little extra time, I found the effect well worth the effort.

Continued on page 4

Make a Multi-Gore, Apollo-Style Cloth Parachute

Continued from page 3

To sew the gores, I started by hemming the tip of each gore, rolling the hem ¼". I did not use a lock stitch on the top hem since each side would eventually be folded into a later rolled seam (**Figure 7, Figure 8, Figure 9**).



Figures 7, 8 & 9: (Left) ¼" rolled hem at the skinny end of the gores. (Right) Simple straight stitch to tack down the rolled hem on the gore tip. I used approximately 10 stitches/inch for all straight seams in these canopies. (Bottom) Rolled hems on gore tips, underside and top side of the canopy.

Once each top hem was done, I laid alternating colors one on top of another with the "outside" of the gores facing each other (**Figure 10**).

Figure 10: Two gores pinned and ready for stitching along the right-hand side.

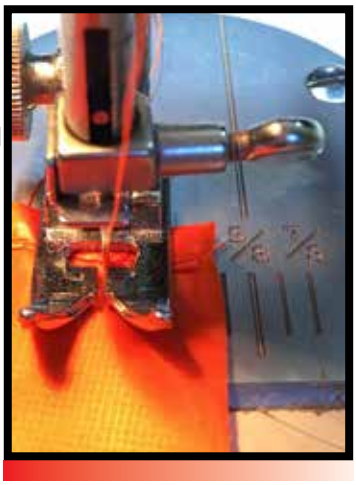


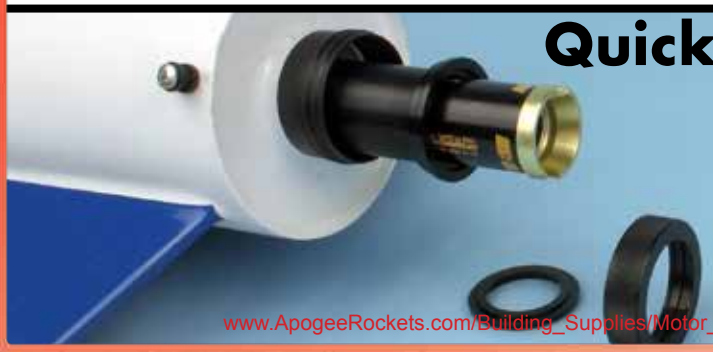
Figure 11: Running a ½" hem along the gore edge. I matched the top and bottom threads on my machine to the fabric color. The seam is lock stitched at the gore tip but not at the skirt end.

The ripstop I ordered had one side slightly shinier than the other and I chose this as my "outside" surface. pinned the edge of the gores to hold the fabric in place and sewed them with a ½" hem (**Figure 11**).

I started at the tip of the gore with a lock stitch and ended at the base of the gore. I did not lock the end of the seam as it would be rolled in the final hem at the skirt of the canopy. I constructed 12 pairs of gores, one white and one orange. I then opened each pair and faced pairs together, pinning and stitching one hem as before (**Figure 12, Figure 13**).

Figures 12 & 13: (Left) Opened up pair of gores (underside shown). (Right) Two pairs of gores superimposed and pinned. Sewn together with ½" margin as before.

Continued on page 5



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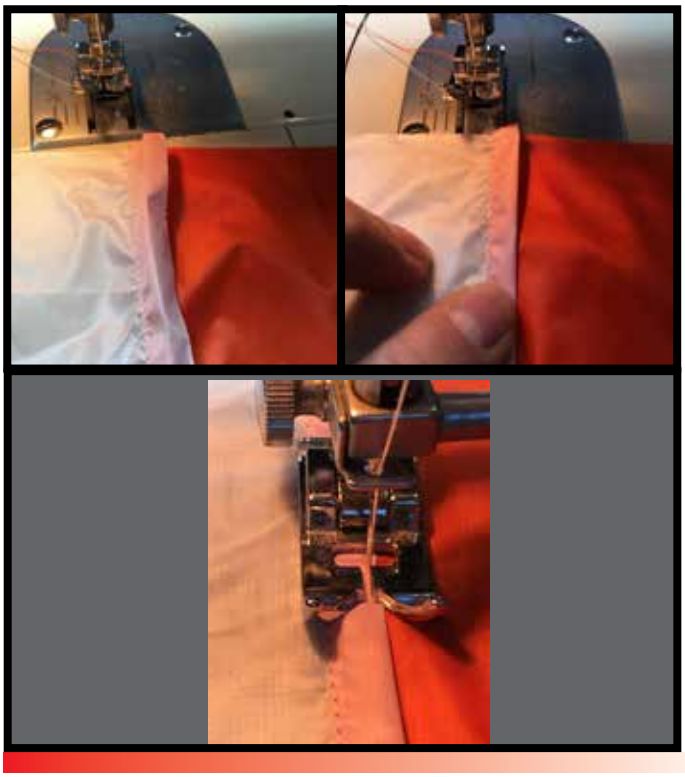
Make a Multi-Gore, Apollo-Style Cloth Parachute

Continued from page 4

Each panel of four gores was then paired and stitched to form three panels of eight gores (**Figure 14, Figure 15, Figure 16**).

Figures 14, 15 & 16: (Left) Two 4-gore panels ready for joining. (Right) One of three 8-gore panels. (Bottom) All three 8-gore panels are ready to stitch the flat fell seams between the gores.

At this point, I chose to sew the flat fell seams between the gores before joining the three 8-gore panels. I folded each ½" hem over and then stitched it down. I chose to fold each hem toward the orange gore to prevent a bleed through of color seen through the outside of the white gores (**Figure 17, Figure 18, Figure 19**). I started each flat fell seam from the skirt end of the gore and worked toward the gore tip. This was a practical measure to make it easier to finish the seam. As I got to the thicker layers of cloth where the rolled gore tip hems were folded over back onto themselves, I manually walked the needle through the last couple of stitches to the end of the gore tip.



Figures 17, 18 & 19: (Left) Folding over the hems between gores, starting at skirt end of the gores. All flat fell seams were folded toward the orange gores. (Right) Folded and flattened gore seams are ready for stitching down. (Bottom) Stitching the flat fell seams.

Continued on page 6

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Make a Multi-Gore, Apollo-Style Cloth Parachute

Continued from page 5

I then changed from a straight stitch to a zero-length zigzag stitch for about 10 passes of the needle to lock the seam at the central vent of the chute (**Figure 20, Figure 21**). Once each hem within the 8-gore panels was finished I joined the three panels and worked inside the canopy to finish the final three seams. From there it was just a matter of rolling a ¼" hem at the skirt of the chute to finish the canopy.

Figures 20 & 21: (Left) Zero-length zigzag stitch to lock the end of the gore flat fell seam. I had to apply moderate side to side tension to the fabric to prevent the needle from dragging the fabric down through the hole toward the bobbin. (Right) Top side of finished gore seams.

The shrouds turned out to be the most challenging part of these chutes. I chose 36" line lengths (measured from skirt to apex of the shroud bundle) or 150% of the canopy diameter. I measured 12 lengths of line twice as long as each shroud and added the allowance for the attachment seams and another inch for the knot at the apex of the lines. On earlier chutes with fewer gores I'd used braided nylon surveyor's line for the shrouds. The nylon line was fat enough that it was easy to run a straight stitch along its length to attach it to the canopy. On the high-gore chutes I thought the thickness of the nylon would look disproportionate given the number of shrouds and the relatively small size of the canopy. I found some Dacron kite line I'd purchased years earlier and decided it looked about right for my needs. The problem was it was only a millimeter or two wide, too narrow to easily run a stitch down the length without it rolling to one side or the other. After some trial and error I found the best solution was a narrow zigzag that would put one stitch just to the side of the line and one stitch through it. I attached 2.5" of the line to the canopy hems (10% of the canopy diameter) using a simple cardstock strip to measure a consistent length of shroud up each gore seam. I started at the skirt with a zero-length zigzag to lock the seam, ran a zigzag up, back and up again to the end of the line where I used another zero-length zigzag stitch to lock the other end of the seam (**Figure 22, Figure 23, Figure 24**).

I used a "purse handle" pattern with the ends of one line stitched to adjacent seams on one gore. The next line was stitched to the seam to the left and right of the first ones and so on around the canopy.

With all the shrouds attached, I gathered the lines and adjusted the gores to find the center of the shrouds at the apex. I took a loop of 500 lb. Kevlar line about 6" long and fed it through the shrouds to make a square knot. This cinched the shrouds together and gave me a loop to attach the chute to its riser. I wrapped a short loop of masking tape around the shrouds just above that knot to secure the ends of the Kevlar line and prevent it slipping loose.

Figures 22, 23 & 24: (Left) Measuring the shrouds using a 2 ½" card from the edge of the hemmed canopy skirt. (Right) Tacking down the shroud lines. I used a narrow zigzag (setting "1" of "5" on my old Kenmore machine) with a stitch length of about 24 stitches/inch. Only one leg of the zigzag caught the shroud on each stitch. (Bottom) Finished shroud lines, top and bottom views.

Continued on page 7

Make a Multi-Gore, Apollo-Style Cloth Parachute

Continued from page 6

With that, the chute was finished. Well, at least the first of the main canopies. I still needed one for the capsule. Given that the kit only called for an 18" flat chute on the capsule, a 24" elliptical canopy seemed a tad much. I therefore resized my gore template to make an 18" x 20-gore chute by similar methods (**Figure 25**).

Figure 25: 18" and 24" canopies for my Saturn V. Not shown is the second 24" canopy for the body.

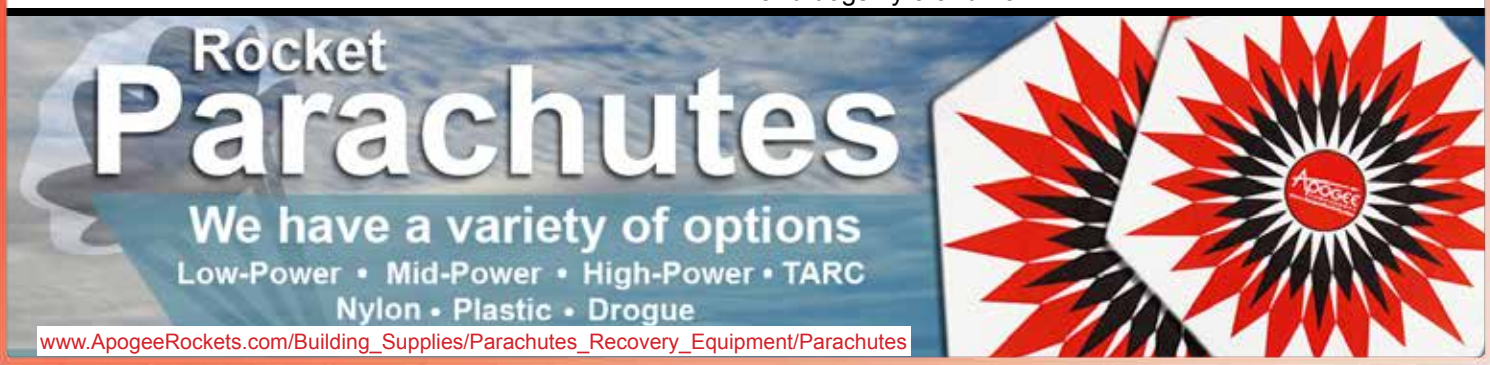
After that, I made a second 24" chute for the main body. From a descent rate standpoint, the elliptical chutes should have approximately twice the Cd of a similar diameter flat chute. My intent is that I'll get a nice soft recovery, especially given that Colorado seems to be distinctly short of nice, grassy fields for recovering scale models! I will need to watch the winds as the extra drag of these canopies will result in significantly more drift but I don't plan on flying my Saturn V unless the winds are pretty calm in the first place.

In the end, it took me approximately 4-5 hours per chute to cut and sew the canopies (**Figure 26**).

At that rate I'm not likely to go into commercial production any time soon! The process sped up as I gained experience and confidence in my sewing skills. I am quite happy with the results and know that they will give my rocket the right touch of elegance on launch day. And the total materials cost for all three chutes was on the order of just $25-30

Figure 26: Inflation test of finished chutes. This cluster has three 24" canopies in it while the intended flight configuration is 2 x 24" for the body and 1 x 18" on the capsule.

I want to thank Richard Nakka for his gore generator spreadsheet and Ben Graybeal of BAMA Recovery Systems for technical discussion and advice along the way.

Biography

Steve Riegel is a high school chemistry teacher, retired Air Force officer, amateur astronomer, and NAR Level 2 certified rocketeer. When not teaching, he enjoys adding steampunk details to model rockets and turning masses of perfectly fine fabric into tiny snips and shreds on his basement floor. He is a member of the Colorado Springs Rocket Society (COSROCS), NAR Section 515, and the Southern Colorado Rocketeers (SCORE), NAR Section 632. He lives in Colorado Springs with his wife, Jennifer, and dogs Lyra and Loki.