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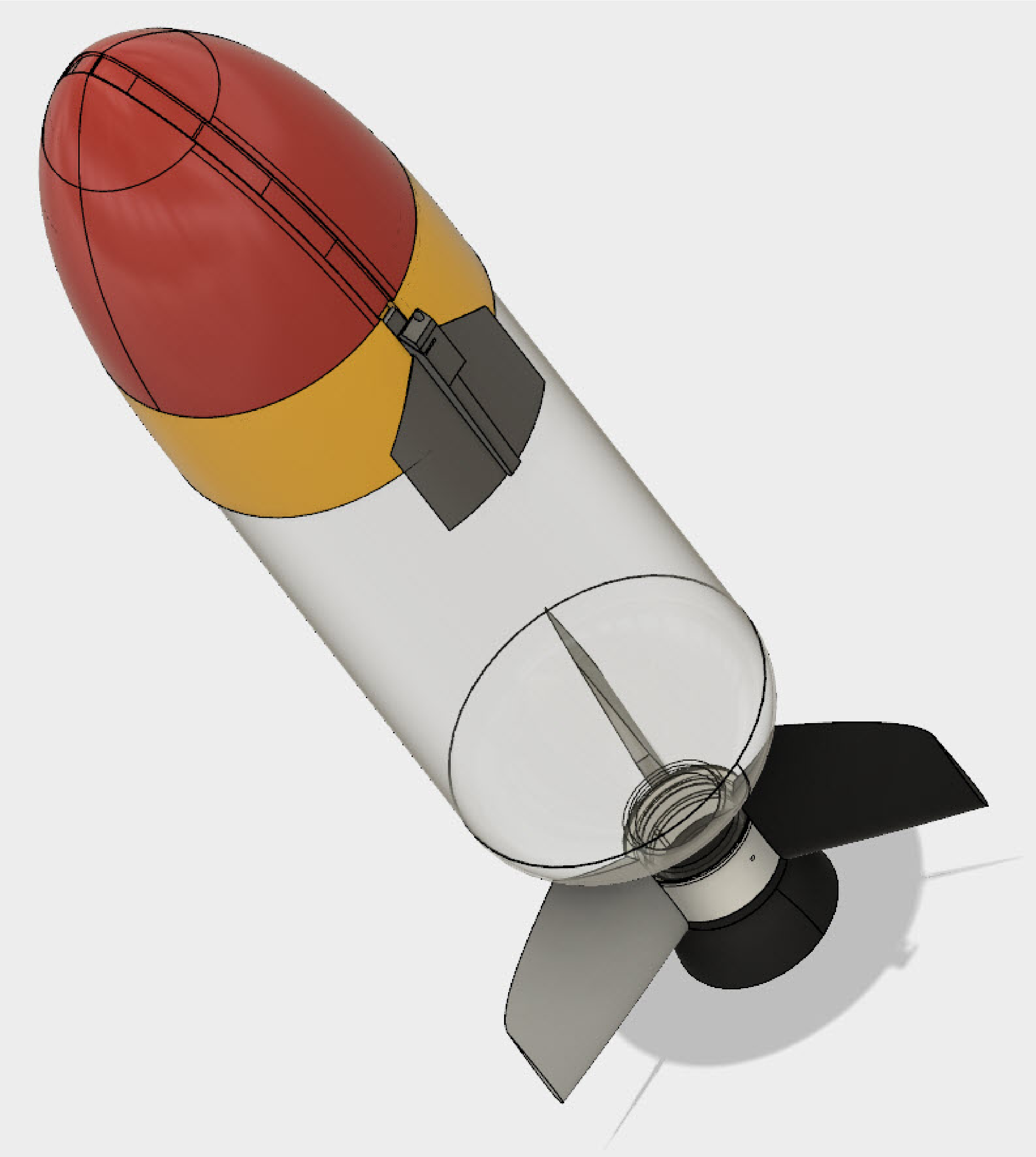
3DLabGANG – Water Rocket and Launch System



Donald Wright

We're fascinated by all things that swim, crawl or fly – especially things that fly! So let's take a short excursion into things that go straight up, rockets!

3D printing gives us the opportunity to dream up wonderful ideas and transform them into reality. Welcome to the world of model rocketry.

This design is for a complete water rocket system. There are no needed electronics and all of the additional inexpensive materials are most likely already in your workshop or at the nearby hardware store. Simple physics allows us to shoot a homemade rocket hundreds of feet followed by a gentle parachute recovery.

With no dangerous chemicals or combustion, water rockets are safe, and with supervision, can be a fun learning experience for the whole family. Kids will look at you as if you're Elon Musk!

Let's get to it.

Bill of Materials

1. A 1 liter soda bottle. This design uses a pop bottle as a pressure vessel. The bottle needed contained cola or sparkling water as sold under the Walmart brand. Other bottles may work as long as the cap thread and diameter (84mm) are the same – the design allows for different threaded inserts which will be added as the forum grows.
2. 1/2" Schedule 40 PVC pipe – about 36" (.840 OD, +-.610 ID)
3. 1/2" PVC Tee – 1 needed
4. 1/2" PVC Cap – 2 needed
5. Automotive Tire Valve Stem – 1 needed (TR 413, .453 rim hole) available at auto supply stores, tire stores, junkyards, etc.
6. Quick Connect Fittings – 2 needed Example 1/4" Male Straight Pneumatic Fitting – Big Box and hardware stores will have these in plumbing, dishwasher, refrigerator hookups. These are used to connect/disconnect our airline, we could also use barbed fittings, your choice here.
7. Tygon/Vinyl Tubing, 1/4" - @25' Used to pressurize our rocket at a distance.

8. Air Pump – a bicycle tire pump is fine, one with a built in pressure gauge is better. A small battery powered pump adds a cool factor, but a pressure gauge is required regardless. If it is integral to the pump, great. If not, you'll be disconnecting the pump to read the pressure.
9. Tire Pressure Gauge – see above.
10. Parachute Material – 1 square foot. Almost anything can be used as long as it's thin, plastic grocery bags, plastic drop-cloths, etc. The best is rip-stop nylon in a color that's easily seen. Example
11. Parachute Cordage –1 Roll, braided mason's line is great - Example
12. Rubber Band – a few needed for spares, etc. #64
13. Medium CA – Small amount needed. Most any brand can be used on PLA plastic
14. CA Accelerator – Small amount needed. The pressurized can last longer.
15. Lead Weight - @1-1/2 oz. Scrap lead, bullets, shot. We have lots of leeway here, we can even use pennies, etc.
16. O-Ring – 1 needed - #94, 7/8" OD x 5/8" ID x 1/8" - hardware store.
17. Angle Iron – 3/4" x 1/8" x 16", our launching stake. Scrap. A bit longer keeps you from kneeling in the dirt. Nothing fancy here.
18. Spring Clamp – 1 needed. Holds the launch assembly to our stake. Example
19. Music Wire - .031" - .037" x @24". This is our launch bridle wire and it needs to be about this diameter and tempered spring wire. Soft wire will not do. This is wire that we typically use for light push-rods, etc. Hobby shop, etc.
20. General Wire - .016" x 6". Regular wire is okay, used for Deployment Lever lock. Stiff Floral wire, etc.
21. Tubing – brass, aluminum or hard plastic. @1/2" long, this is used at the bottom of our launch bridle and must slip over Item #19 and be smaller than 1/8" OD. Small diameter Ny-rod casing is perfect. Even PVC wire insulation will work.
22. Electrical Tape – 3/4" wide, your choice of colors

Videos

Watch the Time-Lapsed videos of printed parts and assembly – these will help with understanding the instructions. Testing Days - Rocket Assembly - Parachute Assembly - Launch System Assembly - Parachute Pack - Launch Tutorial

Printing Parts

No special setups are needed. This is not thin wall printing as with 3DLabPrint's planes. Straightforward geometry with infill for the most part. Use the slicer you are comfortable with – however, we are supplying S3D files and Cura setup suggestions for Prusa i3 and similar printers. Smaller footprint printers may be used, as small as 150MM cubed. An entire assembly can be printed in an evening.

Recommended Printer Setup:

Layer Height -	0.10 – 0.15mm
Nozzle Diameter -	0.40mm
Wall Thickness -	1-2 layers and 10-20% infill (see selected parts files for suggestions)
Top and Bottom -	2-3 layers (see selected parts files for suggestions)
Printing Speed -	45mm/s, 80% under-speed for outer layers, first layer
Material -	PLA, your choice and experience for temperature settings bed and hot end. Regardless, as with all parts, make sure your layers are bonding well.
Supports -	None needed.

NOTE:

I've found that keeping a high bed temp (60c+) with thin parts causes radial shrinkage (5mm-20mm above the bed) during longer prints. My best printing now uses a low heat (35C) bed temp. I print on 3M Blue Painter's tape which I squeegee down on glass with a credit card. A slower first layer speed (60%) at the proper height, gives a great bond for the duration of the print. Make sure the temperature for your particular brand of PLA bonds each layer well. This may change slightly with different colors within the same brand. Accuracy with our prints depends on a tight, well setup machine, quality manufactured filament (diameter tolerance) and lastly accurate temperature management. (Insulation on the hot end helps the controller keep a rock steady temperature)

S3D Factory Files

Included in the Download – For those using Simplify 3D each part has been saved as a *.factory file.

Cura Files

Profiles included in the Download – suggested use as follows

- Prusa Strong 1 – Adapter Push Connect, Adapter Valve Stem, Deployment Lever, Deployment Vane, Launch Block, Launch Lever, PVC Coupler, Fin Ring, Threaded Insert
- Prusa Thin 1 – Bulkhead A, Cone Half A, Cone Half B, Nose Cone
- Prusa Thin 2 – Bulkhead B, Nozzle Standard, Nozzle Vented
- Prusa Thin 3 – Fin Standard, Fin Shark

Time Lapsed Videos

Watch these videos on printing suggestions for any and all parts.

TL Adapter Push Connector - TL Threaded Insert Walmart - TL PVC Coupler
TL Nozzle Standard - TL Nose Cone - TL Launch Lever - TL Launch Block
TL Fin Standard - TL Fin Ring - TL Deployment Vane - TL Deployment Lever
TL Cone Halves AB - TL Bulkhead B - TL Bulkhead A - TL Adapter Valve Stem
TL Adapter Push Connect

Innovation

- Besides being 3D printed, this rocket system has some unique features. The Fin/Nozzle assembly is simply screwed onto the existing bottle threads – no more awkward taping or hot gluing the fins to the side of the bottle.
- The release mechanism is simple. Using a wire bridle below the nozzle, we're able to easily release a fully pressurized container with a light string pull. There are no complicated release mechanisms that attempt to utilize the bottle flange.
- The chute deployment mechanism is simple and takes advantage of a vertically split nose cone. In testing, we've found it extremely reliable.

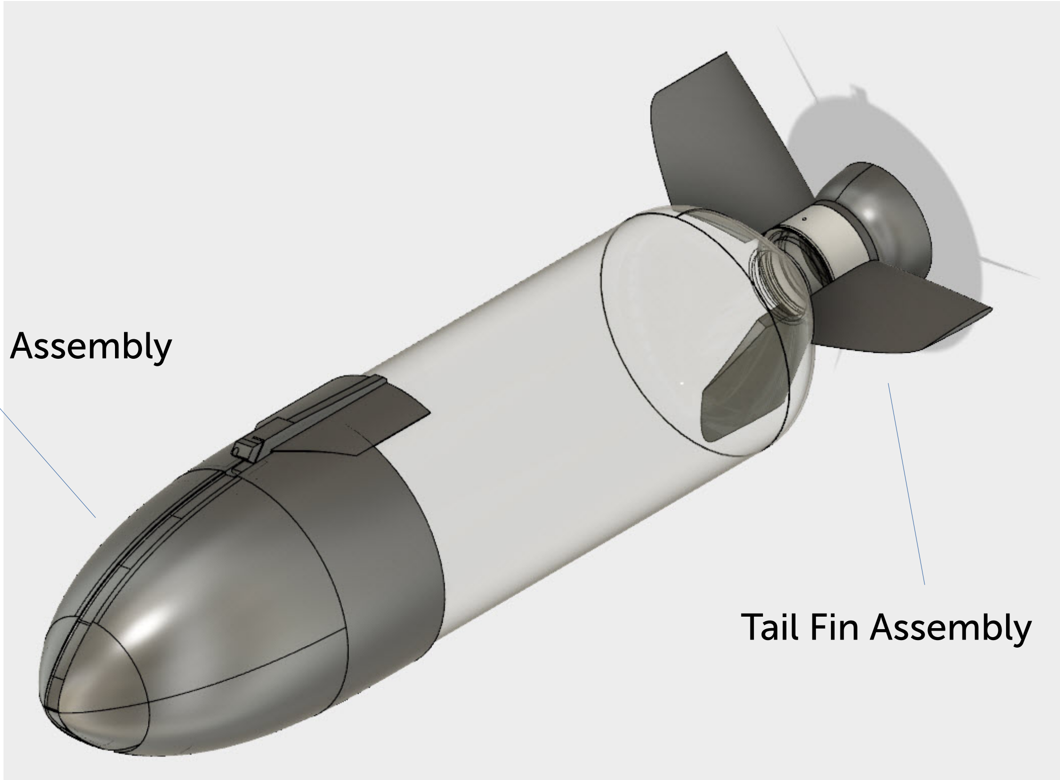
Theory of Operation

Using a standard soda bottle with a 22mm opening, the rocket assembly slides over a 1/2" PVC pipe and onto a O-ring. The pipe serves as a launch rail and as a filler tube which keeps the water from draining back down into the charging assembly. Pressure is held by means of an O-ring on the rocket end and a tire valve stem on the other. T

he launch bridle is held fast by a launch block and release lever. A 22mm nozzle opening translates into 0.58 sq in. At 100 psi of bottle pressure there is 58 psi of nozzle pressure, and essentially 58 lbs of force on the launch block and lever. Once the launch lever is pulled, the rocket moves upward off the O-ring and along the launch rail. This burst of speed along the pipe saves most of the water load for the secondary push.

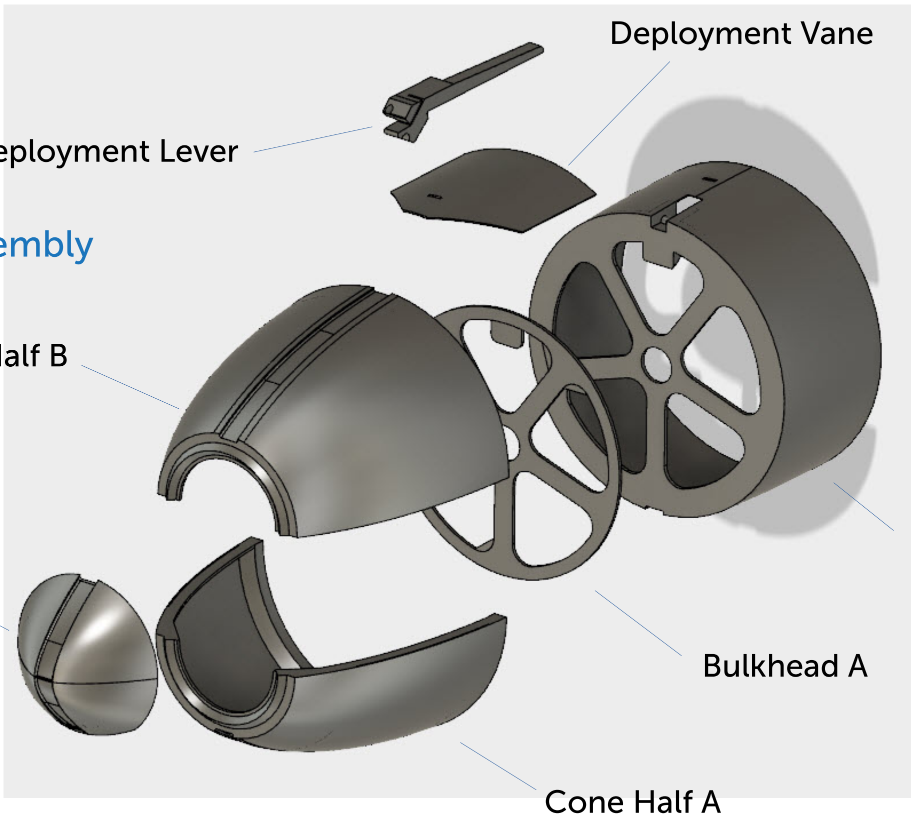
As the rocket clears the "tower," a string attached to the deployment vane is pulled. The high air velocity keeps the vane depressed against the side of the rocket until minimum velocity or apogee is reached. Once there is no air resistance, the deployment vane dislodges and flips over, releasing the two halves of the nose cone, deploying the parachute.

Printed Parts List

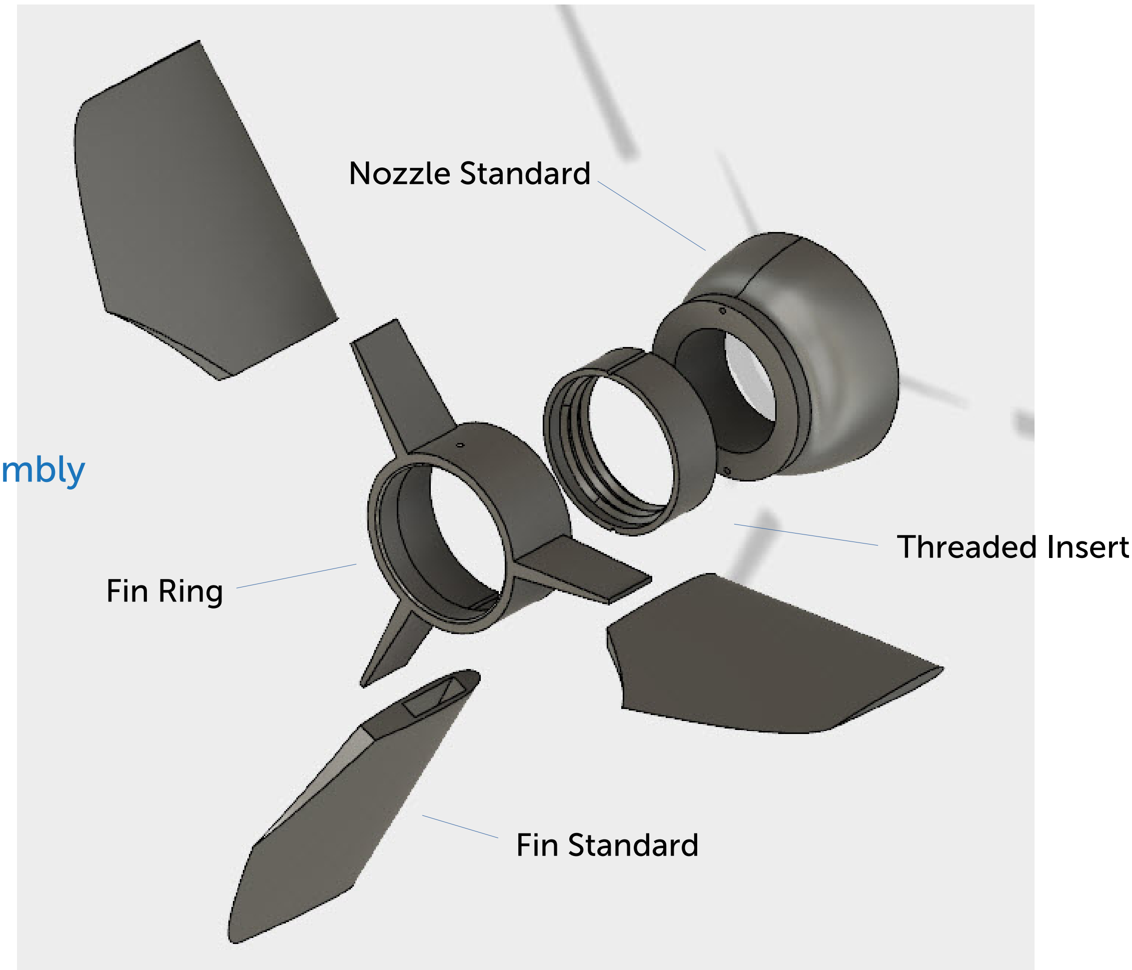


Exploded Views

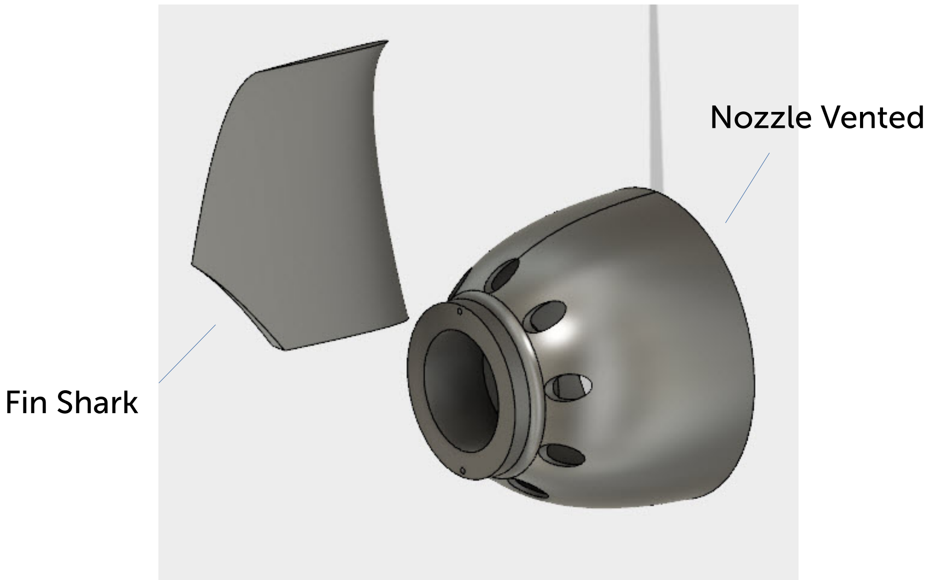
Nose Cone Assembly



Tail Fin Assembly



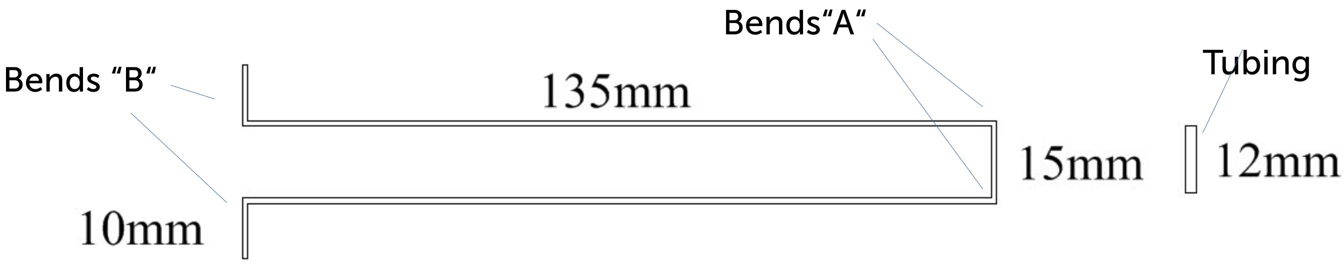
Custom Parts



Assembly

Tail Fin Assembly -

As with all parts – clean/sand away flashing, brim, elephants foot or any other printing anomalies.



Wire Launch Bridle

1. Above is a sketch of the dimensions of the launch bridle which must be bent in a specific sequence. Take a length of the music wire #19 and 12mm length of the tubing #21. Slide the tubing to the center of the wire and make both "A" bends as shown.
2. Slide the desired Nozzle onto the wires through the printed holes. Make sure the exit of the nozzle is facing the tubing.
3. Make both "B" bends – be aware of the 135mm dimension. The legs of the "B" bends will be longer than needed and may be clipped off later.

Fin Ring / Threaded Insert

1. Squeeze the legs of the bridle together and insert into opposite printed holes in the Fin Ring.
2. Position the Threaded Insert between the bridle wires along the printed grooves. Study the threaded insert and you will see the threads are neared to one edge – this is the nozzle exit end.
3. Apply a small amount of CA to the inside of the Fin Ring then press the Threaded Insert flush into position inside the Fin Ring.
4. Apply CA to the top of the Nozzle, slide along the wire to mate to the bottom of the Fin Ring/Threaded Insert assembly.

Fins

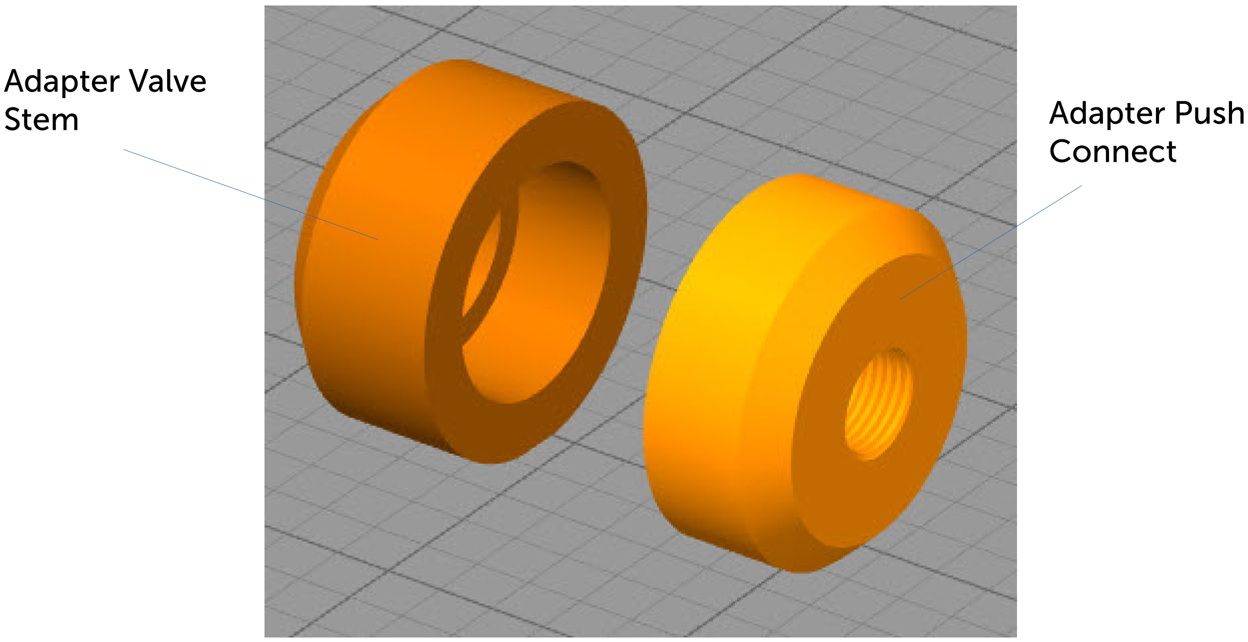
1. Apply a small amount of CA to the Fin Ring Lugs and press the desired Fins into place. This assembly is now complete and ready to screw into place.

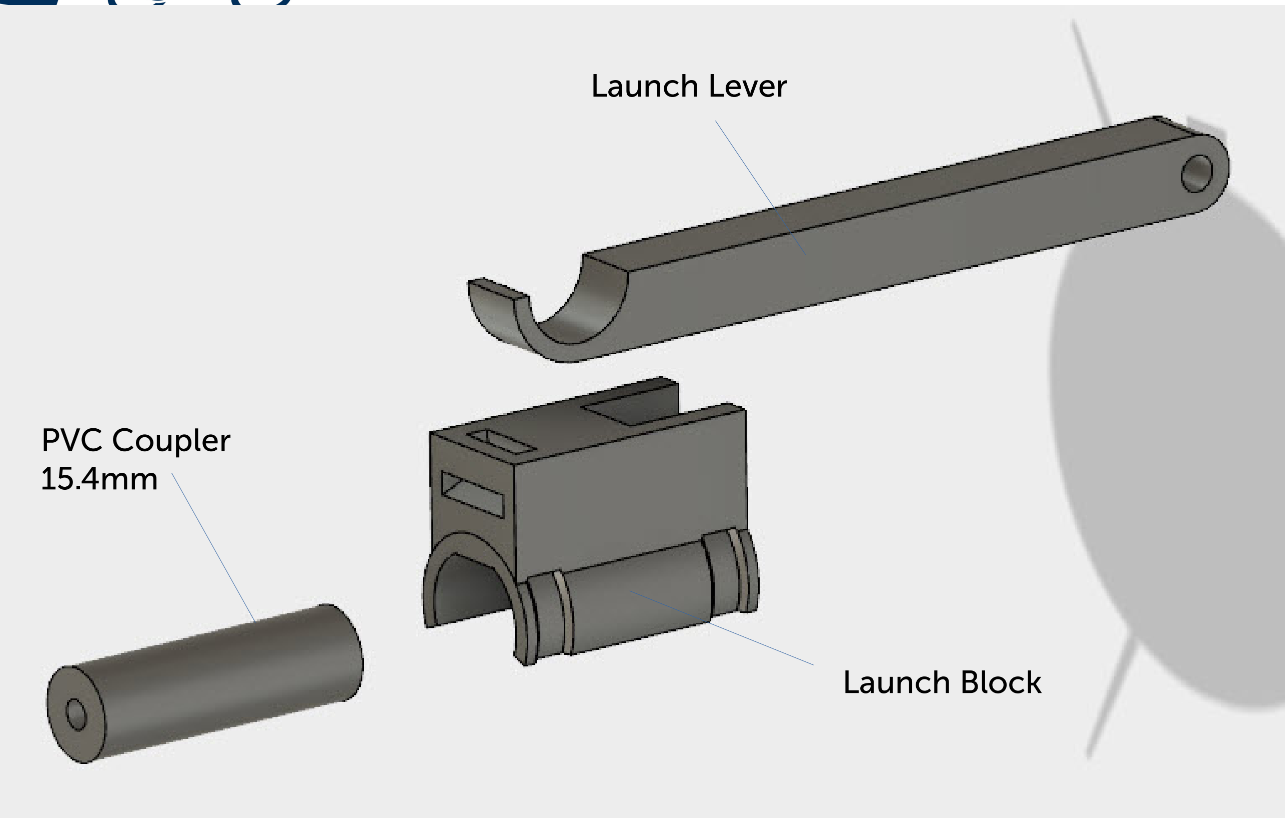
Nose Cone Assembly

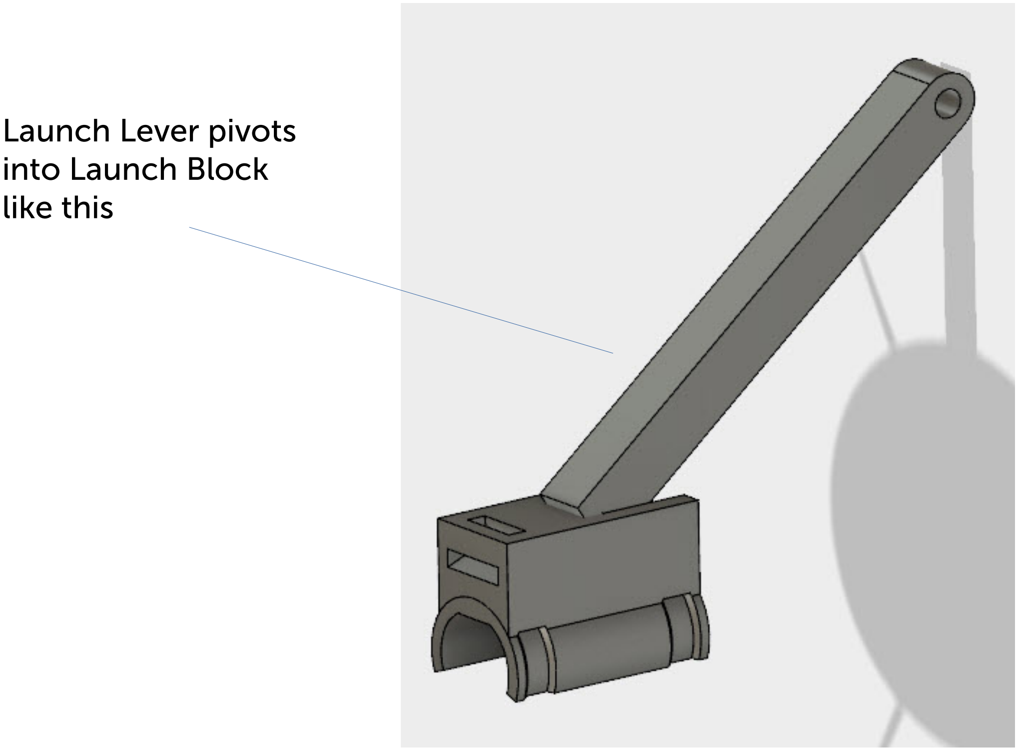
As with all parts – clean/sand away flashing, brim, elephants foot or any other printing anomalies.

1. Take a #64 rubber band and clip to make a single length. Thread one end into, out and around the Bulkhead B connection spot, then back onto itself and secured with a drop of CA.
2. Thread the free end of the rubber band through the retainer on the side of Cone Half "A".
3. Continue to thread the free end of the rubber band through the retainer on the side of the Nose Cone.
4. Take the free end of the rubber band and stretch it tight, this will allow you wiggle it into the slot on the Deployment Lever.
5. CA the Deployment Vane to the underside of the Deployment Lever – be sure to align the "windows" in the vane and the Bulkhead B, it helps to fit the Lever into its position in the bulkhead.
6. CA Bulkhead A onto the face of Bulkhead B – there are alignment tabs on the underside for centering proper.

Launch Parts




Launch Lever
PVC Coupler
15.4mm
Launch Block


Launch Lever pivots
into Launch Block
like this

Launch System Assembly

1. Print out the PVC Coupler and test fit it into the end of the PVC pipe. The fit should be snug and might require a bit of sanding to get it to fit. If the fit is loose, scale the part up in your slicer, try printing at 101% for instance.
2. Cut four pieces of PVC pipe – 1pc 8-7/8", 1pc 15", 1pc 6-3/4", 1pc 1-3/4"
3. Assemble the pieces as shown in the video. The 8-7/8" piece is left loose (we'll tell you why later)
4. Study the inside diameter of the Launch Block, you will see there is a sharp edge at the top. This edge locks into a notch you are going to file in the PVC pipe. The Launch Block should snap into position with this edge in the notch. Measure and notch carefully so the top of the Launch Block is exactly 4-1/2" from the end of the PVC. When you are sure, apply a small amount of CA to the inside of the Launch Block and snap into position. Then take two standard size Ty-wraps and thread into and around the pipe, pull them tight and clip off flush.
5. We need to fit one of our Quick Connects into a hole we've drilled into the PVC cap. Most likely a Quick Connect this size will have an 1/8" NPT thread. If you don't have a pipe tap, you can make a quick substitute by taking an 1/8" pipe nipple, cutting two or three shallow slots across the threads with a Dremel, essentially making a nice thread tap.
6. The connection to the air pump. Print out both halves of the Tire Pump Adapter. Insert the Tire Valve Stem into the proper end. We need to fit our other Quick Connect to the opposite side. Use the method outlined above if needed. Once those parts are attached, glue the assembly together with plenty of CA. I find that using a socket over the Tire Valve and fitting into a vise overnight makes for a rock solid assembly.
7. The final part is the launch pin assembly. This consist of a small loop of the fine wire that protrudes out of the Bulkhead B window, and through the Deployment Vane. Then you will see that by inserting a small piece of wire through that loop and into the hole in the Deployment Lever, you are disarming the system. This allows you to pack and make ready for launch without having to hold down the launch vane – and to have several rockets ready to go!

Parachute

There are countless videos online for making small parachutes – here are my thoughts. Out of all the material available, the rip-stop nylon is the best IMO. The reasoning is that once the material is unrestrained it self-unfolds, which helps with the deployment process. Early prototypes using thin plastic, such as grocery bags and painters covers, had a lower success rate. That material can be bunched up tight, but it tends to stay bunched up – your results may vary. Part of the fun is working through the trials and finding what gets the highest launches and best recoveries.

Here' s my method for making chutes out of the Rip stop Nylon

1. Get a piece of Masonite or other smooth board and draw a 14" circle. Inscribe an octagon within that circle.
2. Lay a piece of fabric over the drawing. You should see the lines underneath.
3. Using your soldering gun (with a knife blade if available) and straight edge, cut the nylon on the octagon lines. It will cut cleanly and fuse the fabric edge at the same time.
4. Cut 9 pieces of the mason's line 14" long. A quick match flame to the ends will prevent fraying.
5. On one corner of the octagon at a time, lay a 1/2" bead of CA, then spritz one end a piece of line with CA Accelerator and press into the bead.
6. Gather the 8 lines together and even up, then wrap and tie these ends with the remaining line. This gives a single lanyard to attach to the rocket.

Hint: While you are making parachutes, make a 12" and 10" size as well – during very windy days you might want to use a smaller chute to keep the downrange recovery to a minimum.

Balancing the Rocket

The rocket will need to be balanced, otherwise it will oscillate during ascent. The typical rocket will need 1-1/2oz of weight in the nose. You can use lead scraps, lead shot (bird shot works best), pennies, almost anything that will fit within the nose cone. My favorite is bird shot and epoxy.

The theory of balancing a rocket is the same as wind vane – regardless of where the CG is, there must be more aerodynamic resistance behind than ahead. To test this on your rocket, find the CG (without lead or weights) and attach a string at that point, (a loop around the rocket held in place with tape works) and swing it around your head. You may find that the rocket does not track well, oscillates, or may even turn tail first!. Now add weight to the nose cone, just tape it into place for now. Re-discover the CG and move the loop unto the rocket is level, now swing around once more. You should find that the rocket now tracks much straighter.

After the weight is permanently attached you can move into the launch testing phase. Pay close attention to the ascents and you may find that there is yet a small oscillation, tail wiggle. A bit more weight will straighten the flight out perfectly. Any oscillation affects altitude.

Launching

Choose a clear field for a downrange recovery. A windy day will carry the deployed rocket downrange over 100 yards! Smaller chutes will help with really windy days.

1. Hammer the angle iron stake firmly into the ground with the point of the "V" facing downwind. A few degrees into the prevailing wind will help with recovery distance, but limit this to no more than five degrees off vertical. Note; the recovery system depends on a minimum velocity during the flight which usually occurs at maximum altitude or apogee. If you angle the rocket too far off from vertical, the minimum airspeed may be too high to deploy the parachute and you'll have to print more parts.
2. Lay out the Launch Line and Tygon tubing upwind from the stake.
3. Attach the pump adapter to the tubing and air pump.
4. Pack the chute and close the nosecone parts. Be sure the Deployment Lever/Vane moves freely. Place a safety pin (toothpick) into the release retainer to hold everything closed.
5. Turn rocket upside down and fill about one third full with water.
6. While the rocket is upside down, insert the launch tube into the nozzle while guiding the launch bridle into it's pocket – the O-ring should be within the bottle opening.
7. Turn assembly upright. Fasten to stake using spring clamp. The "T" of the airline fitting will be over the "V" of the angle iron, this keeps the launch assembly from sliding downwards during liftoff.
8. Attach the airline to the launch assembly.
9. Insert the Launch Lock Lever into the Launch Block.

10. Holding the Deployment Lever in place, remove the safety pin and replace with the Launch Pin. The Launch Pin is simply a 2" long piece of wire with a small loop connecting it to a length of mason line. The other end of the line is connected to the launch assembly. As the rocket clears the tower, the line pulls the Launch Pin free.
11. After making sure all is correct at the launch site, move to mission control and pump up the rocket. Pump to 40psi for the test.
12. Check your surroundings for safety, give the count and pull the string. In a blink the rocket will be gone, wait for chute deployment – success!
13. Repeat!

Debriefing

How high did it go? How high can it go? What happens with more/less water. What is the max air pressure? All great questions that deserve experimentation. I've tested to 100psi, (but that's not the limit). How high? I'll let you discover that – but with spliced bottles and longer launch tube (that's why we didn't glue it in place), out of sight launches are possible.

To share your pictures and results; get more tips; and other helpful links, go to the dedicated forum for this project, 3D LabPrint Forums .

All the best, Don – and the 3DLabGANG