Touching Near Space on a Budget

By Paul Verhage, KD4STH (all photo and graphic credits are Paul Verhage unless noted otherwise)

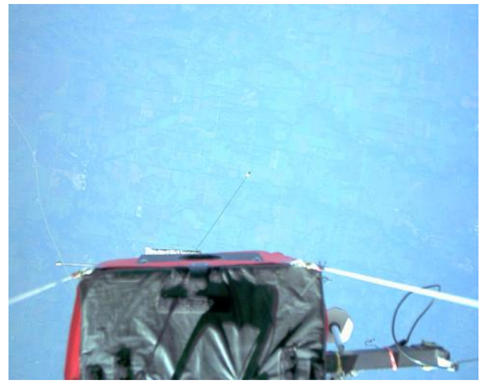
Introduction

Science, technology, engineering, and mathematics (STEM) education is more important than ever as our current STEM workforce nears retirement and our nation competes with a STEM-educated workforce in other countries. Amateur Radio operators have a history of bringing STEM to the public though Field Days, licensing classes, and radio club activities. Here's another way hams can bring STEM education to the public; helping school clubs and groups like the Scouts launch science experiments into near space. To make near space flights possible, it's necessary to track and recover student experiments and this is the perfect job for an APRS tracker. Below are some directions on how to build an APRS tracker suitable for the harsh conditions found in near space.

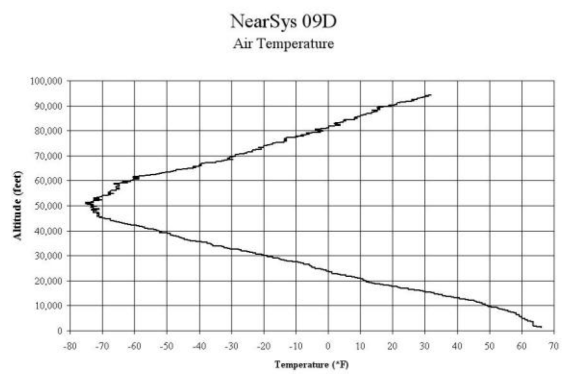
This is what it looks like at an altitude of 86,000 feet. The distance to the horizon is 360 miles and the sky has the inky blackness of outer space. The horizon becomes noticeably curved at this altitude. The snow-capped volcano is Mt. Bachelor in Oregon and the moon is visible at the upper right.]

Near Space

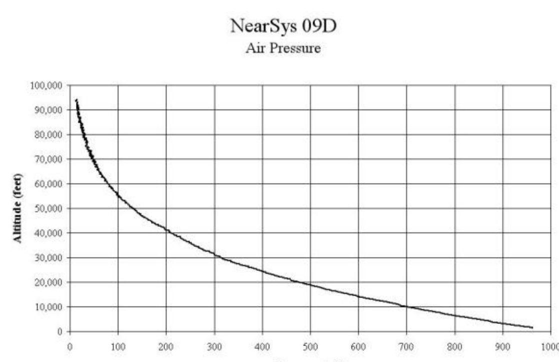
Near space begins at 60,000 feet (the top of controlled air space) and extends to 328,000 feet (the International Aeronautical Federation's boundary for space). Within this region of Earth's atmosphere the sky above turns black, the Earth below turns blue, and the horizon becomes visibly curved. By most measures, the conditions found in near space are much closer to outer space than to Earth's surface. Because of its similarity to outer space, many people feel an excitement launching experiments into near space.



In near space the blue sky is below your feet and not above your head. Notice that the atmosphere subdues some of the ground color. The scene in this picture is about 13 miles across.]



It gets exceedingly cold in near space. Notice however that the air temperature increases with altitude once the weather balloon enters the stratosphere. This is caused by the blockage of dangerous solar ultraviolet by ozone in the stratosphere.



Air pressure decreases by 50% for every 18,000-foot increase in altitude. At 100,000 feet, an altitude that a near space balloon mission can attain, the air pressure is around 10 millibars, or 1% of the average air pressure at mean sea level.

Near Space Tracker: An Overview

The near space tracker described below makes use of commonly available materials where ever possible. That makes it more affordable for amateur radio clubs to bring student experiments to near space. This article focuses specifically on the airframe, antenna, and batteries. (Additional information is available in other articles on the *ARRL Handbook's* supplemental CD.)

Items to Purchase

- A reusable lunch cooler (the insulated, soft-sided, zippered type – see photo)
- A sheet of 2" thick urethane foam rubber (available at fabric and craft stores)
- A sheet of 1" thick urethane foam rubber
- A small sheet of Coroplast (corrugated polyethylene plastic available at sign shops)
- 1" wide nylon strap material (available at fabric and craft stores)
- #8-32 hardware (11 screws 1" long, 11 nylon locknuts, and 22 fender washers)
- Eight 1-¼ inch diameter metal split rings

When not carrying a lunch, this cooler can carry student experiments into near space.]

Assembly: Airframe Attachment Straps

The attachment straps will connect the near space tracker to the recovery parachute, to a second tracker (the backup unit), and to student experiments. The straps attach to the lunch cooler with screws, which is much easier than trying to sew them to the cooler.

1. Cut the nylon straps into four pieces, each 12" long (longer if your lunch cooler is tall)
2. Fold each strap with a 1" overlap as shown below

This nylon strap is shown clamped with this butterfly clip to illustrate the folds and overlap in the strap.]

3. Melt two holes into each strap with an old soldering iron; do not breathe the fumes or smoke. The holes need to be large enough for #8 screws.
4. Place each strap next to a different corner of the lunch cooler and melt holes into the lunch cooler that correspond to the holes in the straps.
5. Attach the straps to the lunch cooler using #8 hardware (place fender washers inside and outside the cooler and the locknuts on the outside).

Two screws, fender washers, and nylon locknuts are more than enough to attach the straps to this lunch cooler.

Assembly: Antenna Boom

The Antenna Boom is a stiff and lightweight platform for holding the antenna to the cooler. And it's easy to replace in case it's ever damaged at landing.

1. Cut a Coroplast strip 18" by 2.5" aligned lengthwise with the cells of the Coroplast for strength
2. Drill three holes in the Coroplast
3. Place the Coroplast against the back of the lunch cooler and melt three holes into the lunch cooler matching the holes in the Coroplast
4. Attach the Coroplast to the lunch cooler in the same way that the straps were attached to the cooler.

The antenna boom is very lightweight, so three small screws are sufficient to hold it into place (the five screws in this image are overkill).

Assembly: Bottom Cushion

A sheet of foam rubber in the bottom of the lunch cooler cushions the tracking electronics at landing. It also creates a layer of insulation to protect them from the cold.

1. Cut a piece of the 2" thick foam rubber so its fits snugly into the bottom of the lunch cooler.
2. Place the foam rubber into the bottom of the lunch cooler.
3. Place the flight battery on the foam rubber and draw and then cut out a pocket in the foam rubber to hold the battery snugly in the foam rubber.

Assembly: Avionics Deck

The electronic modules must be held together rigidly or they're liable to break apart, especially when the balloon bursts. The Avionics Deck creates a lightweight method for keeping the electronics connected together, to the battery, and to the antenna.

This near space tracker is one of my kits. You can also use a TNC and HT.

1. Cut a piece of Coroplast so it fits tightly into the lunch cooler and on top of the Bottom Cushion.
2. Mount the flight computer or TNC/radio to the Coroplast avionics deck (use screws, washers, and locknuts – in a pinch you can use nylon wire ties)

Assembly: Top Cushion

The GPS can't be allowed to flip upside down during the mission or you'll lose track of the near spacecraft. To hold it steady, it is sandwiched between a sheet of foam rubber and the top of the lunch cooler. Sandwiching it like this also gives the receiver a little more insulation from the cold.

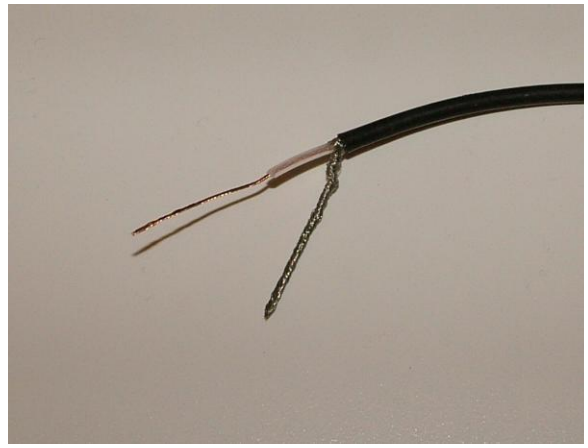
1. Cut a piece of the 1" thick foam rubber so its fits snugly into the lunch cooler (use a thicker sheet if your lunch cooler is tall).
2. Place this foam rubber on top of the Avionics Deck and trim it to fit around the items mounted to the avionics deck (if necessary)
3. Place the GPS receiver on top of the Top Cushion and then close and zip the lid of the lunch cooler.

Assembly: Antenna

The antenna for the near space tracker is a simple dipole antenna. The balloon rotates along its vertical axis during its flight and will constantly change the orientation of the antenna with respect to chase crews on the ground. A dipole is fairly immune to this and except for the null directly beneath, allows for continuous radio reception. The null is not a significant issue since chase crews aren't directly below the balloon for long and there's almost always a digipeater some distance away that's unaffected by the antenna null. The dipole is very lightweight, as well. You'll need the following materials to make the antenna.

- Two foot long coax cable, like RG-174
- #12 AWG solid copper wire
- Perforated board
- Three 1/8" nylon wire clamps
- Seven pairs of nylon screws and nuts (#10-24 ¾" or 1" long, for example)

1. Cut off one of the SMA connectors from the cable (this is the end of the coax that will attach to the dipole elements).
2. Slide a 1" piece of heat shrink tubing over the coax
3. Strip about 1" of the outer jacket off the coax to expose its braid.
4. Remove approximately half of the exposed inner insulation to reveal the inner conductor (leave some insulation remaining between the inner conductor and outer braid).
5. Push the inner conductor and its insulation through the braid.
6. Twist the braid tightly.



The stripped end of the coax.

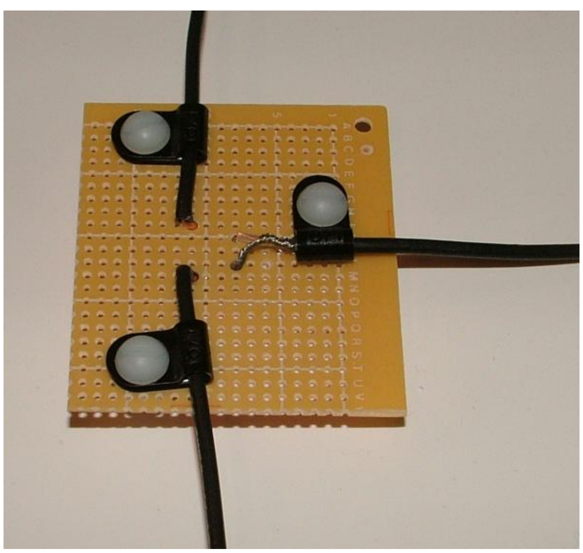
7. Cut a 2" square piece of perforated board.
8. Solder both coax conductors (the twisted braid and inner conductor) to two different pads on the perforated board (you'll need to expand the diameter of one of the holes in the perforated board for the twisted braid).
9. Slide the heat shrink tubing to where a nylon wire clamp will wrap around the coax.
10. Clamp the coax to the perforated board with a nylon wire clamp and bolt (the clamp provide a strain relief for the coax).
11. Cut two pieces of #12 AWG solid wire to a length of 20 inches. Each of these makes up one-half of the antenna.

    Note: these directions assume you're building a 2 meter tracker. The proper length of the wires depends on the frequency of the transmitter and can be calculated with the equation, L (feet) = 485/frequency (MHz). You'll need to divide the result by two for the correct length of each antenna half.

12. Strip off ¼” of insulation off of one end of each #12 AWG wire
13. Bend the short bare end in a right angle.

Very little of the #12 AWG wire needs to be stripped and bent. This is where it will be soldered to the perforated board.

14. Solder the bare ends of the #12 AWG wire to the perforated board so that each half of the dipole electrically connects to one lead of the coax (you’ll need to expand the diameter of the holes in the perforated board).
15. Slide a 1” piece of heat shrink tubing onto the antenna halves.
16. Slide the heat shrink tubing to where a nylon wire clamp will wrap around the antenna halves.
17. Clamp each half of the antenna to the perforated board with a nylon wire clamp and bolt (provides strain relief for the element).

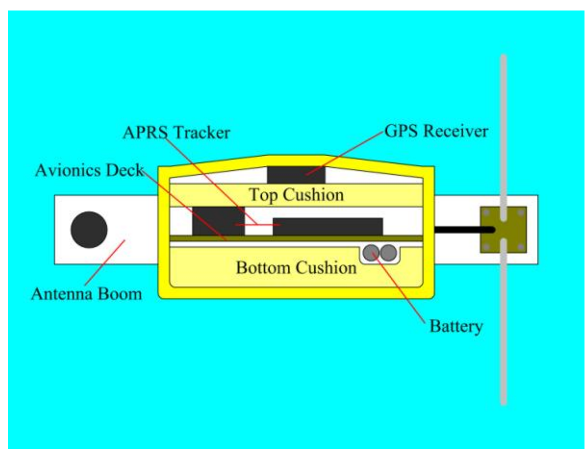


The finished antenna.

18. Drill or enlarge a hole in each corner of the perforated board.
19. Place the perforated board against the Antenna Boom and drill four holes into the Correplast that match the holes in the perforated board.
20. Bolt the perforated board to the Antenna Boom using nylon locknuts, washers, and bolts.

The antenna after it’s been attached to the Antenna Boom. This is a circuit board of my design that I use for making near space dipole antenna.

21. Use an old soldering iron to melt a hole through the side of the lunch cooler where the antenna’s coax will enter the lunch cooler and connect to the radio on the Avionics Deck.
22. Use another nylon wire clamp to secure the antenna coax to the Antenna Boom.

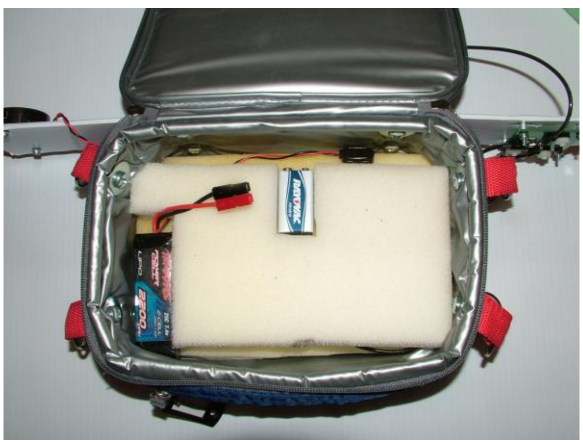


An x-ray view of an idealized Near Space Tracker. It’s essentially a layer cake design.

Batteries

Since it gets bitterly cold in near space, lithium-based batteries are strongly recommended as the power source as they tend to handle the cold temperatures without dropping their voltage. A practical source of lithium batteries is an RC hobby shop. Racing car batteries come in several voltages and capacities. Since many APRS trackers are designed to operate on five volts, select a two- or three-cell battery pack. If your tracker electronics has a low dropout voltage regulator, then your tracker can operate with a two-cell battery pack.

Not only do you have a choice of battery voltages with RC racing car batteries, you also have a choice of capacities. So measure the current draw of your APRS tracker and multiply that value by 24 hours. That will give a rough idea of a good battery capacity for your tracker. Even though missions only last three hours from power up to shut down, it's nice to have the extra reserve to make sure the tracker produces position reports overnight should it get lost during descent.



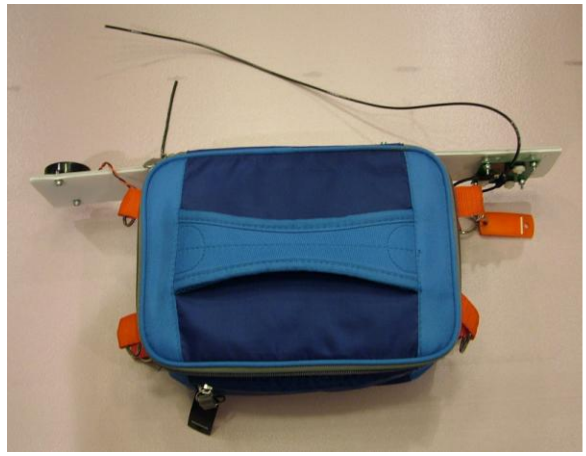
The battery on the left is a 2-cell, 25C, 2200 mAH rechargeable lithium battery. The battery's original connector was replaced with an Anderson PowerPole connector. The 9 V battery is for an audio beacon mounted to the Antenna Boom.

Ready to Launch!

This completes the near space tracker. You'll need to find a parachute before you can launch it, but that's relatively easy to do. Afterwards, you'll need to learn how to fill a weather balloon and how to predict a near space flight. Fortunately, these steps are very easy to learn. You will need a balloon filler — directions for assembling one can be found in my online book, *Near Space with the BASIC Stamp* (**nearsys.com/pubs/book/index.htm**).

You should practice with a couple of near space flights before offering to carry student experiments. The student experiments are often built into modules called BalloonSats. You'll be able to attach six of more BalloonSats (depending on their weight) to your tracker, parachute, and balloon.

Since you're providing the launch and tracking services, students won't need to add tracking electronics to their BalloonSat or need to earn an Amateur Radio license just to fly an experiment. Your help will let students concentrate on their science experiment and the analysis of its data.



The completed near space tracker as seen from the top. Inside this reusable lunch cooler are an APRS tracker and GPS receiver. The left side of the Antenna Boom is carrying an 80 dB piezo alarm that will make locating the tracker much easier.