How to build a heliotrope solar hot air balloon

Daniel C. Bowman

March 29, 2020

1 Introduction

This document describes how to build a 5-gore, 5.8 m diameter heliotrope solar hot air balloon. This is a fairly straightforward process, but it is painstaking. When making the balloons, make sure not to wear anything that can snag the material (badges, etc). Sharp objects or corners should not be present. When laying out, folding, and cutting gores, it is best to wear socks instead of shoes. Tape should never be pulled off of a balloon. If it accidentally touches the balloon material, it should be left in place or cut free. Also, when adding tape (either intentionally or not), no sticky parts should be left. Sticky parts should either be cut free or taped over. Otherwise, the sticky part will grab the balloon envelope and tear it. You are building a 20 ft sphere out of material thinner than a grocery bag – the best guidance is just to use common sense.

2 Required Facilities

A 40x20 ft indoor space is required to lay out and cut the gores. The floor should be smooth and clean. If the floor has things that might tear the plastic, then a tarp or other protection should be laid down first. Taping the gores together and rigging the balloon can be done in smaller spaces such as conference rooms, although having more space makes things easier. Basketball courts make the ideal construction venue, in my experience.

3 Personnel

Two people are required to fold the large sheets of plastic in the beginning of the construction process. It is possible for one person to tape the gores together, but it is easier with two. Multiple people (either individually or in pairs) can greatly speed up gore taping by working in parallel. See the construction procedure section below for ways of complying with COVID social distancing guidelines during taping.

4 Materials

- 12 x 400 ft roll of 0.31 mil HDPE (light duty painter's plastic)
- clear shipping/packing tape
- sharp scissors
- measuring tape (at least 30')
- permanent marker
- paracord or Dacron line

5 Procedure

1. Cut five strips of plastic from the painter's plastic roll. Each strip should be slightly longer than 30 ft. Usually I aim for about 31 ft.

2. Open the first strip until it is fully laid out. You now have a 12 x 30+ ft rectangle of plastic.

3. Fold it once across the long axis, then another time across the short axis (Figure 1). You now have a 6 x 15+ ft rectangle of plastic.

4. Repeat the previous step, then lay the rectangle of plastic on top of the first one **oriented in the same way.** Do this with the remaining strips of plastic. Hold them down with heavy books or gentle chip clips (binder clips can be used, but they are a little sharp).

5. Check to make sure each sheet is aligned. One corner should have five layers, two should have ten, and one should have twenty. This will make sense if you think about it. Also, it helps to use your arm and sweep out any air that got trapped between the layers.

6. Draw the gore curve. Defining Point A in Figure 1 as the origin, the width of the gore is calculated via

$$w = \frac{c}{2n} \cos(2\pi \frac{l}{c}) \tag{1}$$

   where c is the circumference of the balloon, n is the number of gores desired, and l ranges from 0 (Point A; the center of the gore; one corner of the twice-folded sheet) to $\frac{c}{4}$. In this case c is 60, n is 5, and l ranges from 0 to 30. Recall that there may be a little excess material at the end because you cut a slightly longer sheet (better than it being too short!). And that, my friends, is how you turn rectangles into spheres.

7. Now take a sharp pair of scissors and cut along this curve. Do this slowly and smoothly, letting the scissors glide rather than trying to hack through the layers of plastic. If you do this right, you should have five gores that look like blunted diamond shapes.

8. Tape the gores together. Always start from the same end of the balloon (call this the "north pole"): errors accumulate as you move down, so we make the balloon's opening at the far end ("south pole") so we can get rid of all the plastic scraps. Leave a gap in that far end so that air can escape during the taping process. Overlap each section of tape so that there are no holes that air can escape from in flight. Also, avoid gaps of exposed sticky tape between the two gores, since those will grab other parts of the balloon after packing and cause all manner of problems. Be wary of sharp tabs of tape that can slice up the plastic as well. Usually we tape in teams of two: one person holds the gores together and the other folds the tape over the seam (Figure 2, bottom left). However, this keeps two people in close proximity for over an hour per balloon - not a good idea in this age of coronavirus. I have been able to tape gores by laying the two of them on a table, cutting a strip of tape, sliding the seam over top of it, and rolling it over. I recommend doing this until social distancing is no longer required.

9. Once the balloon is fully taped, make a circular cap of plastic and tape it across the north pole. This reduces stress and makes for a more symmetric balloon.

10. Widen the south pole gap to a 6 ft diameter opening, this is the bottom vent of the balloon. Make a loop of paracord or Dacron line about 6 ft across. Pull the south pole balloon fabric through this loop, double it back on itself, and tape it. This loop is where we hang the payloads from. By doubling the balloon fabric across it and taping, we now make it impossible for the payload to fall off without taking at least some of the balloon with it. This slows the payload down in case the balloon experiences what Elon Musk calls a "unscheduled rapid disassembly" during flight.

I will be taking care of rigging the payload load lines and darkening the balloon.

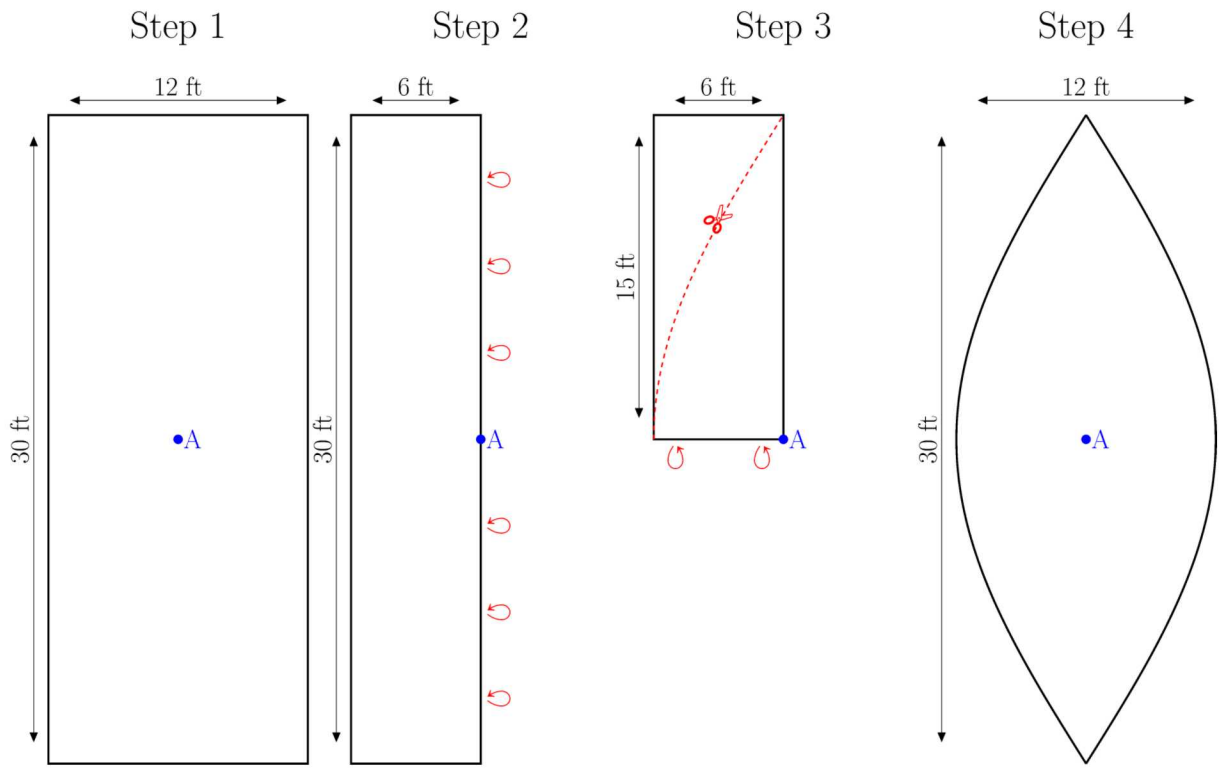

Figure 1: Plastic folding and gore cutting sequence for a 60 ft circumference (5.8 m diameter) Heliotrope balloon. Point A represents the same position on the plastic sheet for each step. Step 1: Unfold each plastic strip into a 12 x 30 ft rectangle. Step 2: Fold the rectangle across its longest dimension. Step 3: Fold the rectangle across its shortest dimension. Point A is now at the lower right corner of a doubly-folded plastic sheet. Stack all the sheets on top of each other, ensuring that Point A is always in the same position for each. Then draw the gore curve on the topmost sheet and cut along the line (see Equation 1). Step 4: A gore after cutting.

6 Acknowledgments

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

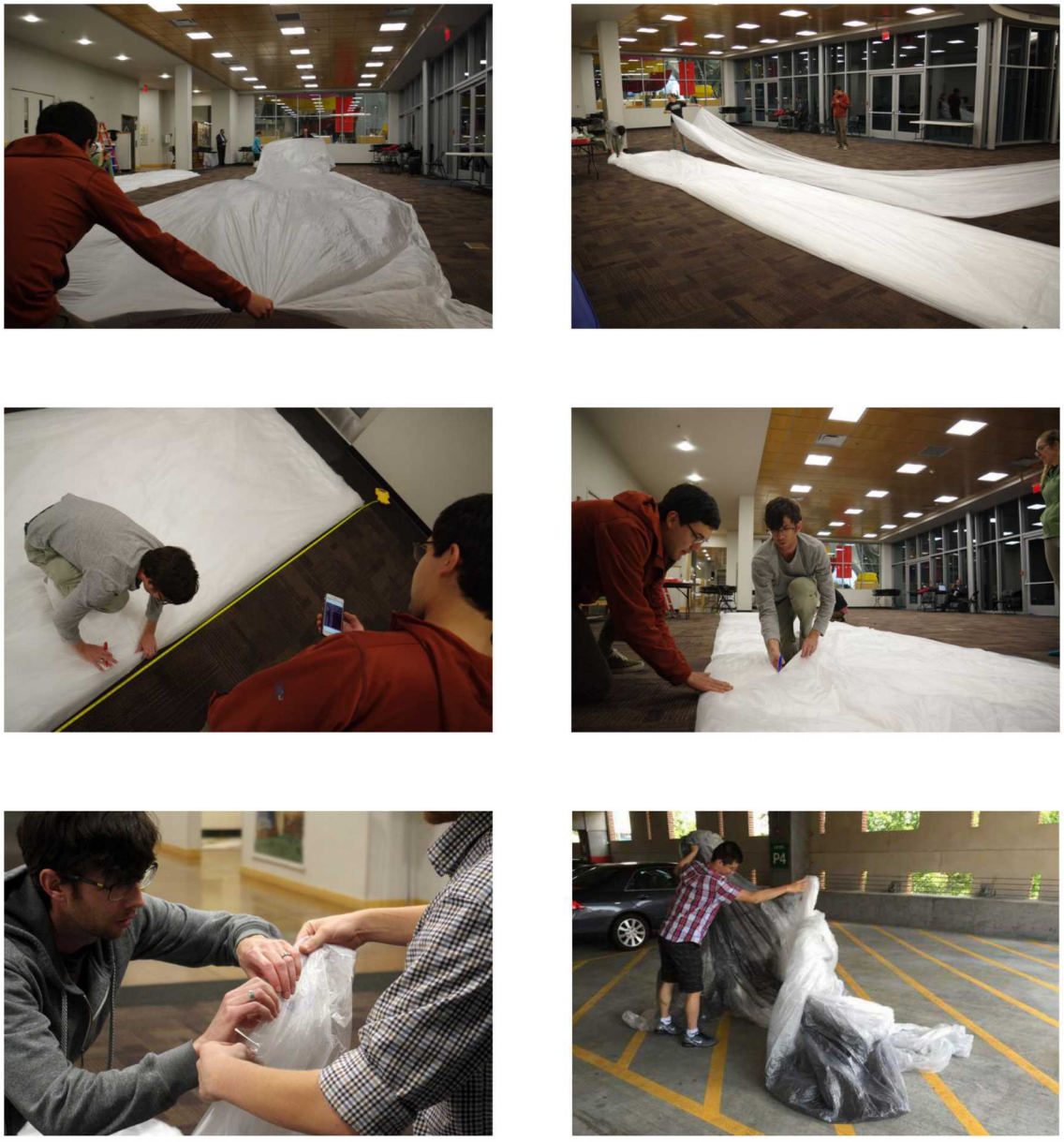

Figure 2: Steps in building a solar balloon. Top left: folding the sheets. Top right: laying the folded sheets on top of each other. Middle left: measuring the gore curve. Middle right: cutting the gores. Bottom left: taping the gore seams. Bottom right: darkening the balloon.