CHAPTER NINE

Launch Support Equipment

"And let's not forget LUNCH following the LAUNCH"
- Bill All (N3KKM), Program Manager of NSBG

Chapter Objectives

1.0 Support Equipment To Collect

The ground support equipment required to launch a near spacecraft consists of a mix of items, some that are purchased ready to use and others that are constructed. The list below groups the ready-to-use equipment into functions. Afterwards the function of various items is described in detail. You'll notice that duct tape is used during balloon filling and stack assembly. One cannot go into near space without duct tape.

Items For Balloon Filling

- Two inexpensive bed sheets (sewn together)
- Mark Conner recommends durable picnic blankets (available at Wal-Mart)
- Tarp (for filling on gravel and wet grass)
- Kneeling pads (recommended)
- Tie down straps for the helium tanks (see Section 1.0.7)
- Roll of duct tape
- Sisal cord
- Scissors
- Electronic fish scale
- Several pairs of soft cotton gloves (use brown jersey gloves without the beaded palms)

Items For Stack Assembly

- Roll of duct tape
- Nylon cord
- Scissors
- Electronic fish scale
- Several 2” to 3” diameter metal craft rings
- Several pairs of soft cotton jersey gloves
- Solar powered calculator
- Small white board and dry erase markers or note pads and pens and pencils
- A selection of link lines in a storage box

- Bag of Styrofoam peanuts
- Laundry bag

Launch Equipment
- Lanyard release (see Section 2.3)
- Kite winders (see Section 2.3)
- Several pairs of leather gloves
  Note: Do not use the leather gloves when working with the balloon

Items For Capsule Closeout
- Folding table (recommended)
- Jeweler's screwdrivers
- One pair of straight slot and Phillips screwdrivers
- Small wire cutters
- Small parts like nuts, bolts, and coax barrel connectors
- Plastic zip ties and twister seals
- Lens brush
- A digital multimeter
- Flashlights(s)
- Butane lighter
- Shipping labels

Items For Organizing Equipment
- Boxes for small parts
- Several large gym bags or plastic tubs with lids
- Labels for bags or tubs

1.1. 1.0.1 Ground Support Equipment

Equipment - *Gloves, knee pad, duct tape, etc.*

Place two inexpensive bed sheets or picnic blankets on the ground before unpacking the balloon. Even when filled indoors, the balloon must be protected from dirt on the ground. The abrasive nature of dirt damages the balloon skin during filling. Sew the bed sheets or picnic blankets together to create a large enough clean work space. For those mornings the grass is wet or when the balloon is filled on a gravely surface, place a tarp on the ground before the bed sheets. This may not be necessary with the picnic blankets as they may have a waterproof lining. Balloon Crews usually fill the balloon working on their knees. Help them out by giving them kneeling pads. Kneeling pads are available at garden supply stores. Capsule closeout can be performed on a launch tower or the bed of a truck, but it's easier if done on a table. Bring a portable folding table to the launch site if the Launch Crew cannot closeout the near spacecraft on a truck bed.

1.2. 1.0.2 Balloon Filling Equipment

Duct tape is used to seal the balloon after inflation. Don't purchase inexpensive duct tape with a weak adhesive. Instead, purchase a duct tape with a really strong and gooey adhesive. Sisal cord is the brown natural fiber cord with lots of frayed threads. The fraying threads increase its surface friction, making it more difficult for its knots to slip. While scissors are needed to cut cords, never let them near the balloon. Have crews cut cord away form the balloon. Electronic fish scales are available at fishing tackle stores. Electronic scales contain something like a strain gauge that determines force acting on them and a digital read-out. The scale measures the weight of the modules making up the near spacecraft and the lift generated by helium in the balloon. Use only one scale to measure both weight and lift, as two separate scales may not be calibrated the same. Anyone handling the balloon is required to wear soft cotton gloves. Gloves prevent abrasive skin from contacting the balloon. Gloves also keep skin oils off the latex of the balloon, where it may weaken the balloon (I don't know this for certain, but the concern has been expressed repeatedly by others). In addition to protecting your investment in the balloon and helium, gloves make balloon filling more comfortable for the balloon crew. Helium expanding out of the tank sucks up heat from filling equipment. Even during the summer, balloon crews will want to wear warm gloves.

1.3. 1.0.3 Stack Assembly Equipment

All knots tied in the load line are taped over with duct tape. The Stack Crew and the Balloon Crew can share the same duct tape, since it takes only a few moments to get the needed tape. Do not use the inexpensive "fake" duct tape. Nylon cord forms the backbone of the near space stack and is called the load line. Load line is used to unite the balloon to the parachute. An inexpensive twisted nylon cord is sufficient. Scissors are needed to cut the load line. As mentioned earlier, use the same electronic fish scale to measure the weight of each module as is used to measure the balloon's lift. Metal rings are used to as a pulley to raise (or lower) the balloon in preparation for launch. Craft stores and the crafts department of retail stores carry a selection of two and three-inch diameter metal rings that are suitable. The rings are made from approximately 1/8" diameter wire and are used for crafts like macramé. Even if the ends of the rings are welded together, cover the weld (or butt joint) with a wrap or two of duct tape. The tape smoothes the joint and protects the lanyards from getting cut as they brush against the sharp joint. One ring is needed for a launch and the ring is reusable if the capsules are not separated from the balloon. If flight termination units (FTUs) are used on near space missions, then one ring per launch is needed. Regardless, purchase at least half a dozen rings to ensure having one on hand at launch. A roll of sisal line is needed to tie off the balloon. Sisal line has a rough surface from its exposed threads and is less likely to come untied. The Launch Crew needs access to a calculator with solar cell backup. Don't rely solely on the human brain for mathematical calculations when attempting to launch a minimum lift balloon. Forgetting to carry the one from an addition dooms the flight to bouncing across the ground rather than ascending into near space. Rather than risk someone forgetting his or her calculator, toss an inexpensive calculator into the launch equipment. If you're not supposed to rely solely on the human brain for calculations, you should not rely solely on the human memory to recall launch calculations and plans. Have a small white board and dry erase marker handy at the launch site to record launch plans like weights and lifts. Barring a white pad, at least have access to a note pad and pencil to document the same information (don't forget to bring your notes back with you for use in a final report on the mission – please do not litter). Before launch the interior space of each module is filled with loose Styrofoam peanuts. Purchase the real peanut-shaped peanuts and not the disc-shaped peanuts. Do not use the cornstarch based biodegradable peanuts that turn to mush when exposed to water unless you want to hose out the modules of the near spacecraft. Stores like Mailboxes Etc sell Styrofoam peanuts. Use clean peanuts, do not use recycled ones. Finally purchase a mesh laundry bag to store the Styrofoam peanuts. Along with some mesh laundry bags; stores sell an opened plastic frame for holding the bag open. Purchase one of these if you can find it.

Styrofoam Peanuts - *in mesh laundry bag*

1.4. 1.0.4 Miscellaneous Tools

Miscellaneous Tools

The miscellaneous tools are seldom needed, but at times they are needed, they will save a launch. A set of wire cutters are needed to perform surgery on the avionics or to cut bad zip ties. If a nylon line must be cut in the field, use the lighter to melt the cut end of the nylon line to prevent it from fraying. There should be no frayed nylon lines, either melt them or cover them in duct tape. A quick wipe with a lens brush before launch allows the near spacecraft to return higher quality images. Keep spare shipping tags with the launch equipment to label capsules with lost or damaged shipping tags or for those times when the original shipping tag needs to be updated at the last minute. A digital multimeter (DMM) is needed to measure battery voltages before flight (ensuring discharged batteries are not sent on a mission) and to troubleshoot last minute errors. A DMM is another one of those tools that can literally save a launch. Flashlights are needed for those early morning launches. Don't rely solely on headlights, as there are times you need to look into the airframe. Carry spare items like, nuts, bolts, and washers, spare fuses (if used in the avionics), spare BNC barrel connectors for antennas, and twist ties into the launch equipment also. Use a clear plastic container to hold these small items as it makes it easier to determine if the container has the parts needed without having to open it (and risk spilling small parts). Many of the miscellaneous tools are easy to lose, so pack them inside a small box or durable bag. The storage box or bag needs to be closed tightly to keeps item from falling out, so purchase a container with a lid or integral seal like a zip lock seal. Finally several large gym bags or plastic boxes are needed to haul this equipment around.

Besides making it easy to move the launch equipment, boxes or bags keep the launch equipment together and reduce the chances of losing them. Launch equipment lost or left at home ruins a launch. Imagine how aggravating it is to fill a $50 balloon with $75 worth of helium and discover there is no load line at the launch site. Do not use cardboard boxes to store equipment as they are not durable enough in the long run and will eventually let equipment fall out. Divide the launch equipment among several bags or boxes or else it becomes too difficult for one person to move the bags. Besides, packing lots of equipment into a container too small results in broken equipment. The bed sheet and kneepads are large enough to need their own bag. Besides, you don't want potentially dirty bed sheets and kneepads inside the other equipment bags. The balloon should have its own bag or box. Do not carry other equipment in the same container as the balloon.

Balloon and Bag

The possibility of damage to the balloon is too great. Wrap the balloon with an inexpensive towel for additional cushioning and remember to not remove a balloon from its shipping bag until it is ready to be filled. Finally, label every bag or box with its contents or function. Keep all the launch equipment containers stored together and only use them to launch balloons.

1.5. <u>1.0.5 Hauling Helium Bottles</u>

The tanks of helium used to fill weather balloons weight around 120 pounds. With all that helium inside of them, you would think they would be lighter. Hauling helium tanks that are free to roll around creates one heck of a noise when they crash into each other. Never haul any pressured gas cylinders this way. Cylinders must be restrained during transport and storage. It's safest to move tanks in the back of an opened truck, as opposed to the confined volume of a car. Use strong nylon tie-down straps to restrain the tanks if the car is durable. Some cars have tie down points that are too weak for two 120-pound tanks. Rather than damage the car pack a blanket around the tanks to keep them from banging into each other every time the car or truck makes a turn. Due to their restraining system, welding supply stores move their helium tanks standing up.

Remove jewelry and watches when carrying tanks, as their weight will damage them (two people can carry a tank). At the launch site, place the tanks on their side; do not leave them standing up.

2.0 Support Equipment To Be Built

There are several items that are not readily available off-the-shelf, and must be built before launching your first near spacecraft. I recommend building them in conjunction with the near spacecraft so they can be completed before the near spacecraft. Finishing them before the near spacecraft allows training and gives launch crews the chance to practice procedures. Items to construct include the following.

- Weighing Frame
- Balloon Filler
- Two Launch Lanyards and a lanyard release
- Launch Tower
- Warning Signs

2.1. Weighing Frame

To make it easier to weigh the modules of the near spacecraft, construct the weighing frame described below.

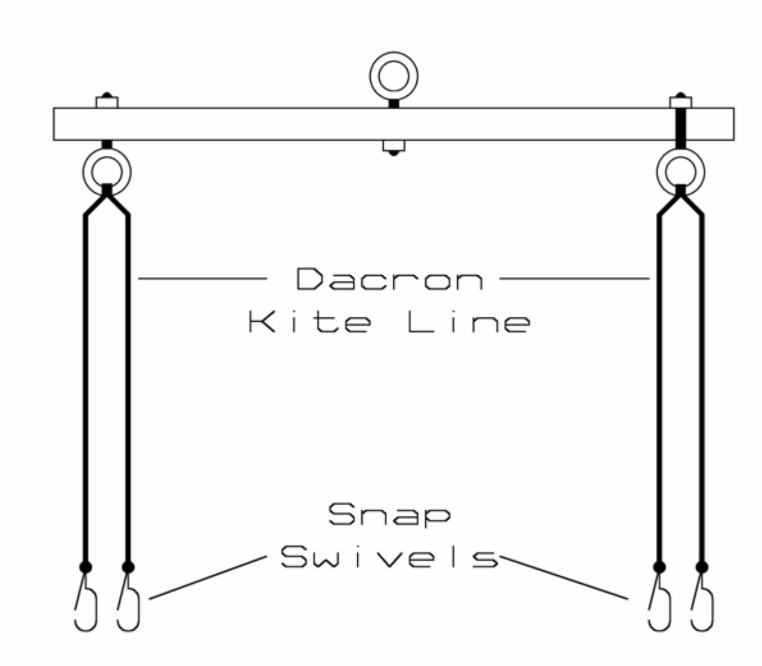
Weighing Frame - *Mark Conner (N9XTN) and Dan Miller (KC7SLC) weighing a module of a near spacecraft*

2.1.1. Materials

- 3/4" square pine trim, twelve inches long
- Three inexpensive eyebolts, nuts, and washers
- Four snap swivels (use the larger ones)
- Woven Dacron kite line, #200 test
- Printed sign and laminator
- Two #6-32 mounting hardware, one-inch long

2.1.2. Procedure

√ Locate and mark the center of the ¾" pine trim
√ Mark one inch from both ends of the ¾" pine trim
√ Drill three holes at the marked locations that are large enough for the eyebolts
√ Bolt the eyebolts to the ¾" pine trim



Eyebolts in Weighing Frame

Note: The two eyebolts at the end terminate on the same side and the middle eyebolt terminates on the opposite side of the ¾" pine trim

√ Cut two lengths of woven Dacron kite line three feet long and melt the cut ends
√ Find and mark the center of the kite lines
√ Tie the Dacron line at its middle into the two eyebolts located at the end of the ¾" pine trim
Note: Use a simple overhand knot
√ Tie the snap swivels to the ends of the woven Dacron
Note: This is one of the few places you can use snap swivels in a near space program
√ With a word processor, type a sign saying something to the effect,

√ Weigh the modules and any FTU and beacon
√ Add the weight of the parachute

√ Laminate the sign
√ Bolt the sign to the side of the weighing frame

2.1.3. Using The Weighing Frame

To use the weighing frame, slip the open snap swivels into the lift rings of the module to be weighed. Hook the electronic scale into the center ring of the frame and lift the module. Read the weight after the scale reading settles down. Record the measured weight on a white board or pad of paper. Don't rely on memory, as an under filled balloon is only suitable for plowing a field and is very difficult to correct.

2.2. Balloon Filler

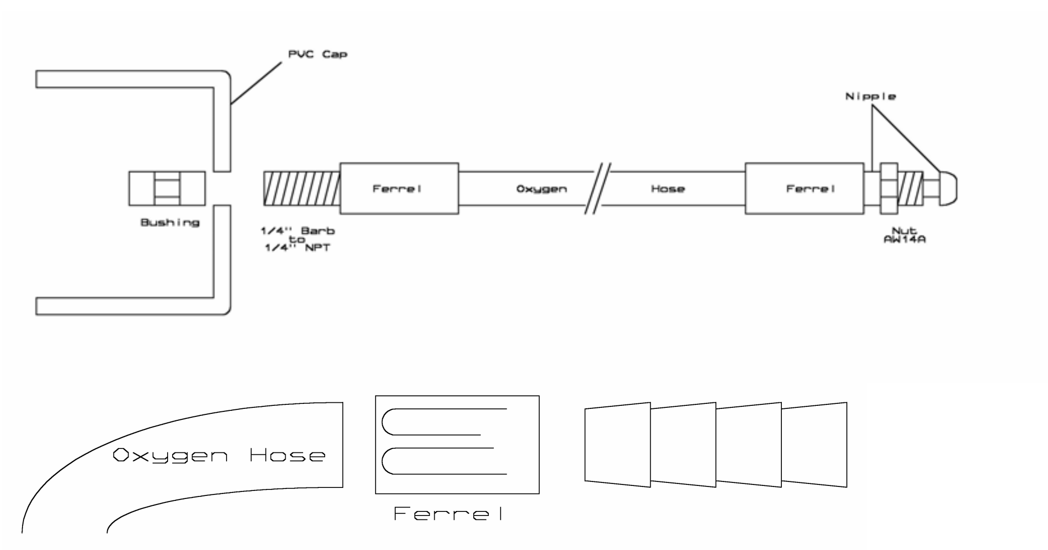
A weather balloon requires on the order of 300 cubic feet of helium, an amount that a toy balloon filler is incapable of providing in a reasonable amount of time. There is no known commercially available filler capable of handling a 300 cubic foot balloon. The filler described here is design specifically for weather balloons and is constructed with inert gas components (components use right-handed threads).

Balloon Filler

2.2.1. Materials

Visit your local welding supply store for the following parts (support your local businesses when possible). Your welding shop may use a different supplier, but the parts listed are commonly used in welding.

- One Helium Regulator[A]
- Ten Feet of 200 PSI 1/4" ID Oxygen Hose
- One 541 ¼” barb to ¼” NPT (National Pipe Thread)
- One BF 4HP Female to Female Bushing
- One AW15A
- One AW17 Nipple
- One AW14A Nut
- Two 7325 Ferrules



***Oxygen Hose** – Diagram of Parts*

The remaining items are available at your local hardware store

- A six-inch length of 1 1/4" PVC pipe
- A 1 1/4" PVC cap
- PVC cement
- Epoxy or RTV
- Sisal cord
- Duct tape

2.2.2. Procedure

Regulator Modification

√ Remove the string cutter if the regulator has one
Note: The string cutter is used to cut strings for toy helium balloons and has a sharp edge

√ Remove the tilt valve
Note: The tilt valve is the rubber filler value for toy balloons. The tilt valve is sealed when straight and lets helium flow when tilted

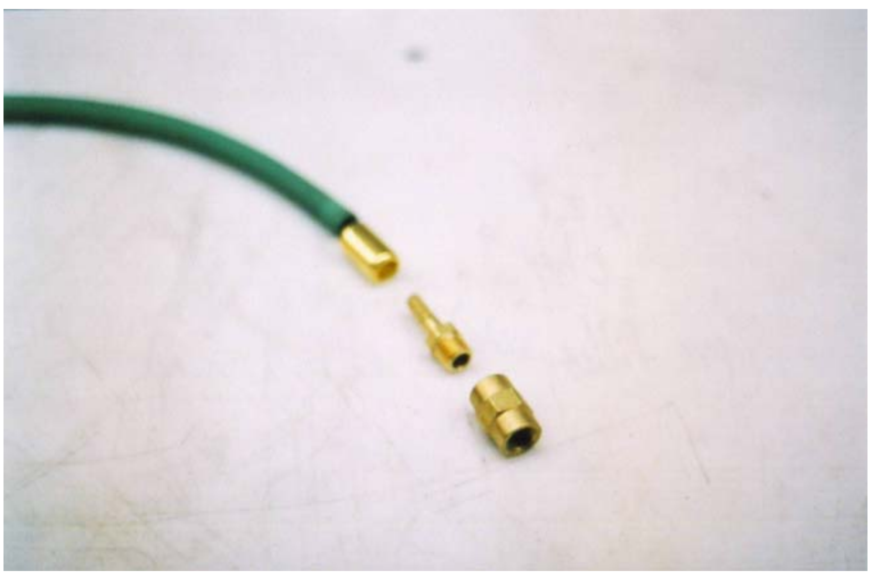
Oxygen Hose

Ask a Welding Shop to do the following

On one end of the hose, install the following:

- 7325 Ferrule
- 541 ¼” barb to ¼” NPT

This end of the hose connects to the PVC pipe



PVC Filler Side of oxygen hose

On the other end of the hose, install the following

- 7325 Ferrule
- AW17 Nipple
- AW14A Nut

This end of the hose connects to the regulator through an AW15A

Regulator Side of oxygen hose

PVC Filler

- √ Screw AW15A into regulator end of oxygen hose
- √ Screw AW15A into regulator
- √ Find and mark the center of the PVC cap (don't sweat if it's not perfect)
- √ Drill a 1/4" hole in the bottom of the PVC end cap.
- √ Pass the male pipe into the hole in the PVC cap
- √ Bolt the PVC cap to the hose with a BF 4HP Bushing
  Note: At this point you should have an ¼" hose that is secured tightly to a PVC cap
- √ Fill around the BF 4HP Bush with either epoxy of RTV
  Note: This makes an airtight seal around the ¼" hose where it enters the PVC cap
  Note: Be careful you don't overfill the cap, as you still have to glue the PVC pipe into it.
- √ Let the adhesives set over night
- √ Look over the fill making sure there are no open gaps that can leak helium gas

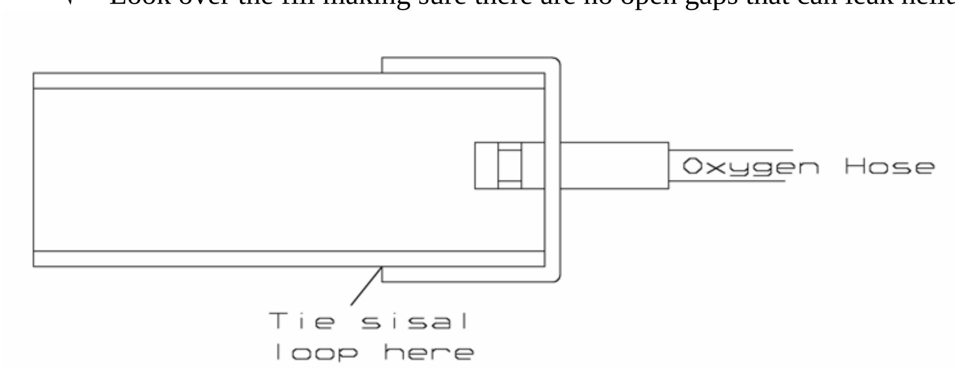


Diagram of PVC End of hose

- √ Sand the ends of the PVC pipe to make it free of burrs that may abrade the balloon nozzle
- √ Test the fit of the cap and pipe and ensure the PVC pipe seats deeply into the cap where the PVC cement can weld them together
- √ Cement the PVC pipe into the PVC cap with PVC cement
- √ Let the cement set for a couple of minutes before testing the connection.
- √ Cut two feet of sisal cord
- √ Fold the sisal in half and tie to the bottom of the PVC pipe, where it meets the PVC cap
- √ Wrap the sisal in duct tape where it is tied around the PVC pipe

Close-up of filler end

2.2.3. Using The Filler

- √ Screw the regulator into the helium tank
  Note: Only make this connection hand tight, it doesn't require tools to tighten the regulator to the tank
- √ Insert the PVC pipe of the filler into the nozzle of the balloon
- √ Wrap the pipe and nozzle in duct tape to keep the balloon from slipping lose
  Note: Some groups, like EOSS use a hose clamp for attaching the balloon nozzle to the filler. KNSP used the same techniques for its first balloons. The author has not found them necessary if quality duct tape is used. However, when using a hose clamp, only use a nut driver to tighten and loosen the hose clamp and not a straight bladed screw driver (bad news around a balloon).
- √ Begin filling the balloon
- √ Connect the electronic fish scale to the sisal loop to measure the balloon's lift
  Note: The filler adds weight to the balloon, so the scales measured lift is a little lower than the actual lift amount. Minimize the length of hose hanging from the filler when making the lift measurement of the balloon. This is not as important of a factor if the balloon is filled outdoors in a gentle breeze. The wind affects the lift measurement of the balloon, making it less accurate.

2.2.4. Additional Optional Modifications

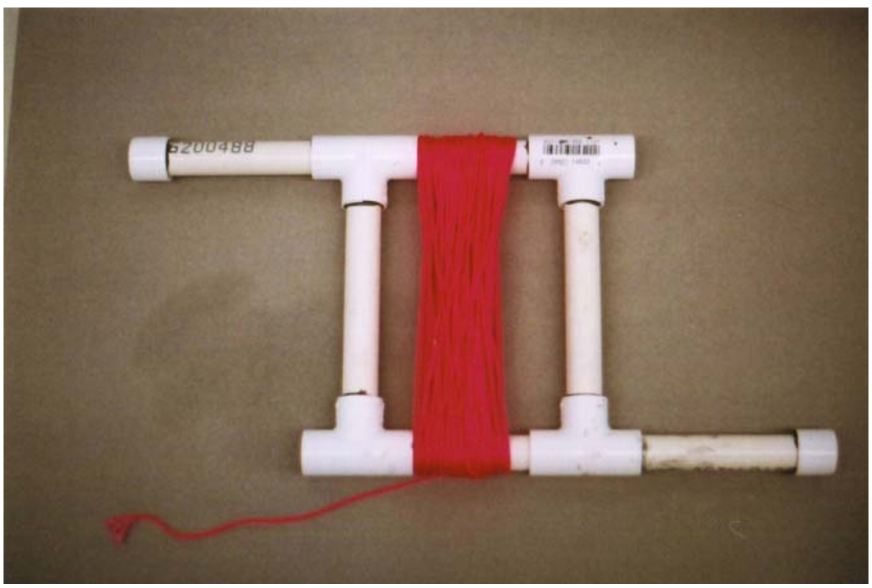
Large balloons like 2000 and 3000-gram balloons have larger nozzles than the balloons most commonly used. The author has not found it necessary to change the diameter of the PVC pipe of the filler for these larger balloons. The excess nozzle is wrapped around the pipe and the entire nozzle tapped down. Other amateur near space groups use adapters to increase the diameter of the PVC pipe when filling these larger balloons. If you desire to use this method, then purchase the next size lager PVC pipe (1-1/2" PVC?) and an adapter for 1-1/4" to 1-1/2" PVC. Cement the adapter to the larger PVC pipe and store in a bag along with the rest of the filler. To use it, tape the adapter to the filler then attach the balloon nozzle. Taping the adapter ensures it does not come lose while filling the balloon.

2.3. Launch Lanyards And Lanyard Release

It is difficult to control the raising of a balloon when your only grip is on the load line. Handling just the load line increases the chances the balloon slipping free, resulting in a painful string burn. Handling just the load line also places greater stress on the load line or near spacecraft. Using a set of launch lanyards reduces the risk of string burn while launching a near spacecraft, reduces the chance of breaking a load line due to G snaps, and makes it easier and less tiring to raise the stack. The lanyards and lanyard ring act as pulleys that raise the stack off the ground without jerking snaps acting on the load line.

The launch lanyard forms a tripod structure around the stack. One person on the lanyards (the one with the ½" diameter PVC pipe) is the lanyard release. The two other people control the kite winders. Crews holding the winders raise the balloon keeping it under full control. There is virtually no risk of string burn with this system. The lanyards and kite winders method allows the balloon to safely be lowered if necessary.

In the past I have purchased a pair of kite winders for the lanyard lines ($7.00 for a small winder). To keep the cost down I used small kite string winders. They were sufficient to hold the line, but being small, they made it difficult to raise the stack smoothly. Every turn of the small winders sent snapping shocks up the lanyards to the balloon neck. I've made larger winders from wood in the past, but those required tools that many people do not have at home. Mark Conner (N9XTN) recommended I use winders made from PVC pipe similar to the ones he makes. So here are the instructions I developed from Mark's concept. Thanks for the idea, Mark. Modify these directions as necessary.



PVC Winder

2.3.1. Materials

- Six feet of ½" PVC pipe
- Eight ½" T's
- Four ½" caps
- One can of PVC cement (use the smallest can)
- Small saw (an Exacto saw or hack saw works well)
- Beaded chain

- Two enclosed blade letter openers or seat belt cutters

Note: The total cost for PVC materials is about $6.00

2.3.2. Procedure

√ Cut the ½" PVC pipe as follows
√ Four pieces 4" long
√ Four pieces 5" long
√ Four pieces 6" long

√ Divide the pieces into two piles. Each pile constructs a single winder.

PVC glue gives a few seconds to work with it. So first glue together the pieces that don't have critical alignment issues.

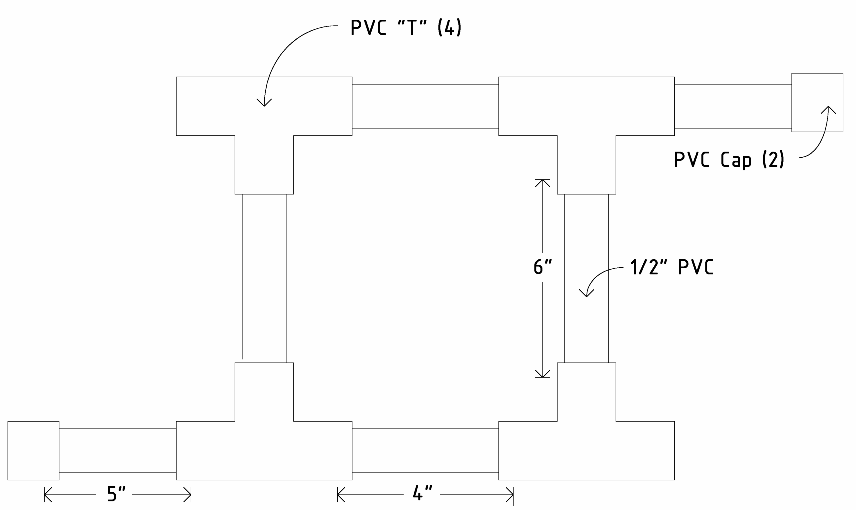
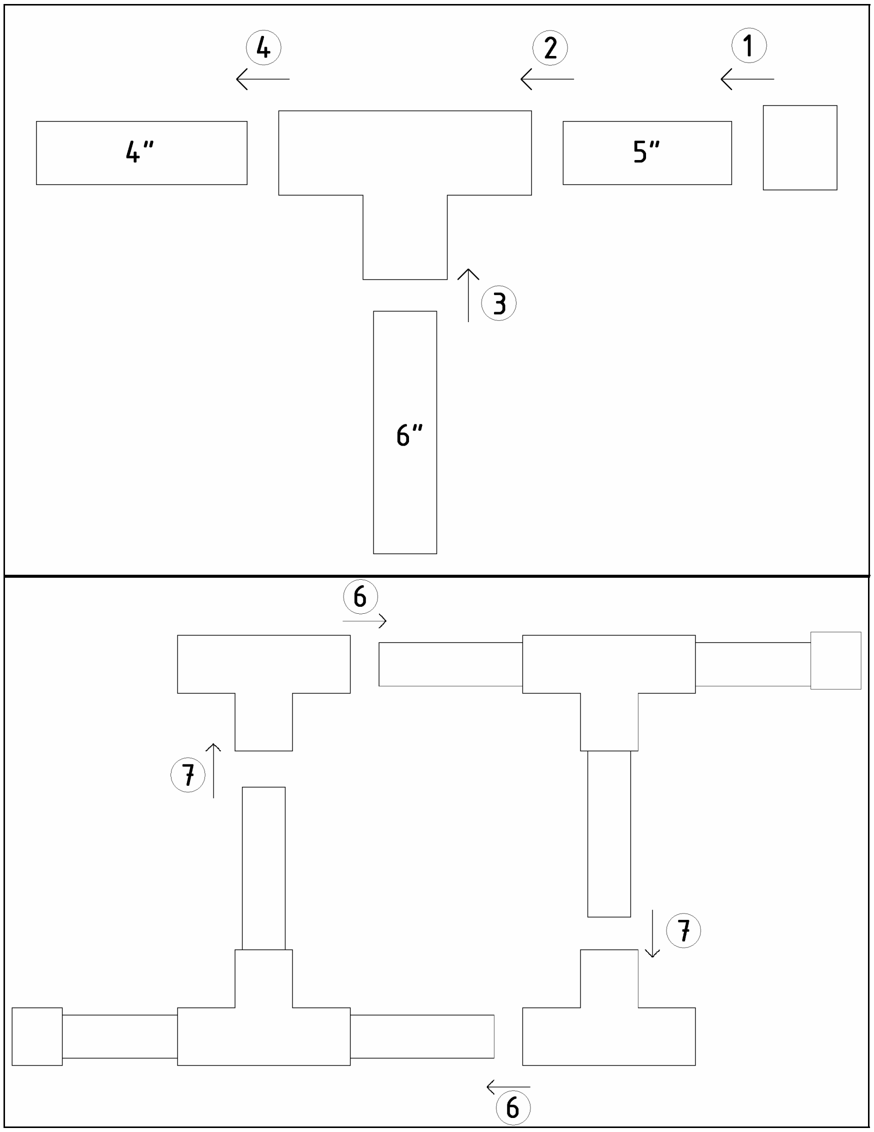


Diagram of PVC Winder

√ Glue a cap onto the end of a five-inch length of pipe
√ Repeat for the second cap and five-inch pipe
√ Glue the open end of the five-inch pipe into one arm of a T
√ Repeat for the other five-inch pipe and a second T
√ Glue a six-inch pipe into the center port of the above T
√ Repeat for the second T and six-inch pipe
√ Glue a four-inch pipe into the remaining arm of the first T
√ Repeat for the second four-inch pipe and the second T



PVC Winder Assembly Steps

In Rapid Succession

- √ Glue the remaining T's onto the open end of the four-inch pipe and them glue the two halves together to finish the winder
- √ Lay the completed winder on a flat surface and press down on its corners
- √ Let the PVC cement set for an hour

There's raised lettering on the center port of the T's. Two of those will rub against the hands of crews using the winder, so file off the raised lettering and smooth the surface of the T's.

- √ Cut one last piece of PVC pipe to a length of twelve inches (the lanyard release)
- √ Sand the cut ends smooth

Winding String On The Kite Winders

First I have several notes about winding the lanyard lines to the winders. It's helpful for the Launch Crew if the two lanyards lines use different colors. Do not tie the line to the winder as the winder must fall free of the lanyard lines should the lanyard and winders accidentally get launched with the stack. When the winder is tied to the end of the lanyard, its weight may let the lanyard wrap around the parachute and shroud lines. This is not a problem during the ascent of the stack, but is big trouble during the descent after balloon burst. Without weights hanging off the ends of the lanyard cord, the cord tends to swing away from the parachute when the stack spins during the ascent. If the lanyard line is twisted when it is wound on the winder, then the lanyard line will untwist itself in the air when released from the PVC release and will tie a knot in the lanyard ring. The untwisting lanyard can tie a knot in the lanyard ring, snagging the lanyard ring and preventing the launch. So wrap the lanyard lines on their winders by laying the lanyard on the ground first, and then wrap it onto the winder. Do not wrap the line onto a stationary winder, but instead wind the winder, taking up the lanyard line. This method will reduce the chances of twisting the lanyard lines as they are wound on the winders.

- √ Since the near space stack is about 50" tall, wind at least 200' of 1/16" woven nylon line on each winder
- √ Melt the ends of the lanyards with a lighter
- √ Tie a one-inch diameter loop at the free end of the lanyard line

An option to think about
The loop at the end of lanyard represents a place to snag the lanyard ring. Not tying a loop in the end of the lanyard may be an option if the Launch Crewmember holding the lanyard release can hold the ends of both lanyards to the lanyard pipe with his or her thumbs. Better yet is to wrap the ends of the lanyards around a short length of separate PVC pipes. The combination of the friction from wrapping of the lanyard and thumb pressure may keep the lanyard securely on the release pipe until it is time to release the stack. At this time, this method has not been tested.

Finishing the winders by adding the emergency cutaways

- √ Drill a small hole in one of the handles of each winder
- √ Drill a hole in the letter opener or seat belt cutter
- √ Use the beaded chain to attach a cutter to each winder

Finished Winder

2.3.3. Using The Launch Lanyards

Follow this procedure after the balloon is filled and the lanyard ring is attached

- √ Pass the looped ends of both lanyards through the same side of the lanyard ring

- √ Pass the lanyard release through both loops
- √ Raise the balloon (explained in detail in Chapter Ten, Section Six)
- √ Release one lanyard at a time
- √ Use the emergency cutaway to slice the lanyard should it get knotted on the stack's lanyard ring or if unsafe wind levels begin picking up

2.4. Launch Tower

***The Launch Tower –** Holding the assembled near spacecraft. The modules and parachute are all linked up. Mr. Bunny will skydive from 50,000 feet on this mission.*

Module closeout and testing can be performed on a table at the launch site. But when it comes time to connect their link lines and umbilical together, invariably the link lines get twisted around one another. To prevent the twisting, place the modules to a gantry-like structure that supports the modules in a flight-like configuration. The spacing between the modules is shorter then they are in flight, but good enough for linking the modules together correctly. The gantry also provides a structure for mounting laptops, heaters, extension cords, and wheels. Why wheels? Once the near spacecraft is assembled on the gantry, the gantry also acts like a dolly. One person can move the entire near spacecraft around, if necessary.

The launch tower described in this section has two removable platforms for setting the near spacecraft modules on. The platforms are removable to make it easier to transport the tower. On the back of the gantry are two optional coat hooks for wrapping an extension cord. The extension cord provides power to the tower if an outlet is available. Long Velcro straps attached to the side of the tower lock the modules against the gantry. This way the modules can't shift around or fall off. The Velcro straps extend around the back of the tower where they can strap the parachute to the back of the tower.

2.4.1. Materials

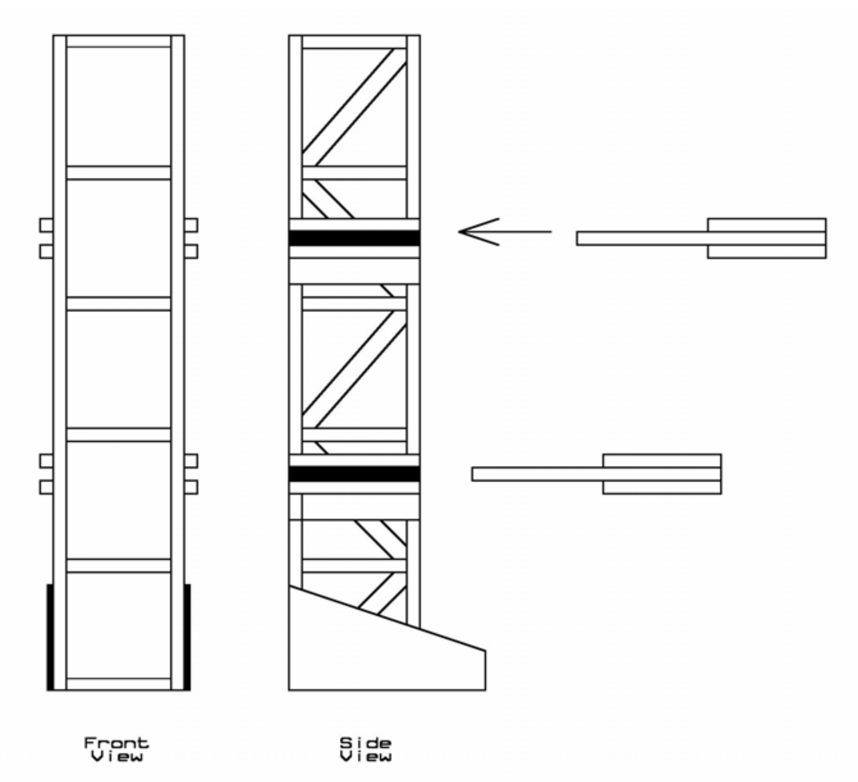
- ¾” square pine trim
- 1/8” plywood door skin
- ¾” thick Styrofoam
- At least twelve feet of one-inch wide Velcro tape (non-sticky back variety)
- Assorted fasteners like screws and finishing nails
- Wood glue
- Paint (red and white is traditional)

- 70-pound bag of tube sand (traction sand for cars and trucks)

Note: The TVNSP launch tower was constructed in a kitchen using hand tools and clamps.

2.4.2. Procedure

Built the tower to suit your specifications. The directions below describe how TVNSP built its launch tower.



Launch Tower – *Side View (left) with sliding trays, Front View (right) shows rails for sliding trays.*

Tower

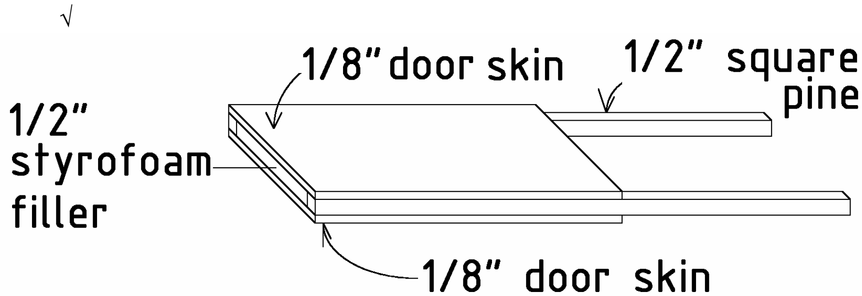
The TVNSP launch tower is six feet tall and made up of six, one-foot tall repeating units. Cross braces are glued diagonally between levels of the tower. Occasional sheets of 1/8” plywood door skin covers sides to strengthen the tower. The TVNSP launch tower is not as wide as an airframe, so the left and right sides of airframes extend beyond the edges of the launch tower.

√ Cut four lengths of pine to match the height of the tower (these are the vertical elements
√ of the tower)
Note: TVNSP extended the length of the front two vertical elements by six inches to

- √ restrain the parachute ring
- √ Determine the width and depth of the tower
- √ Cut multiple units of pine to match the width and depth of the tower
- √ Glue and nail the tower sides together
- √ Measure the length needed for the diagonal cross braces
  Note: The cross braces need 45-degree cuts in their ends to fit within the tower side
- √ pieces
- √ Cut the cross braces out and trim the corners
- √ Glue and nail the cross braces into place
- √ Cut four pieces of pine trim to form a rectangular ring for the bottom of the tower that is
- √ the tower's width but twice it's depth (this will become the tower's base)
- √ Glue and clamp the ring together
- √ Cut plywood door skin to the same dimensions of the ring
- √ Glue and clamp the door skin to the bottom of the ring
- √ Attach the ring to the base of the tower with the door skin on the very bottom
- √ Measure the length of pine trim needed to make cross braces between the tower and it's base
- √ Glue and clamp the braces to the tower and its base
- √ Cover with more door skin if necessary
- √ Determine where you want to attach plywood door skin faces
  Note: The TVNSP launch tower has them primarily at the top and bottom of the tower

Platforms

- √ Measure the width of the launch tower
  Note: You need an accurate measurement; don't use the planned dimensions of the tower, measure it to be sure
- √ Determine how long you want the platforms to be (platform depth)
  Note: TVNSP platforms extend about ten-inches from the tower
- √ Cut two pieces of ¾" Styrofoam to the measured width of the tower and to the desired platform depth
- √ Cut four pieces of pine trim to a length equal to depth of the tower and the extension length of the platforms (platform rails)
- √ Lay two pieces of pine beside the cut Styrofoam with one pine trim on each side
- √ Measure the width of the Styrofoam and pine (the platform width)
- √ Cut four pieces of 1/8" plywood door skin to a dimension of the platform width and the platform depth
- √ Glue and clamp the platform rails to the sides of the face of the platform with the Styrofoam between the rails
- √



X-Ray View of Launch Tower Platform

- √ Trim the extra Styrofoam from the platform
  Note: TVNSP feed the platform through a sanding planner to make the Styrofoam and rails the same thickness
- √ Glue and clamp the second plywood door skin face to the platforms

Note: A cast iron corn muffin pan comes in handy here

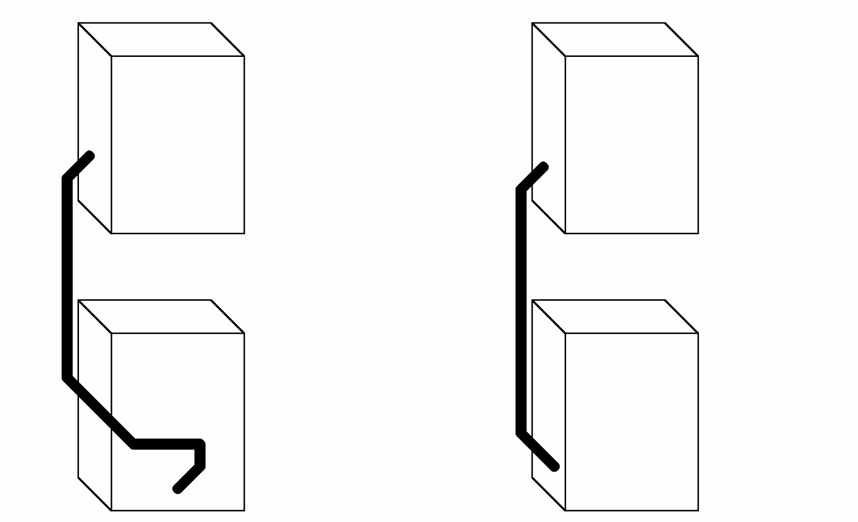
√ Cut eight pieces of pine trim to a length equal to the measured depth of the launch tower
√ Temporarily clamp the platforms to the launch tower at the desired heights
Note: You may have to trim the inside edges of the platform rail to get them to slide on and off the launch tower
Note: Place an airframe on the platforms when doing this to ensure the spacing of the platforms is sufficient
√ Use a carpenter's level to make sure the platforms are level
√ Glue and clamp one piece of pine to the launch tower beneath each platform rail (remove the platforms before they have a chance to glue to the tower)
Note: At this point you are attaching a two-piece railing to the tower for the platform rails to ride in
√ After the glue dries, slide the platforms back onto the tower
√ Glue and clamp a second piece of pine above each platform rail (again remove the platforms before they have a chance to glue to the launch tower)
√ After the glue dries, test fit the platforms
√ Add narrow pieces of plywood door skin above and below the tower rails to strengthen them
√ Strengthen all weak joints in the tower
√ Paint the tower
Note: Radio towers have seven bands of color, with red as the top and bottom color and bands of white between

2.4.3. Using The Launch Tower

Note: Store the launch tower with the Velcro straps attached to each other
On launch day do the following

√ Set up the tower near the balloon
√ Lay a bag of sand on the feet of the launch tower for stability
√ Unstrap the Velcro bands
√ Insert the platforms
√ Place the modules on their proper platforms and proper orientation
√ Strap the modules to the tower with the Velcro bands
√ Attach link lines between modules
√ Attach the umbilical (if there is one) between the modules

Note: The umbilical should run along the same side of both modules and not wrap around



Umbilical Placement – *The left diagram shows bad umbilical placement, resulting in a twisted umbilical. On the right, good umbilical placement, keeping the entire umbilical on the same side.*

- Attach parachute to the top module

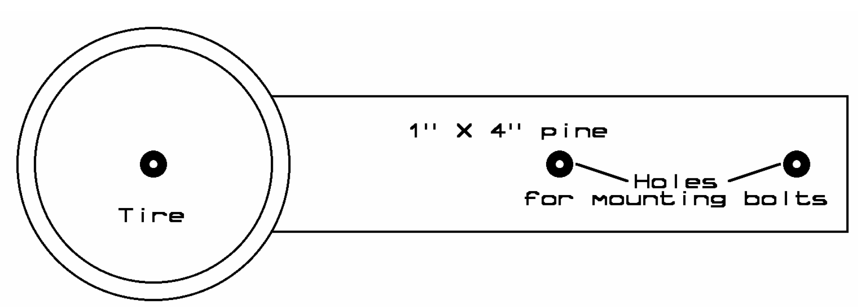
  Note: Have a second crewmember verify the split key rings are still properly attached to the Dacron loops of the abrasion jacket. Often, when someone is attaching a swivel to a split ring, they begin disconnecting the split ring from the Dacron loops of the abrasions jacket.

- Drape parachute over the back of the tower and Velcro it to the launch tower

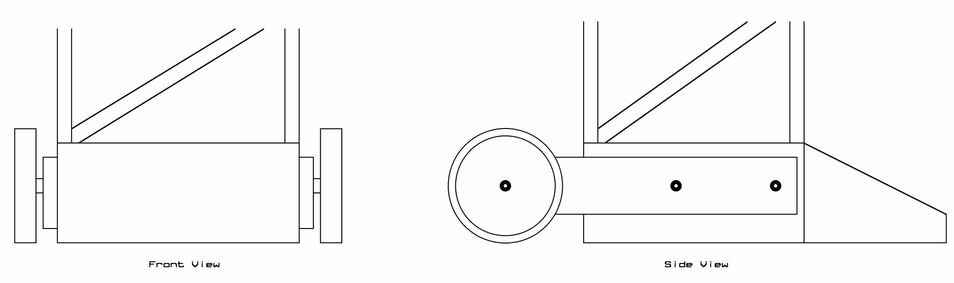
2.4.4. Possible Modification To Launch Tower

Tower Wheels

Two balloon tires and handles can be added to the back of the gantry. Mounting tires to a wide base increases the tower's stability. One person can pull back on the handles and shift the weight of the tower and modules to the wheels. Then the tower is moved around like a hand truck or dolly. Don't mount the axle and balloon tires permanently to the tower. By removing the wheels, the tower can be packed into the back of an SUV or truck without taking up as much space.

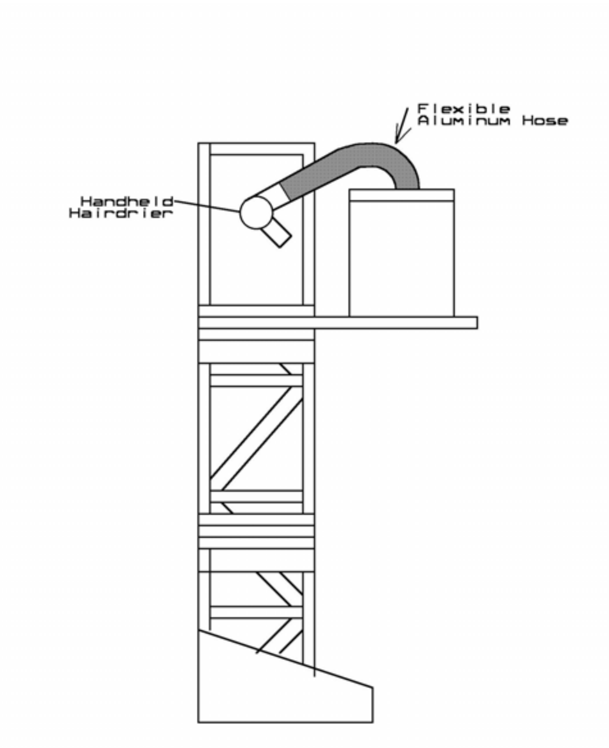


Wheel Diagram – *Make two. Use wing nuts on the wheels so they are easy to remove.*



Front and Side View of Wheels Mounted to the Launch Tower - *You could leave the mounting bolts permanently in the tower.*

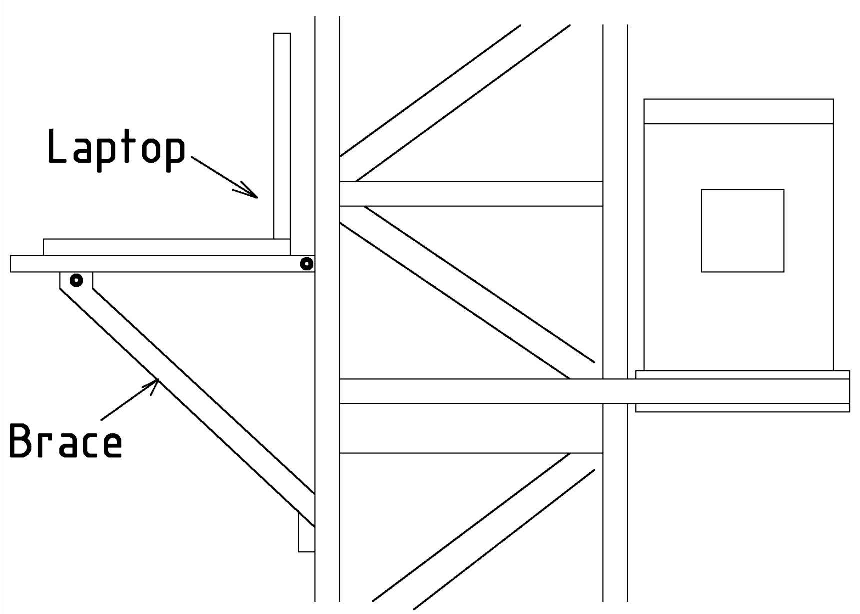
Module Heaters



Launch Tower Module Heater

If an extension cord is available at the launch site, then handheld hair driers can be operated at the tower. The warmed air from a drier at low setting can be directed inside the modules while they wait for launch. The higher internal temperature of the capsules at launch keeps them from cooling down as much during the flight. Be sure the hair driers are set to a low enough temperature that they do not melt the plastic inside the modules. Use flexible aluminum heater duct (or other materials able to withstand the heat) to direct heat flow into the modules.

Laptop Table On Tower



Laptop Table – *Place the laptop on the back of the tower so its weight is balanced by the near spacecraft modules*

Another possible modification to the launch tower is to incorporate a removable table or platform for a laptop into the tower's design. A laptop platform allows the closeout crew to monitor the near spacecraft before launch while it's still sitting on the launch tower. They can also load test programs into the near spacecraft before launch, letting them test experiments on the near spacecraft. Be sure the closeout crew loads the flight code into the flight computer before the launch. Launching the near spacecraft with test code makes for a real bummer of a flight.

2.5. Warning Signs (optional)

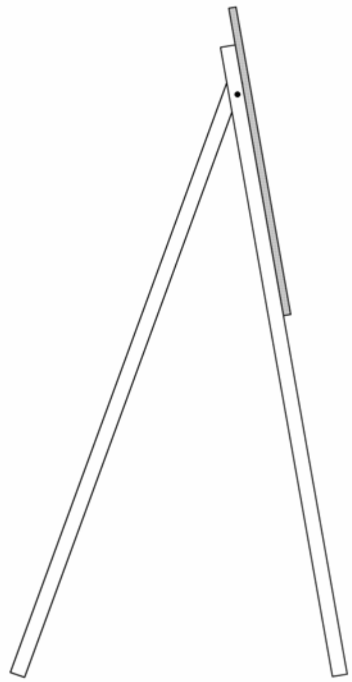
While filling the balloon, people may not be cognizant of the hazards they pose to the balloon. Placing warning signs near the balloon can help. The signs are designed to warn spectators and crews that the balloon envelope is fragile and that no sharp objects are allowed near it. Bursting a filled balloon can be a $150 loss! It's fine to lose the balloon once the stack makes 90,000 feet, but an entirely different matter if the balloon makes an altitude of zero feet before the balloon bursts. Signs should specifically state that rings, bracelets, and other jewelry are not permitted near the balloon. The procedure described here explains how KNSP made a warning sign for balloons. TVNSP crews fill balloons out of doors where spectators tend not to get close to the balloon, so they do not use warning signs (at this time).

Warning Sign – *"Caution – Balloon Filling in Progress. No sharp edges including rings and bracelets allowed near the balloon. Wear cotton gloves before handling balloon or lift line."*

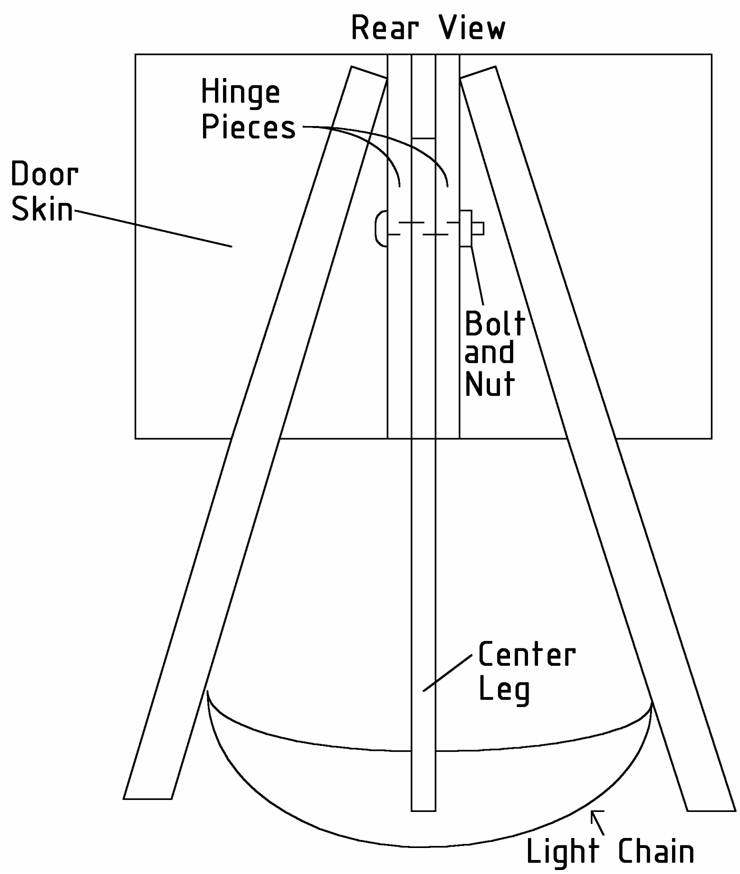
2.5.1. Materials

- ¾" square pine trim
- 1/8" plywood door skin or masonite
- Light duty steel chain
- #6-32 mounting hardware
- Fluorescent paper
- Laminator

2.5.2. Procedure



Warning Easel – *Side View*



Warning Easel – *Rear View*

√ Cut three pieces of pine to a length of four feet (legs)

- √ Cut two pieces of pine to a length of 12 inches (hinge pieces)
- √ Cut a piece of door skin into a triangle about 12 inches high and 18 inches wide (easel face)
- √ Clamp two of the legs to the sides of the door skin so that they spread out at a 30-degree angle
- √ Find the center line of the door skin
- √ Clamp the hinges to both sides of the third leg with their tops flush
- √ Mark about 1-1/2 inches below their top
- √ Drill a hole through the hinges and center leg
- √ Run a #6-32 bolt, washers, and nut through the hinge and third leg
- √ Clamp to the two hinges and third leg to the center line of the door skin, with hinge pieces extending about three inches above top of the easel face
- √ Verify the third leg can swing out from the door skin
- √ Glue and screw the two side legs and the hinges to the door skin
- √ Cut a length of pine trim to a length equal to the bottom width of the door skin
- √ Glue and screw the pine to the bottom of the door skin
- √ Bolt the chain to the legs, near their bottom, to keep them from spreading out too far

- √ With a word processor, make a warning sign
- √ Print the sign on fluorescent paper
- √ Laminate the sign for durability
- √ Clamp the sign to the folding easel

Good To Know - Lapse Rates, Dew Points, And A Stable Atmosphere

A less dense item floats in a denser medium because it displaces less weight than the same volume of the medium. A warm parcel of air in the atmosphere is less dense than the colder air surrounding it. The buoyancy of warm air keeps it floating (rising) as long as the air parcel remains warmer than the air surrounding it, as can be seen with hot air balloons.

The troposphere is not heated by its exposure to the Sun, but instead by its contact with the ground. As a result, the troposphere cools with increasing altitude. The amount the air temperature changes per change in altitude is called the lapse rate. At the same time the buoyant air parcel rises, the atmospheric pressure around it is lowering. The lowering air pressure forces the air parcel to expand. The Ideal Gas Law[B] states that the temperature of an adiabatic parcel of air lowers as its pressure exerted on it lowers. The term adiabatic means that no matter or energy enters the air parcel. While not strictly true for an air parcel, it is close enough to adiabatic for our needs.

Now add another factor to the change in temperature of our buoyant (and expanding) parcel of air, phase change. Does it take the same amount of energy to raise the temperature of a volume of water by two degrees Celsius from 94° to 96° C as it takes to raise the temperature of the same volume of water by two degrees Celsius from 96° to 98° C? The answer is yes, or close enough for our purposes. How about raising the temperature of the same volume of water by two degrees Celsius from 99° to 101° C. Does it take the same amount of energy as in the last two examples? The answer is a definite no. The volume of water remained in the liquid phase in the first question, but changed phases in the second question. Water cannot remain a liquid at 101° (this is an ideal example)[C] without the water molecules first gaining enough energy to break free of each other (to go from a liquid to a gas). The energy required to change the phase of any liquid to a vapor is called the heat of vaporization. What happens to this energy after water changes phases? It's stored in the motion of the water molecules. Until the water molecules in the water vapor slow down enough to begin sticking together to form a liquid, the energy required to vaporize the liquid remains trapped in the kinetic energy of the water molecules. Note that the water vapor is an invisible gas and not the white-colored steam coming from a boiling teakettle.

Keeping this in mind, what happens when water vapor in the atmosphere changes phase from a gas to a liquid? First we begin to see what was invisible water molecules begin to appear as tiny droplets of liquid water. Since these droplets grow large enough to Rayleigh scatter all wavelengths of visible light, the droplets appear to be white when seen in a large enough quantity. A large enough quantity of water droplets is called a cloud. The second noticeable change is that energy trapped in the kinetic energy of the water molecules in the vapor phase becomes available to warm the air. Remember that the water molecules “absorbed” enough energy to change phases. Now that this energy is no longer needed to maintain the vapor phase of water it has to go somewhere, since energy, like mass, cannot be created or destroyed. As a result the energy is released and heats the surrounding air. The energy released when vapor condenses to form a liquid is called the latent heat.

So now our picture looks like this. The Sun shines on the ground, warming it up. The air in contact with the ground also begins to warm up. A warm air parcel containing water vapor begins rising because it is warmer than the air surrounding it. As the air parcel rises it expands and cools. As long as the air parcel remains warmer than the surround air, it continues rising and cooling until its dew point is reached. At this point, the water molecules begin changing phase from a gas to a liquid. As the water molecules change phase they warm the air parcel. The air parcel continues cooling as it rises, but not as quickly as before the water began condensing. This process is most effective on spring afternoons, when the ground is warming from the increasing hours of sunlight and the air aloft is still chilly from the winter. The Sun’s light only warms the very top layer of ground, but that’s enough to warm the air.

In a stable atmosphere, any air parcel that becomes a bit warmer than the surrounding air will only rise a short altitude before cooling down enough to stop being buoyant. A stable atmosphere has little vertical mixing and if it has clouds, they tend to be stratoform types. In an unstable atmosphere, any air parcel that becomes a bit warmer than the surrounding air will continue rising because it never cools enough to stop being buoyant. An unstable atmosphere has lots of vertical mixing and if it has clouds, they tend to be cumuliform types.

Just to add unnecessary complication, but to be excruciatingly correct, regardless of their temperature, water molecules in the air are always changing from the liquid to the gas phase and back again. At lower temperatures more water molecules transition from a gas to a liquid than transition from a liquid to a gas. But for our purposes, water molecules begin condensing from a vapor a liquid once the temperature drops below the dew point of the gas. The dew point by the way depends on the amount of water vapor dissolved in the atmosphere. Dissolved? Yes, gases can dissolve into each other just as metals are dissolved into each other in an alloy.

The decrease in atmospheric density and pressure ideally follows a simple rate of a 50% change in pressure with every 18,000-foot change in altitude. As a result the temperature of a buoyant air parcel decreases at a fixed rate for every fixed increase in altitude. However, because of the change in phase when the temperature of the air parcel drops below its dew point, there are two lapse rates. Since the air parcel is nearly isolated from the surrounding air, we can refer to these lapse rates as being adiabatic. The lapse rate for an air parcel at a temperature above its dew point is called the dry adiabatic lapse rate. The lapse rate for the same air parcel once its temperature is below its dew point is called the moist adiabatic lapse rate.

The dry adiabatic lapse rate is 5.4° F per 1000 feet and the moist adiabatic lapse rate is between 20 and 40 F per 1000 feet. For those practicing to use the metric system, the dry adiabatic lapse rate is 9.80 C per kilometer (close enough to 100 per kilometer) and the moist adiabatic lapse rate is between 40 and 70 C per kilometer.

Determining Lapse Rates From Environmental Sounders

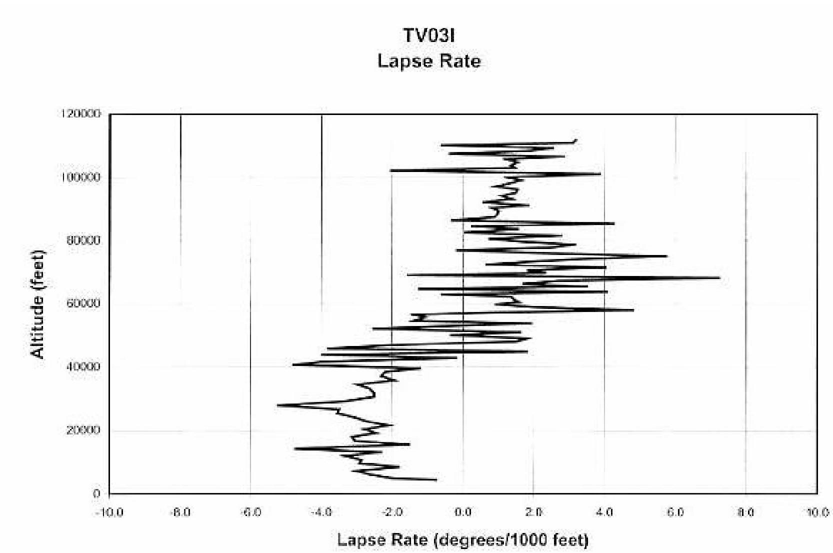
After processing air temperature and altitude data from a near space flight, create a new column for the lapse rate at each recorded altitude. Take the air temperature at a given altitude and subtract the air temperature in the previous record. Divide the change in air temperate by the change in altitude between the two records. Since the lapse rate is given in units of 1000 feet, multiple the results of the previous division by 1000. The equation in each cell looks like this

```
(+D4 – D5) / (+G4 – G5) * 1000
```

Where:
The D column is the altitude in feet column
The G column is the air temperature in degrees F

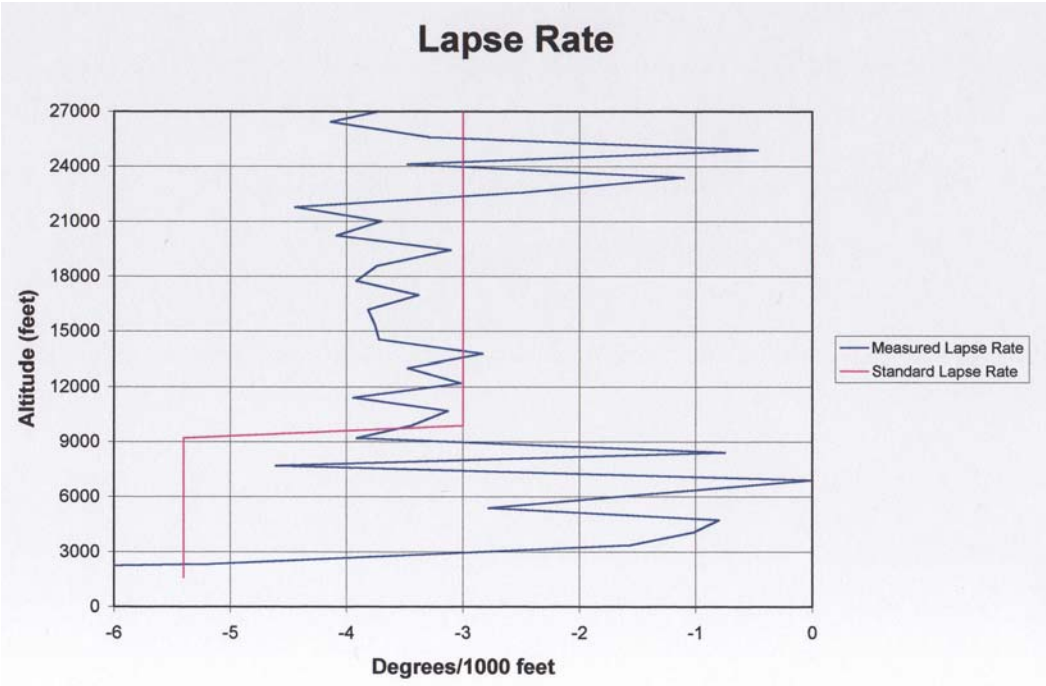
Note: Graphing the lapse rate in the troposphere is more important than in the stratosphere.

Create graph of lapse rate and altitude. Place the altitude in feet in the vertical column and the lapse rate for each altitude in the horizontal column. Label the graph as the Lapse Rate for that particular flight. One thing you'll notice is that the lapse rate is negative in the troposphere and positive in the stratosphere (if calculated there). If you don't observe this, then you've done something wrong in making your graph. You'll also notice that there are a lot of zigzags in the graph. It's not as smooth as we would like. Part if this is due to the fact that the atmosphere really is messy. But it's also due to the fact that the temperature sensor and GPS altitude have errors that are constantly varying in direction and magnitude.



***Lapse Rate Graph –** Lapse Rate (degrees/1000 feet) vs. Altitude (feet)*

So far, so good. But with this graph you can also determine of the if the atmosphere is stable or not. Determine at what attitude the air temperature drops below the dew point. This can be determined by a report from the National Weather Service at the time of launch. You can also determine the dew point at launch yourself with a sling psychrometer. See the next section for directions for making a sling psychrometer and how to use it to determining dew points. Once you have the dew point, insert a new column to the spreadsheet, called the Ideal Lapse Rate. This column has one of two numbers in it, either 5.4 or 3 (the average of the moist adiabatic lapse rates). Put a 5.4 in the column where the row has an air temperature above the dew point and a 3 into the column with a row with an air temperature below the dew point. Now update the Lapse Rate graph with a second series, the Ideal Lapse Rate column and only plot it to the tropopause. Use a different color or different line style for the two lapse rate columns. Now print this graph.



Lapse Rate Graph with Stability Line

When the ideal lapse rate is smaller (more negative) than the lapse rate calculated from flight data, the atmosphere is stable at that altitude. When the ideal lapse rate is greater (more positive) than the calculated lapse rate, then the atmosphere is unstable at that altitude. So in the example above, the atmosphere is stable until an altitude of around 8,000 feet when the dew point is 65° F.

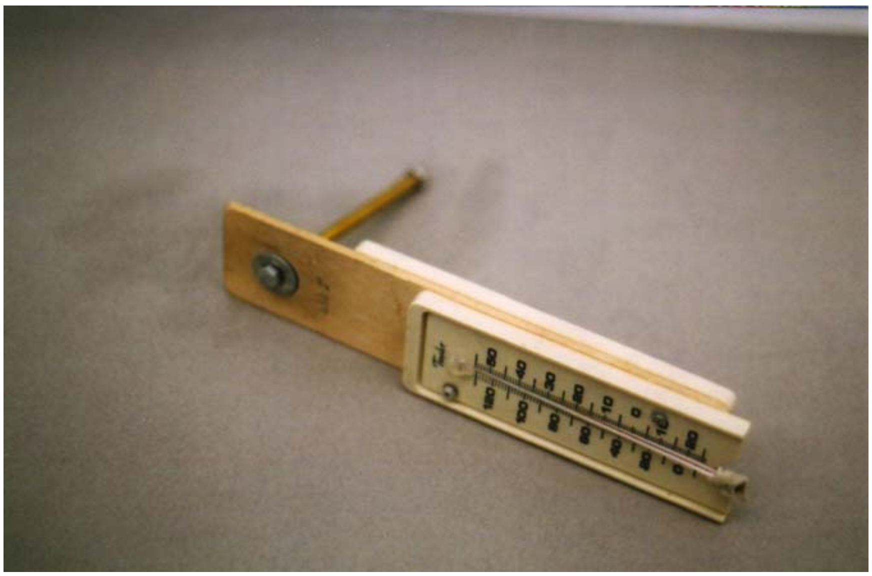
Making a Sling Psychrometer

The sling psychrometer is an instrument for determining the atmosphere's properties in regards to water. Specifically, measurements of humidity and dew point are determined with the sling psychrometer. If a current weather report is not available, then use a sling psychrometer determines the dew point at the time and location of launch. The author has used the design given in this section for a home weather station.

Theory of Operation

Energy is required to evaporate water. That energy can come from an object that the water is sitting on when it evaporates. So a thermometer bulb covered in evaporating water indicates a lower temperature when compared to a dry thermometer bulb because the heat of vaporization required evaporating the water is coming from the thermometer. The amount of cooling depends on a combination of how much heat flows out of the thermometer bulb into evaporating water and how much heat is flowing into the bulb from the surrounding air. How fast water evaporates from the bulb depends on the air temperature and the amount of water dissolved in the air (called the absolute humidity and given in units of grams of water per kilogram of air). The maximum amount of water that can be dissolved into the air depends on the atmosphere's temperature. The ratio of the maximum amount possible to the current absolute humidity is the relative humidity. If the absolute humidity doesn't change, then as the air temperate rises, the relative humidity decreases and as air temperate drops, the relative humidity increases. The temperature at which the air can hold no more water than is currently dissolved in the air is called the dew point. Ideally, at the dew point, condensation becomes visible on cars and grass. In reality, dew usually appears at temperatures above the dew point because of the presence of condensation nuclei. Of course if the dew point is below the freezing point of water, then you don't get dew, but frost instead.

The sling psychrometer[D] consists of two thermometers mounted in close proximity. One is exposed to the air while the other one is covered in evaporating water. The sling psychrometer swings to force air to pass over the thermometer bulbs. The temperatures of the two thermometers are referred to as the dry bulb temperature and the wet bulb temperature. Columns on a table determine the dew point and relative humidity of the air by comparing the dry bulb temperature to the difference between the dry bulb and wet bulb measurements.



Completed Sling Psychrometer

Materials

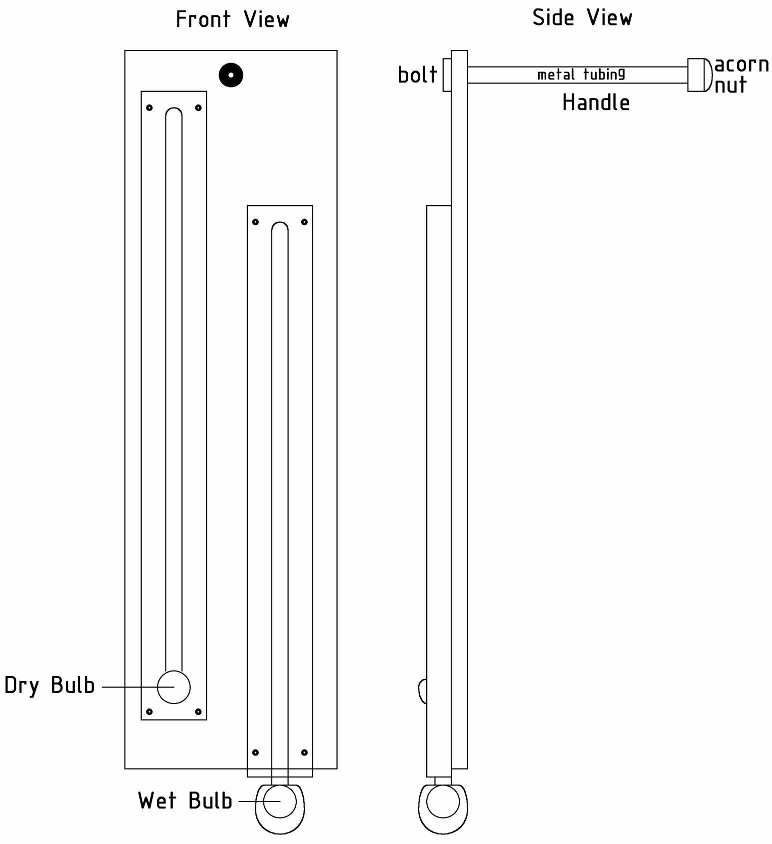
- Two small thermometers[E]

Or

- Two garden thermometers[F]
- A base (use either a thick plastic or model aircraft plywood)
- Short length of shoelace
- Cotton thread
- ¼-20 bolt, 5 to 6 inches long
- Brass or aluminum tubing, large enough to cover the bolt without binding
- ¼-20 nut
- Three ¼-20 washers
- ¼-20 acorn nut
- 4-40 hardware for bolting the thermometers to the base, include lock washers

Construction

You have two choices here. Either the thermometers can be mounted side by side or on opposite sides of the psychrometer base. However, keep in mind the following. The handle needs to be mounted to the top of the base. The handle is used to swing the psychrometer. Also, the thermometer to become the wet bulb must be mounted such that its bulb extends beyond the base on the side opposite from the handle.



***Psychrometer –** Front View (left), Side View (right)*

Handle

- √ Lay the thermometers on the material chosen to be the base
- √ Determine the position of the bolt handle and the thermometers
- √ Drill a hold for the ¼-20 bolt
- √ Attach the bolt to the base with washers and a nut
- √ Attach the acorn nut to the end of the bolt and measure the open space between the bottom nut and the base of the acorn nut
- √ Cut the aluminum or brass tubing to this length
- √ Remove the acorn nut and slide the tubing over the exposed threads of the ¼-20 bolt
- √ Place a washer over the end of the tubing and screw on the acorn nut
  Note: The acorn nut will tighten enough against the tubing to keep it from spinning because the tubing is too long
- √ Estimate how much the tubing needs to be shortened before it can spin freely around the bolt
- √ Remove the tubing and shorten it
- √ Test the fit again
  Note: You want the tubing just short enough that the tube can spin when the acorn nut is tightly screwed to the bolt, but without bolt threads or metal edges exposed. The tubing forms a comfortable grip for the sling psychrometer without exposing your hands to rapidly spinning sharp metal edges.
- √ Cut the tubing again if necessary

Thermometers

Remember that the thermometer to become the wet bulb must be mounted such that its bulb extends beyond the base. However, do not extend the thermometer bulb much beyond the base, just enough to expose the bulb.

- √ Carefully drill 4-40 holes in the thermometer bodies to mount the thermometers securely to the psychrometer base
- √ Use bolts and lock washers to ensure the thermometers are securely mounted
  Note: You want to ensure the thermometers do not go flying away every time you take a measurement
- √ Take the sling psychrometer outside and spin it a few minutes

  Note: Keep people and important possessions away from the potential ballistic trajectory of a thermometer when swinging the sling psychrometer for the first time

- √ Check the bolts after the test; make sure they're still tight
- √ Use the short length of cotton shoelace to cover the wet bulb like a sock
- √ Use the cotton thread to tie the lace above and below the bulb.

- √ If the bulbs do not indicate the same temperature, then write on the sling psychrometer the correction needed.

Using The Psychrometer

- √ Soak just the cotton lace of the wet bulb; do not get the dry bulb wet.
- √ Spin the sling psychrometer for a few minutes
  Note: After a few minutes the maximum difference between the wet and dry bulb should occur
- √ Record the dry bulb temperature and the difference between the dry and wet bulbs
  Note: This difference is called the wet bulb depression.
- √ Use the table below to determine the relative humidity and dew point

In this table, the dry bulb reading is found in the vertical column on the left, while the wet bulb depression is found in the row on the top. Cross-reference the row and column and you'll find two numbers. The first number is the dew point and the second number is the relative humidity in percent. Record the dew point at the time of launch.

Dew Point Table[G]

Air temp. (F)	Depression of the wet-bulb thermometer													
	1	2	3	4	6	8	10	12	14	16	18	20	25	30
0	-7	-20												
5	-1	-9	-24											
10	5	-2	-10	-27										
15	11	6	0	-9										
20	16	12	8	2	-21									
25	22	19	15	10	-3	-15								
30	27	25	21	18	8	-7								
35	33	30	28	25	17	7	-11							

40	38	35	33	30	25	18	7	-14						
45	43	41	38	36	31	25	18	7	-14					
50	48	46	44	42	37	32	26	18	8	-13				
55	53	51	50	48	43	38	33	27	20	9	-12			
60	58	57	55	53	49	45	40	35	29	21	11	-8		
65	63	62	60	59	55	51	47	42	37	31	24	14		
70	69	67	65	64	61	57	53	49	44	39	33	26	-11	
75	74	72	71	69	66	63	59	55	51	47	42	36	15	
80	79	77	76	74	72	68	65	62	58	54	50	44	28	-7
85	84	82	81	80	77	74	71	68	64	61	57	52	39	19
90	89	87	86	85	82	79	76	73	70	67	63	59	48	32
95	94	93	91	90	87	85	82	79	76	73	70	66	56	43
100	99	98	96	95	93	90	87	85	82	79	76	72	63	52

Example
Say you measure a dry bulb temperature of 70° F and a wet bulb temperature of 60° F.

Subtract the 60 from the 70 to get a wet bulb depression of 10° F. Go to the table and find the intersection of the 70° F air temperature row with the 10° F wet bulb depression column. You'll find the numbers 70/56. This indicates the relative humidity is 70% and the dew point is 56° F. The air is holding 70% of the water vapor it can hold at this temperature and if the air temperature drops below 56° F, there will be dew. Note that if the dew point is below 32° F, then there will be no frost until the air temperature drops below the dew point. So if can be below freezing without there being frost. Be sure to add measuring the wet and dry bulb temperatures to your launch checklist (if these measurements are needed).

Near Space Humor - Near Space Comix #1

[A] One regulator is the Profill Balloon Regulator (Crammer Decker), model BR 3855 with gauge and hand tightener. If the regulator does not have a hand tightener, then also purchase a crescent or box wrench.

[B] As you no doubt recall from high school chemistry, the Ideal Gas Law is stated in the equation:

PV=nRT

Where:

P is the pressure exerted by gas
V is the volume occupied by a gas
n is the amount of gas (in moles) in a sample or parcel
R is Boltzmann's constant
T is the temperature in an absolute scale (Kelvin or Rankin)

[C] Water can remain a liquid below 0 degrees Celsius or above 100 degrees Celsius. But eventually the water does change phases, either with a little more time or with a further change in temperature. The purer the water, the longer it can remain a liquid.

[D] The name originates from psychro (cold), not psych (mind)

[E] These are available at school supply stores or science catalogs

[F] When purchasing thermometers, select two that read the same temperature

[G] Table from http://www.jsu.edu/depart/geography/mhill/phygeogone/unit2/dewtablf.html, Dr. M.H. Hill, Jacksonville State University