CHAPTER TWO

Near Space Avionics, Part One
Simple Near Space Trackers and Telemetry Systems

"I care not what may be the condition of the earth
-it is the sky that is for me now.
What serenity!
*What a ravishing scene!"*
- Jacques Charles*

Chapter Objectives

1.0   Selecting Near Space Avionics

Now that you have a near space airframe, it's time to decide on the avionics to go inside. I have broken them down into the following choices, listed from least capable to most capable. The more capable type can replace all functions of the previous type.

- Beacon
- Tracker
- Flight Computer

This chapter presents complete step-by-step instructions for building each of the avionics shown below.
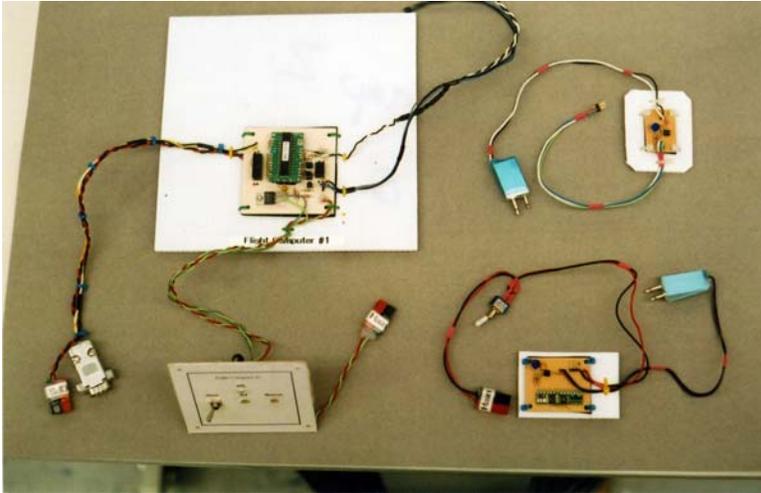
Beacons and A track –
Clockwise from left – Tracker,
Simple Beacon, and Stand-alone
beacon.

1.0.1 Beacon
A beacon is used to direction-find (DF) a capsule. Beacons are systems consisting of a radio and circuitry to key the radio and send tones. Beacons are usually the last hope for locating a lost near spacecraft. They can also be used as a wow factor, letting people know they are listening to transmissions from 100,000 feet. Do not use a beacon as your primary means of tracking unless you enjoy DFing. The beacon described in this chapter uses a BASIC Stamp 1 and an Alinco DJ-S11 HT (Handi-Talki).

1.0.2 Tracker
A tracker reports the position of the near spacecraft according to the on-board GPS receiver. Trackers consist of a radio, GPS receiver, and a TNC. Trackers make a good back-up system for locating a recovered near spacecraft. Because they are constructed more quickly than a flight computer, trackers are a fast way to get your first near spacecraft launched. Three simple trackers are described in this chapter of the book.

1.0.3 The Flight Computer
A flight computer is used to operate every aspect of an entire near space mission. Flight computers consist of a microcontroller, GPS receiver, TNC, and radio. They are the way to have some intelligence onboard the near spacecraft in the way it performs experiments or responds to near space events. The two flight computers described in Chapter Three of this book are based on the BASIC Stamp 2.

1.1. Redundancy
Why depend on only one means of recovering a near spacecraft? Rest assured that one or more of your near space missions will fail in some fashion at some time. If you're lucky, it's just an experiment that didn't return data. Other times, however, it is tracking that fails. You'll learn the most from failures, so they're not necessarily bad. But you can only learn from failures if you can recover the evidence. Using redundant tracking systems increases the odds of recovering the near spacecraft after its mission. If you want redundancy (highly recommended), then it's easiest if two modules are launched on each mission. In the two-module near spacecraft configuration, one module carries the flight computer and the other module carries a tracker and/or beacon. Divide experiments

between the modules and use an umbilical cable to connect the flight computer to the experiments located in the second module.

1.2. Before You Begin Construction

Before you begin constructing the various avionics and experiments in this book, you will need to have the proper soldering tools and techniques. Investing your time in reading these instructions and practicing your soldering on some spare defunct parts may save you a lot of time, money, and aggravation as you prepare for your first mission.

1.2.1 Soldering Iron and Soldering Components

First of all, you will need a small soldering iron, as opposed to a 100-Watt soldering gun. Small 25-Watt soldering irons are available from Radio Shack. Even better is a soldering station with adjustable heat output. Keep the tip of the soldering iron clean with either a damp sponge or wire coil-cleaning pad. Keep the tip of the iron well tinned and shiny. When soldering use a minimum of solder. Before applying solder to a copper pad, make sure both the printed circuit board (PCB) pad and the component lead are hot, but not so hot that the copper lifts up off the PCB. The lifting of copper pads is prevented if you quickly apply solder and then get the iron and solder away from the board. When soldering, use eye protection. Skin can heal when it is burned, but blobs of solder in the eye can leave permanent damage.

While at an electronics store, pick up a lead bending tool and wire snips. The lead-bending tool allows resistor leads to be bent accurately to 0.4" with minimum strain on the component. After soldering component leads and verifying the solder joint is good, snip away excess component lead. Be cautious and do not snip away the copper trace. Some solder must remain on the copper pad after snipping away the excess lead. When cutting leads, be sure pieces of wire do not go flying across the room or into an eye. Inspect solder joints with an inexpensive loupe and bright light. This allows a close inspection of the joint to make sure it was soldered properly. Properly soldered joints should be shiny, not blobby or pitted, and show the lead or wire soaked in solder.

Never use a pair of wire cutters to strip insulation from wire. Doing so nicks wire and cuts strands of wire in cables, weakening the wire. Murphy's Law says weakened wires fail at 100,000 feet rather than on the ground during a test. To make it more difficult for Mr. Murphy, use wire strippers to remove insulation. There are several types available. The simplest stripper uses sized holes for cutting through insulation and not copper wire. More expensive types have jaws that clamp onto the wire before stripping the insulation, saving you the effort of pulling on the thin wire in the stripping hole. Finally, there is a hot stripper that melts through the insulation, preventing the wire from being nicked at all. When using a mechanical stripper, be sure to use the proper sized stripping hole for the gauge of wire being stripped.

Occasionally you'll have to remove excess solder, so pick up a small hand operated solder pump or solder wick. Pick up some additional solder pump tips to replace the original after you melt it with the soldering iron. Keep the soldering iron tip well tinned while removing excess solder. You actually are adding solder to remove solder. A well- tinned soldering iron tip transfers heat more quickly to a blob of excess solder. Press the plunger on the solder pump before heating the solder pad. Once the solder is melted, place the tip of the pump into the melted solder and press the pump's button. The solder pump suctions the molten solder into the pump where it cools. When removing excess solder with a solder wick, place the wick over the solder pad and component lead. Now place the well tinned soldering iron over the wick. Once the wick is hot and the excess solder has melted,

pull the solder wick through the molten solder while maintaining contact between the soldering iron, wick, and pool of molten solder. The hot wick absorbs the solder, removing it from the PCB solder pad.

2.0   Beacons

A near space beacon keys an amateur radio, generates tones for the radio's audio, and then unkeys the radio. The process repeaters either on a fixed or as-needed basis. The generated tones typically are the call sign of the near spacecraft, but can also include status data. Two beacons are described in this section. The first is a stand-alone beacon containing a BASIC Stamp 1 (BS1) and is suitable for operation with a photovoltaic array. The second beacon operates from the logic of a flight computer.
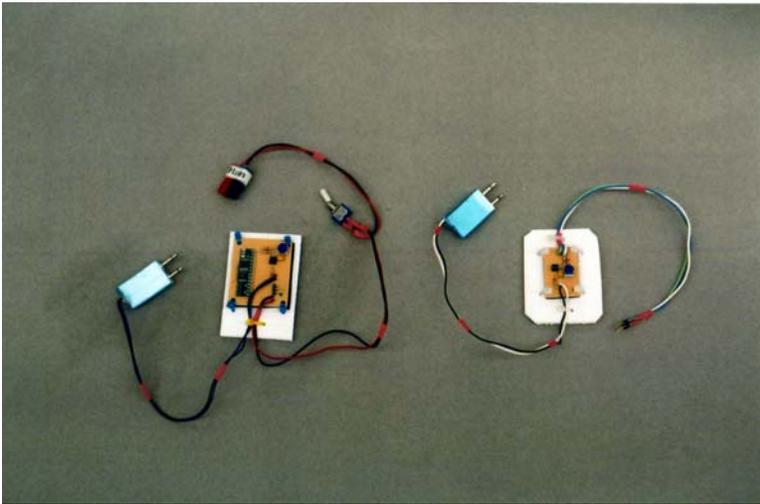
Beacons – The stand-alone (left) and simple (right) beacons.

2.1.   Theory of Operation

Before tones can be sent to the microphone of a radio, its push-to-talk (PTT) button must be depressed. Depressing the PTT button of a radio closes an opened circuit in the radio. To do this, connections from the PTT switch are connected to the collector of a bipolar transistor and to the emitter of transistor. A BASIC Stamp I/O pin connected to the base of the transistor (through a current limiting resistor of 10k ohms) operates the transistor switch. As long as the transistor is not conducting (because the I/O pin is LOW) resistance between the collector and emitter is infinite as far as the PTT is concerned and the HT does not key up. HIGHing the I/O pin causes the transistor to saturate and resistance between the emitter and collector of the transistor becomes very low (on the order of tens of ohms). At that point the PTT wires are shorted together and the radio keys up.

Tones to the radio are generated by the TONE command of the BS-1, or the FREQOUT command of a BS-2. A capacitor in the audio line provides the necessary filtering. A voltage divider on the audio line controls the volume of the tones.

2.2.   Materials

This beacon is designed for the Alinco DJ-S11. The beacon should work on other HTs, but I have not tested them yet.

2.2.1. Simple Beacon

- 0.1 uF capacitor
- 1k resistor
- 2.2k resistor
- 4.7k resistor
- 5k trimmer
- 2N3904 NPN transistor
- 1/8" phono jack
- 3/32" phono jack
- Three lengths of 22 AWG stranded wire, different colors
- 1" diameter heat shrink tubing
- Hot glue
- 0.03" polystyrene plastic sheet
- 3mm thick Foamies® *
- Coroplast™ **
- Nylon wire ties
- Simple Beacon PCB

2.2.2. Stand-Alone Beacon

In addition to the items above, add the following components to make a stand-alone beacon:

- Three pin male header, preferably right-angle headers
  (0.025" square, 0.1" between centers)
- One pair Powerpole® connectors***
- Clear heat shrink tubing to cover the Powerpole® connectors
- Label marked BEACON
- Subminiature toggle switch
- BS1-IC****

In place of the flight computer operated beacon PCB, use the stand-alone beacon PCB

Note: the capacitors used in the beacon PCB have leads spaced 0.1" apart.

* Foamies® is the name of a brand of neoprene foam manufactured by Darice Inc. and is available at crafts stores.
** Coroplast™, a form of corrugated plastic, is available at plastic suppliers. Coroplast™ is a trademark of the Coroplast™ company (www.coroplast.com).
*** Powerpole® connectors are made by the Anderson Power Products company (www.andersonpower.com).
**** BASIC Stamp microcontrollers including the BS1-IC are available from Parallax, Inc. at www.parallax.com.

2.3. Construction

The first item constructed is the HT cable, then its housing, followed by the beacon PCB.

2.3.1. HT Cable

Connections to the MIC (3/32" phono jack) and Audio (1/8" phono jack) are required in order to operate the HT. Make a single HT connector by encasing the connectors in a plastic housing after the connectors are soldered.

*Mic and audio jack connections*
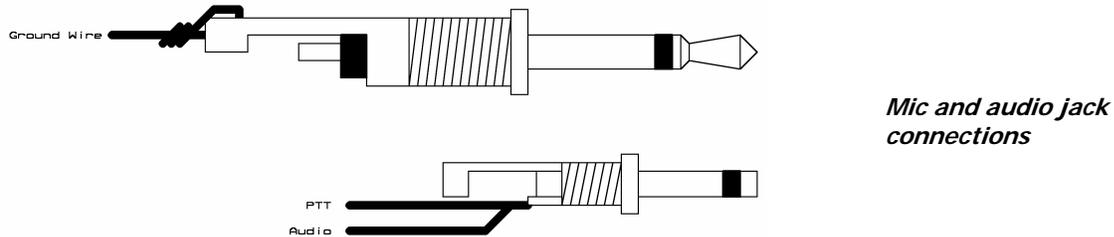
Wiring the MIC and Audio Jacks
- √ Cut twelve inches of #22 or #24 AWG stranded wire, one length of black wire, and one length of a different color.
- √ Strip ¼" of insulation from one end of each wire and ½" of insulation from the other end.
- √ Solder the ½" bare ends of the wires to the phono jacks as directed below:
    - o Black wire to the base connector of the 1/8" phono jack.
    - o Other wire to the tip connection for the 3/32" phono jack.

Making the Plastic Housing for the MIC and Audio
- √ Plug the phono jacks into a radio.
- √ Cut two pieces from the sheet of 0.03" thick polystyrene so that they are large enough to cover the phono jacks.

Note: At some time you may want to use external power on the HT. So, plug a DC power plug into the HT (4.0mm X 1.7mm for the DJ-S11) when plugging in the phono jacks. I do not recommend making the power connector a part of the phono housing, as you can't run the HT on internal power if a power plug is connected. However, keep the power plug connected to the HT when making the phono housings so that the housing will be made the proper size.

- √ Use hot glue to begin filling space in between the jacks. Note: Be sure not to glue the housings to the case of the DJ-S11!
- √ Press the first sheet of polystyrene onto one face of the glued connectors.
- √ Flip the HT over to its other side and press the second rectangle of plastic onto the combined connectors.
- √ Unplug the glue gun and let it begin to cool.
- √ Remove the glued connector from the HT once the glue in the DJ-S11 plug has cooled. Fill the voids in the HT connector with the now warm, hot glue.
- √ Let the unified connector cool once all the voids between the plastic sheets and housings are filled.
- √ Trim the edges of the unified HT plug with a sharp Exacto knife.
- √ Cover the unified connector with heat shrink tubing.
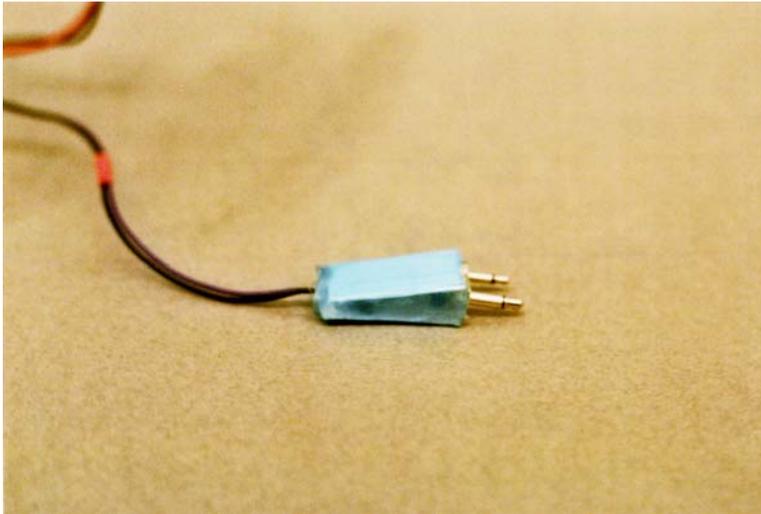
Completed Jack Housing – *Not beautiful, but solid and easy to assemble.*

2.3.2. Assembling the Beacon Board
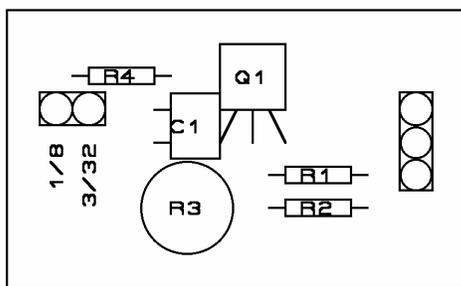

```
R1      1k
R2      4.7k
R3       5k
R4      2.2k

C1    0.1 uF

Q1    2N3904
```

Simple Beacon – *Parts placement.*

Solder the following components into the PCB:

- C1   0.1uf capacitor (use a small dimension polyester cap)
- R1   1k resistor
- R2   4.7k resistor
- R3   5k trimmer
- R4   2.2k resistor
- Q1   2N3904 NPN transistor
- HT cable into the pads labeled 1/8" phono and 3/32" phono

Additional Steps for the Simple Beacon

Adding a Control Cable to the Simple Beacon
- √   Cut three 12" lengths #22 AWG stranded wire, one black and the others two different colors.
- √   Strip ¼" of insulation from one end of each wire.
- √   Solder wires to the PCB, with the black wire in the solder pad marked GND.
- √   Strip insulation from the other end of each wire and terminate in a connector for your flight computer.
- √   Now go Section Four, Testing.

Additional Steps for the Stand-Alone Beacon
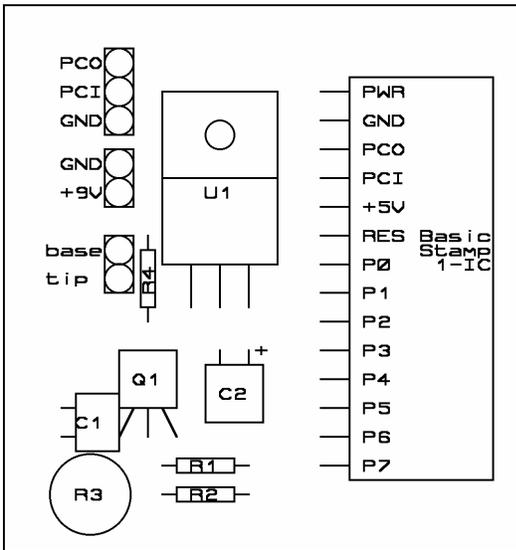
Stand-alone Beacon - *Parts placement.*

Additional Parts for the Stand-Alone Beacon
- J1   Three pin male header

Paint a green dot near the ground pin of the programming header, which is the top of the three pins. This dot prevents you from connecting your programmer cable in backwards.

Adding a Power Cable to the Stand-Alone Beacon
In the final assembly step, a power cable, switch, and power plug connectors are added to the PCB.

- √   Cut two 18" lengths #22 AWG stranded wire, one black and the other red.
- √   Strip ¼" of insulation from one end of the red wire and one end of the black wire.
- √   Solder the two wires to the power pads of the PCB, making sure to solder the black wire to the GND pad.
- √   Strip 1" of insulation from the remaining ends of both wires.
- √   Fold the wires in half.
- √   Crimp Powerpole® connector to the red and black wires.
- √   Solder the wires inside the crimps.
- √   Slide housings on the crimps, matching the colors of the connectors to the wires.
- √   Wrap the BEACON label on the housings and cover in clear heat shrink tubing.
- √   Cut the red wire two-thirds of the way from the PCB.
- √   Strip ½" of insulation one end of each red wire.
- √   Solder each red wire to a terminal of the switch. Note: if using a SPDT switch, connect one wire to the center pin.
- √   Slide a ½" long piece of heat shrink tubing onto each half and cover the soldered connection.

2.4.   Testing

2.4.1. Testing a Simple Beacon

Measure between the power and ground pins: there should be no continuity between them.

Now go to Section Five, Software.

2.4.2. Testing a Stand-Alone Beacon

Apply power to the beacon board. There should be no sparks or smoke. Measure the voltage at the BS-1IC pads marked +5V and GND. If the voltage is within 0.25 volts of 5.0 volts, then proceed with the final assembly. If not, then look for shorts, bad solder connections, or reversed power connections.

2.4.3. Final Assembly of the Stand-Alone Beacon
   √   Solder the BS-1IC into place.
   √   Backfill the Powerpole® connectors with hot glue.
   √   Label the Powerpole® connector and switch.
   √   Cut Foamies® to fit the back of the PCB, then punch holes in the corners to line up with the PCB.
   √   Cut a Coroplast™ sheet 1" larger than the PCB.
   √   Zip tie the Foamies® and the PCB to Coroplast™.
   √   Zip tie the cables to the Coroplast™ to act as strain relief.

2.5.   Software

2.5.1. Directions for the Stand-Alone Beacon Test Software

Modify the Stand Alone Beacon code to reflect your call sign.

You'll have to recall your call sign in CW to program the stand-alone beacon. The call sign is stored in a lookup table. The lookup table uses a 0 to represent the pause between characters, a 1 to represent a dit and a 2 to represent a dah.

So for example, the string 1,2,1,0,1 becomes • – • (pause) • or R E.

A .▄	N ▄.	0 ▄▄▄▄▄
B ▄...	O ▄▄▄	1 .▄▄▄▄
C ▄.▄.	P .▄▄.	2 ..▄▄▄
D ▄..	Q ▄▄.▄	3 ...▄▄
E .	R .▄.	4 ....▄
F ..▄.	S ...	5 .....
G ▄▄.	T ▄	6 ▄....
H	U ..▄	7 ▄▄...
I ..	V ...▄	8 ▄▄▄..
J .▄▄▄	W .▄▄	9 ▄▄▄▄.
K ▄.▄	X ▄..▄	Fullstop .▄.▄.▄
L .▄..	Y ▄.▄▄	Comma ▄▄..▄▄
M ▄▄	Z ▄▄..	Query ..▄▄..

Morse Code

After entering the dits, dahs, and pauses into the lookup table, count the number of characters in the look up table and change the upper limit on the FOR-NEXT loop. The upper limit is one less than the total number of characters (0,1,2) in the look up table.

√ Connect the PCB to the HT.
√ Connect the PCB to the parallel port of a PC.
√ Power the HT and beacon.
√ Start the BS-1IC programmer.
√ Download the stand-alone beacon program into the BS-1IC.
√ Adjust the audio volume while listening to a second radio. Adjust the volume to just below the point at which the HT's audio is overdriven.

Stand Alone Beacon Code

```
' {$STAMP BS1}
' {$PBASIC 1.0}
'*************************
'  Stand Alone Beacon
'  Code for the BS1-IC
'*************************
'Sends slow cw once every two minutes
'for the first 90 minutes
'Then sends cw once per minute
' In the lookup table...
' dit   = 0
' dah   = 1
' pause = 2
'*************************
'  I/O Pins
```

```
'**************************
'pin 7 tone
'pin 6 ptt
'**************************
'  Variables and Constants
'**************************
SYMBOL character = B2
SYMBOL ditdah    = B3
SYMBOL timer     = B4

timer = 0

CWID:
HIGH 6                                    'key ht
FOR character = 0 TO 23                    'get character
  LOOKUP character,(1,0,1,2,1,0,0,2,0,0,0,0,1,2,0,0,0,2,1,2,0,0,0,0),ditdah
  IF ditdah = 0 THEN dit                   'do a dit
  IF ditdah = 1 THEN dah                   'do a dah

  Space:                                   'leave a pause
  PAUSE 500
  GOTO EndCW

  dit:                                     'dit routine
  SOUND 7,(120,14)                         'dit tone
  PAUSE 100                                'slow characters per minute
  GOTO EndCW

  dah:                                     'dah routine
  SOUND 7,(120,42)                         'dah tone
  PAUSE 100                                'slow characters per minute

  EndCW:
NEXT                                       'get next character
LOW 6                                      'unkey ht
PAUSE 60000                                'wait a minute
IF timer > 45 THEN goback                  'has it been 90 minutes?
timer = timer + 1                          'increment timer
PAUSE 60000                                'wait another minute

goback:
  GOTO CWID                                'restart call sign
END
```

2.5.2. Directions for the Simple Beacon Software

Modify the Simple Beacon code to reflect your I/O pins.

The simple beacon is plugged into two I/O pins and ground. HIGHing the PTT keys the HT. Audio tones for the dits and dahs are sent as FREQOUT commands. If used in other than the BS2p, then the times and periods of each tone must be modified.

Modify the Simple Beacon code to reflect your call sign.

You'll have to recall your call sign in CW to program the stand-alone beacon. The call sign is stored in a look up table. Like the stand-alone beacon, the simple beacon stores the call sign in a lookup table that uses a 0 to represent the pause between characters, a 1 to represent a dit and a 2 to represent a dah

So for example, the string 1,2,1,0,1 becomes ● – ● (pause) ● or R E.

After entering the dits, dahs, and pauses into the lookup table, count the number of characters in the loop up table and change the upper limit on the FOR-NEXT loop. The upper limit is one less than the total number of characters (0,1,2) in the look up table.

- √ Connect the Simple Beacon to the Flight Computer.
- √ Connect the PCB to the HT.
- √ Connect the PCB to the parallel port of a PC.
- √ Power the HT and beacon.
- √ Start the BASIC Stamp 2 programmer.
- √ Download the simple beacon program into the flight computer.
- √ Adjust the audio volume while listening to a second radio. Adjust the volume to just below the point at which the HT's audio is overdriven.

Simple Beacon Code

```
' {$STAMP BS2p}
' {$PBASIC 2.0}
'**************************
'*      Simple Beacon      *
'*      Code For BS2p      *
'**************************
' In the lookup table...
' dit = 0
' dah = 1
' pause = 2
'**************************
'*         I/O Pins        *
'**************************
Audio           CON     9
PTT             CON     8
'**************************
'* Variables and Constants *
'**************************
character       VAR     Byte
ditdah          VAR     Nib

beacon:
HIGH ptt
FOR character = 0 TO 23
  LOOKUP character,[1,0,1,2,1,0,0,2,0,0,0,0,1,2,0,0,2,1,2,0,0,0,0],ditdah
  IF ditdah = 0 THEN dit
  IF ditdah = 1 THEN dah
  space:
    PAUSE 500
    GOTO EndCWID
  dit:
    FREQOUT audio,1000,100
    PAUSE 250
    GOTO EndCWID
  dah:
    FREQOUT audio,2000,100
    PAUSE 250
  EndCWID:
NEXT
LOW ptt
RETURN
```

2.5.3. Final Assembly of the Simple Beacon

√   Cut a rectangle of Foamies® to fit the dimensions of the PCB.

√   Place the Foamies® pad beneath the PCB.

√   Attach the PCB to a sheet of Coroplast™ with nylon wire ties. Note: This is an easy method to "bolt" PCBs to a base that protects the underside of the PCB from shorts, while still making it possible to get at the traces to fix a problem.

√   Create strain reliefs for beacon cables by zip-tying the beacon cables to the Coroplast™.

√   Cut the Coroplast™ large enough to rubber band to the back of the HT.

√   Build a Styrofoam box to house the HT and beacon. Note: Design the box to prevent HT buttons from being pressed during the mission.

3.0   Trackers

Trackers are more elaborate than beacons in that they telemeter data to ground stations, in this case by sending digital data over radios. Radios, like telephones, are inherently analog devices. To enable radios to send digital data, the data must modulate an analog carrier. Upon reception, the analog signal is demodulated. The device used to modulate and then demodulate an analog signal is the modem (modem is a contraction of the terms, modulate/demodulate). In the case of radios, the modem is referred to as a terminal node controller, or TNC. TNCs function like modems, but TNCs use radio waves in place of phone lines. A modem can be used in place of the TNC with balloons capable of carrying a 100-mile long phone line. Be sure to use Cat 5 wiring to ensure good communications.

Data sent to a TNC for transmission is first broken into packets (if the amount of data is large enough), given headers, a Cyclical Redundancy Code (CRC) for error correction, and then converted into audio tones. Afterwards the TNC keys the radio, sends the audio tones over the radio, and then unkeys the radio. On the ground a second TNC repeats this process, but in the opposite direction. The receiving TNC uses the CRC to determine if there are any errors in the decoded data. In some cases the CRC can be used to correct bad data. If the errors are too severe, then the second TNC asks for the first TNC to retransmit the data. Whether or not the TNC asks for a retransmission depends of the type of connection between the two TNCs. The TNCs do all the work. All you see is the data that was transmitted by the first TNC. The coding and decoding process is invisible to you, the user.

3.1.   Tiny Trak II Near Space Tracker

Tiny Trak III *– A completely assembled Tiny Trak. Yours will be similar. (Photo by Byon Garrabrant)*

Byonics makes a simple single board tracker kit suitable for near space. Order the kit (http://www.byonics.com/) and build it with the modifications specified below (less than an hour's work). Attach the Tiny Trak II to the NearSys Tiny Trak II PCB and a pallet, along with a GPS receiver and HT, and you have yourself a near space tracker. Mount the pallet inside an airframe, and you have yourself a simple near spacecraft.

3.1.1. Theory of Operation

The Tiny Trak II by Byon Garrabrant is a PIC based TNC. However, unlike the MIM or KPC-3+, the Tiny Trak II accepts only the GPGGA and GPRMC sentences from a GPS receiver. Defined by the National Marine Electronics Association (NMEA), the GPGGA sentence contains time, latitude, longitude and altitude information, while the GPRMC sentence adds to this speed and direction. The Tiny Trak then formats elements of those two sentences into a posit following the APRS standard. Data cannot be telemetered through the Tiny Trak II, only position reports are transmitted. The Tiny Trak II makes a great backup beacon for a near space capsule. For more information on Global Positioning System issues, please read the Good to Know section of Chapter Four.

A GPS35 requires in the neighborhood of 130 mA of current, far exceeding the capability of the regulator built into the Tiny Trak II. The voltage regulator (LM2940) on the near space tracker PCB is capable of supplying up to 1 amp of current, enough for both the Tiny Trak II and GPS receiver. Because the LM2940 is a low drop out voltage regulator, the Tiny Trak II and GPS35 can operate from a six volt source. Powerpole® connectors and a toggle switch provide the external power and control for the PCB and GPS receiver. An LED indicates when power is supplied to the Tiny Trak II and GPS receiver.

3.1.2. Materials
- Tiny Trak II kit
- LED (use the power LED from Tiny Trak II kit, or purchase an ultrabright LED)
- 22 uF tantalum electrolytic capacitor
- LM2940T-5 voltage regulator
- Male DB-9 solder pin connector
- DB-9 plastic housing
- Mounting hardware for LM2940 heat sink (#2 and #3 works)
- 1/8" phono jack

- 3/32" phono jack
- Two subminiature toggle switches
- Two pairs of Powerpole® connectors
- Coax-style DC power plug, 4.0 mm X 1.7mm (with solder tabs)
- #22 or #24 AWG stranded wire (at least two different colors)
- Heat shrink tubing for wire
- Label with GPS printed on it
- Label with MAIN printed on it
- Clear heat shrink tubing large enough to slide over two power connectors
- 3mm thick Foamies®
- Nylon zip ties
- Three #2 mounting hardware

3.1.3. Procedures

First assemble the Tiny Trak II according to the directions below and then mount it to the Tracker PCB. When done, complete assembly of the PCB.
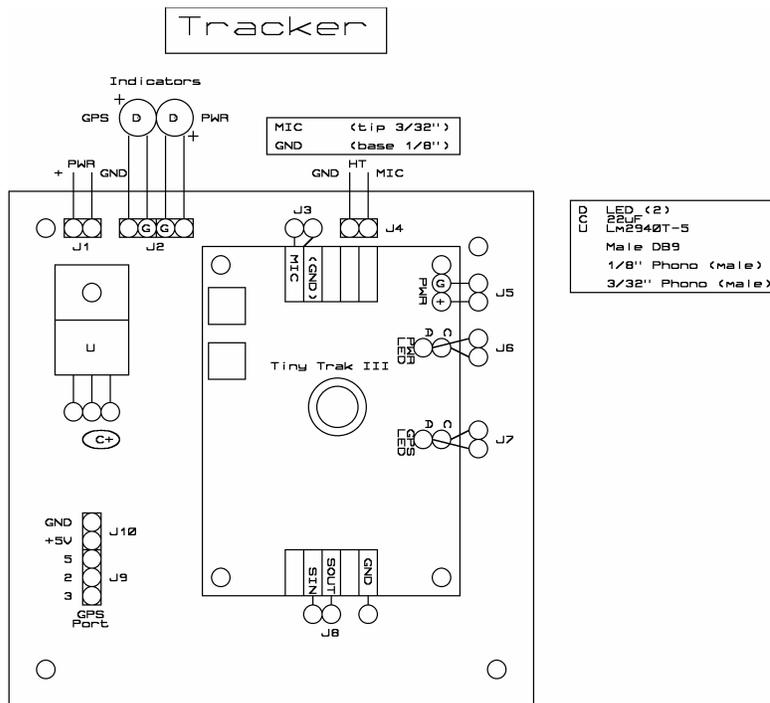
Tiny Trak III Near Space Tracker – Parts placement.

Assembling the Tiny Trak II
Build the TinyTrak II, except, DO NOT add the following components:

- J1   Female DB-9 connector
- Q2   78L05 voltage regulator
- C3   0.1 uF capacitor
- C4   0.1 uF capacitor
- D4   Red LED

After completing the Tiny Trak II, cut nine lengths of #24 AWG stranded wire to a length of two inches. Strip ¼" of insulation from both ends of all the wires. Solder the wires to the following pads

Wires from:	Solder to:
Power	+5V and GND
Serial Port	Pins 2, 3, and 5
HT Connection	GND and Audio
D4 Red LED	Cathode and anode

Mounting the Tiny Trak
Now the Tiny Trak is ready to be attached to the PCB.

- √ Cut a pad of neoprene to fit the underside of the Tiny Trak II.
- √ Punch three small holes in the neoprene to match the mounting holes of the Tiny Trak II.
- √ Bolt the Tiny Trak II to the PCB, with the neoprene sheet beneath it.
- √ Solder the Tiny Trak's wires to their corresponding pads on the PCB.

3.1.4. Completing the Tracker PCB

Now that the Tiny Trak II is secured, complete the PCB. Solder the following components to the PCB:

- 22 uF capacitor
- LM2940T-5 voltage regulator

Bolt the heat sink of the LM2940 to the PCB with the mounting hardware.

LED Power Indicator
- √ Cut at least 12" of two wires; one needs to be black.
- √ From each wire, strip ¼" of insulation from one end and ½" from the other end.
- √ Solder the black wire to the pad labeled G on the PCB diagram.
- √ Solder the other wire to the pad to its right.
- √ Slide both wires through a single 1" length of heat shrink tubing to cover the LED leads.
- √ Slide a 1" length of narrow heat shrink tubing on each wire to cover the soldered joint.
- √ Clip the LED leads to a length of ½".
- √ Tin the LED leads and wires.
- √ Solder the wires to the LED leads.
- √ Cover the solder joints with the heat shrink tubing.
- √ Cover the individual wires and LED leads with the larger heat shrink tubing.

Serial Cable
- √ Cut at least 12" of three wires, one needs to be black.
- √ Strip ¼" of insulation from both ends of all the wires.
- √ Solder the black wire to the pad labeled 5 of the GPS Port.
- √ Solder the remaining two wires to the pads marked 2 and 3.
- √ Slide ½" lengths of thin heat shrink tubing over all three wires.
- √ Solder the wires to the solder cups of a male DB-9 connector (note that each wire is named after the solder cup it is soldered to).
- √ Apply a thin layer of hot glue to the solder cups of the BD-9 male connector.
- √ Fill the bottom half of a DB-9 housing with hot glue.
- √ Press the DB-9 male connector into the bottom half of its housing, while the glue is still hot.
- √ Apply a coat of hot glue to the top of the wires, filling any open gaps.

√   Fill the top half of the DB-9 housing with hot glue.
√   Press the top half over the bottom half of the housing.
√   Bolt the housing together.
√   Backfill the rear opening of the housing to close up any openings.

GPS Power Cable
√   Cut two lengths of #24 AWG wire (make one wire red and the other black).
√   Strip ¼" of insulation from one end of each wire and 1" of insulation from the other end.
√   Solder the ¼" end to the PCB at the pads labeled GPS Port +5V and GND.
√   Fold the one inch end over and crimp in a Powerpole® crimp.
√   Fill the crimp with solder.
√   Insert the crimps into their plastic jackets.
√   Slide the jackets together .
√   Apply the GPS label and cover in clear heat shrink tubing.

HT Cable
√   Cut two lengths of #24 AWG wire (two different colors).
√   Strip ¼" of insulation from one end of each wire.
√   Solder the wires into the pads labeled as MIC GND and Audio.
√   Cut the other ends of the wires to appropriate lengths. Note: The other end of the MIC GND is soldered to the base of a 1/8" phono jack and the other end of the Audio is soldered to the tip of a 3/32" phono jack.
√   Solder the wires to the appropriate points of the jacks.

DJ-S11 MIC, Audio, and Power Connectors
Since I recommend your near space capsule use an Alinco DJ-S11, I have documented the proper connections for the DJ-S11.

MIC and Audio
√   Strip back ¼" of insulation from one end of two wires, using two different colors.
√   Solder a black colored wire to the GND pad of the HT pads and other wire to the TX/PTT pad of the PCB.
√   Solder the other end of the GND wire to the base of the 1/8" phono jack.
√   Plug the Ground plug into the HT and stretch the wire out taut.
√   Plug the 3/32" plug into the HT.
√   Stretch out the other wire to the center connector of the 3/32" plug.
√   Measure the proper length of the wire, cut and strip its end.
√   Solder it to the tip of the 3/32" phono jack.
√   Plug the phono jacks into the DJ-S11.
√   Squirt a little hot glue between the jacks, without getting hot glue on the HT.
√   Put a thin coat of hot glue on one piece of polystyrene.
√   Press the first sheet of polystyrene onto one face of the glued connectors.
√   Put a thin coat of hot glue on the second piece of polystyrene.
√   Flip the HT over to its other side and press the second rectangle of plastic onto the combined connectors.
√   When the glue in the DJ-S11 plug has cooled, remove the plug from the HT.
√   Fill the voids in the HT plug with the warm hot glue.
√   Let the unified connector cool.
√   Trim the edges of the HT plug with a sharp Exacto knife.
√   Finish the housing by covering it with heat shrink tubing.

Power
- √ Cut two wires, both 18" long (use a red and black colored wire).
- √ Remove ½" of insulation from one end of both wires.
- √ Solder the red wire to the center connector of DC power plug and the black to the ring of the connector.
- √ Slide a length of heat shrink tubing over the positive wire, covering the soldered connection.
- √ Squirt a drop of hot glue between the soldered connections.
- √ Screw on the plastic cap and fill the interior space with a little bit of hot glue.
- √ Strip 1" of insulation for the other ends of the wires.
- √ Double over the exposed wire.
- √ Crimp Powerpole® connectors on the wires.
- √ Slide the crimps into their jackets, using the proper colored housings to indicate positive and ground.
- √ Slide the Powerpole® jackets together.
- √ Wrap the jackets with a label marked HT.
- √ Cover the jacket and label with clear heat shrink tubing.
- √ Cut the red wire about two-thirds of the distance away from the coax power plug.
- √ Strip ¼" of insulation from the ends of the wires.
- √ Slide heat shrink tubing over the wires.
- √ Solder the wires to the pins of a toggle switch.
- √ Cover the soldered connection with heat shrink tubing.

PCB Power Cable
- √ Cut about 18" of two pieces of stranded wire, one red and one black.
- √ Solder the red wire to the pad marked + Power.
- √ Solder the black wire to the pad marked GND.
- √ Slide two 1" lengths of heat shrink tubing over both the red and black wire.
- √ Strip 1" of insulation from the other end of the red and black wires.
- √ Fold the stripped wire over.
- √ Crimp the wires in a Powerpole® connector pin.
- √ Fill the crimp with solder.
- √ Snap the crimps into their Powerpole® jackets.
- √ Fill the interior space with hot glue.
- √ Slide the jackets together and wrap the MAIN label around them.
- √ Cover the jacket with clear heat shrink tubing and heat the tubing.
- √ Backfill any remaining gaps.
- √ Cut the red wire about two-thirds of the way between the coax power connector and the Powerpole® (closer to the Powerpole®).
  Note: be sure there is a heat shrink tubing on both sides of the cut wire.
- √ Strip ¼" of insulation from both ends.
- √ Slide a 1" length of heat shrink tubing over both wires.
- √ Slide thin heat shrink tubing over each wire.
- √ Solder the wires to the pins on the back of the subminiature toggle switch.
- √ Slide heat shrink tubing over the soldered pins.
- √ Twist the wires together to form a "Y" shaped cable.
- √ Keep the "Y" together by shrinking the tubing on each arm of the "Y".

Test continuity between the +5V Powerpole® and the ground Powerpole®. If there is continuity, then you have soldered in a short. Check your connections.

After programming (next section) and testing the Flight Computer, then finish the Flight Computer by attaching it to an avionics pallet as follows:

- √ Cut Foamies® to fit back of PCB and punch holes in the corners to line up with PCB.
- √ Cut Coroplast™ sheet large enough to fit the bottom of an airframe.
- √ Zip tie Foamies® and PCB to Coroplast™.
- √ Zip tie cables to Coroplast™ to act as strain relief.

3.1.5. Programming the Tiny Trak II

Once you have assembled the Tiny Trak II, use its configuration software to program it for flight. The software to program is available from the Byonics website at www.byonics.com. After installing theTiny Trak II software to your PC, install a battery in the tracker and plug it into the PC's serial port. Start the program. After the program finds the tracker, it displays a menu of items you can change.

I suggest you program the Tiny Trak II as follows:

Field	Value	Explanation
Call sign:	Your Call sign	
Digi Path:	WIDE3-3	Use three hops when sending telemetry
Symbol:	–11	The –11 SSID is standard for a balloon
Table/Overlay	/O	APRS symbol for a balloon
Transmit altitude:	Enable	Hey, it's a balloon!
Send only valid position	Not Enabled	If there's a problem, we want what data we can get
Timing Transmit Every:	60	Once a minute is good enough
Status Beacon Text:	Capsule Name	You are naming your capsule, right?
Send Every:	5	Once every five minutes is good enough
MIC-E Settings	Not Enabled	We're not sending voice
Time Slotting:	Either enabled or disabled	Enabled will avoid stepping on other packets
Transmit Offset	Pick a value	Seconds after the minute
Smart Beaconing:	Not Enabled	We want all the flight data

Sample Flight Data
Below is a sample of data taken from a near space mission:

```
KD7INN-11>APT202,WIDE3-3:!4401.43N/11724.04WO156/008/A=002991
```

The APRS standard for a posit has the following fields:

```
Call sign-SSID, Path:!  Latitude N / Longitude W O Heading/Speed/A= Altitude
```

This is a posit, a type of "formatted data" from APRS. Normally we send an entire GPS sentence. However, with the TinyTrak, a posit is created from the GGA and RMC sentences. The posit sends just the information on location and movement of the GPS receiver (since the GPS is attached to the balloon, the posit also locates the balloon). A posit is a very brief packet of information, there is not extraneous information.

All licensed radio operators have a call sign that identifies them. At times during transmission, they must identify themselves with their call sign. Packet radio allows multiple simultaneous transmissions, so each transmission is identified with a SSID. The SSID is the dash number after the call sign. The SSID of "-11" is used to identify balloons. So the first block of information is the call sign and SSID (as is required by the FCC).

Next is the path. Radio packets can be sent to any or all licensed ham(s), either directly by stating the destination, or by specifying a path. The path will say things like, send my packet through this radio on the ground and let it then send the packet to this destination. Sending my packet though someone else's radio is called repeating. In the case of digital radio (like packet), it's called digi-peating. Digi-peating is done through radios and antennas located on mountain tops or other high locations. Digi-peating allows my signal to travel to more distant locations. For example, in Boise I can see APRS traffic from residents of Salt Lake City. Their signals go through a couple of repeaters to make it to Boise. The WIDE3-3 is saying I want my packets to go through any three digi-peaters. When a digi-peater receives my packet, it lowers the 3-3 to 2-2 and resends the packet. The next digi-peater receives the packet, reduces the count to 1-1 and resends it. This occurs once more. Any digi-peaters receiving a packet with 0-0 knows not to resend it. The really neat thing about this is that digi-peaters in various directions are doing this. This passes packet signals over a very wide region very quickly. Most packet stations are located where they can hear multiple stations. As a result, packet radio is very robust. A digi-peater can miss receiving a packet but the communication doesn't come to a halt.

Next in the posit is the ! followed by the latitude and longitude. The ! symbol is a part of the standard for posits. A PC sees this and knows to interpret it as latitude and longitude.

The capital O indicates the next two blocks of data are heading and speed. The heading is in true north, and the speed is in mph, rather than knots, which is the NMEA standard. The /A indicates the next field is altitude. NMEA sends altitude in meters. The /A field requires altitude in feet, so the TinyTrak does the conversion.

4.0   More Capable Terminal Node Controllers (TNCs)

In this section, we'll discuss two TNC trackers: The Kantronics KPC-3+ and the APRS MIM.

4.1.   Kantronics KPC-3+

Kantronics KPC-3+ - Photo by Kantronics.

The first tracker described is a Kantronics KPC-3+ Packet Communicator (www.kantronics.com/kpc3+.htm). For our purposes, this TNC (terminal node controller) will be connected to a GPS receiver and HT. The directions in this section are written specifically written for the KPC-3+ with version 8.3 firmware loaded in its EEPROM. Older versions of the firmware can function as a tracker, but they are not as capable. One feature of the KPC-3+ (and other TNCs) is its ability to retransmit digital signals that it receives. Called digi-peating, this allows a TNC to extend the communications range of a packet station. However, for near spacecraft it is not recommended to

use your primary telemetry method to send other peoples' communications. If you want to digi-peat from near space, use a second TNC on a separate frequency. There are two ways to send telemetry from the KPC-3+, either using TNC buffers or by placing the TNC into transparent mode.

Unless the KPC-3+ is put into transparent mode, telemetry sent to it is ignored unless the TNC is programmed to store the text into buffers. Several buffers can be programmed into the KPC-3+. After defining buffers, the KPC-3+ is programmed to send the contents of each buffer at some interval of time. As an example, the KPC-3+ can be programmed to send the contents of one buffer every minute and the contents of the second buffer every two minutes. Not only can the transmission of buffers be programmed for different periods, but they can also be programmed to transmit data at specific times after the minute. As an example, one buffer can be programmed to transmit 15 seconds after the minute while a second buffer can be programmed to transmit 45 seconds after the minute. Transmitting position data every minute is frequent enough. Less important data can be transmitted less frequently. Transmitting at different times after the minute prevents packet information displayed on APRS from being immediately covered up by the next packet.

Alternatively, the KPC-3+ can be set up in transparent mode. In transparent mode the KPC-3+ transmits everything it's sent over its comm port. No buffers are used. The flight computer then controls the KPC-3+ and what is telemetered.

To use the KPC-3+ as a tracker, the following modifications must be made:

- √ Make hardware changes to the KPC-3+
- √ Program the KPC-3+
- √ Connect the GPS receiver
- √ Connect the HT

4.1.1. Making Hardware Changes to the KPC-3+

There are five hardware changes you can make to the KPC-3+. The radio port and one of the battery connection changes are required while the other changes are optional.

- √ Wire the Radio Port (includes modifications for a second comm port).
- √ Wire the Computer Port (includes adding access to the TNC's ADCs).
- √ Wire the internal and external power connectors.

A few notes about these changes. The first change is mandatory because without it, the TNC cannot transmit data to ground stations. A second comm port and access to the TNC's ADCs is through the Radio Port. The second change is optional, but without it, the TNC can't receive data from an external flight computer. The KPC-3+'s internal battery can either act as a backup battery if there is an external battery or it can be the only battery for the TNC. One way or another, at least one of these battery connections must be made. One benefit of using external power is that it lets you power up the KPC-3+ without opening the near spacecraft. The following paragraphs explain the modifications in detail.

Wiring the Radio Port
The TNC needs a radio to communicate with the ground stations. There are two points to be aware of before wiring up the HT. First, the KPC-3+ is capable of receiving transmissions as well as sending transmissions. From near space, the KPC-3+ hears transmissions from over 300 miles away in all directions. This means the KPC-3+ hears packet transmissions from thousands of square miles and

potentially transmissions from over 100 packet stations. This creates the risk of accidental or malicious tampering with TNC settings. For this reason, I recommend that a remote login be setup and that the TNC be programmed to disconnect everyone else. Second, I recommend programming the KPC-3+ to not hold off transmissions when it hears other transmissions. Remember, the KPC-3+ is hearing transmissions from hundreds of miles away while chase crews are only hearing transmissions from a few miles away. If the near spacecraft is within 300 miles of a major city with lots of packet traffic, the KPC-3+ may never transmit. Besides, I believe a $1000 capsule at 100,000 feet has priority over ground stations.

The KPC-3+ Manual illustrates the specifics of connecting the TNC to different types of HTs. Below, the proper connections for the Alinco DJ-S11 HT is documented.

The Radio Port is wired for both the HT and GPS Receiver.

List of Components
- Six 12" lengths of #22 or #24 gauge stranded wire, in three colors with two black wires for ground connections
- 0.1 uF capacitor
- 2.2k 1/8th Watt resistor
- 1/8" male phono jack
- 3/16" male phono jack
- Two male D-subminiature connectors (DB-9)
- Female D-subminiature connectors (DB-9)
- Three ½" lengths of ¼" diameter heat shrink tubing
- Two ¾" lengths of ¼" diameter heat shrink tubing
- Two DB-9 plastic housing kits

Procedure to make the HT Cable
Strip back ¼" of insulation from one end of each wire. Solder the wires to the solder cups of one of the male DB-9 connectors as listed below:

GND:	pin 6	Use both black colored wires
TX:	pin 1	
PTT:	pin 3	
NMEA Input:	pin 2	
Audio Input:	pin 5	

√ Slide a length of heat shrink tubing on each wire and cover the exposed solder connection.
√ Cut both leads of the resistor and capacitor to a length of ½".
√ Solder one lead of the capacitor and resistor to the tip connection of the 3/16" phono jack.
√ Tin the other lead of the resistor and capacitor.
√ Strip two inches of insulation from the other end of one of the black GND wires.
√ Connect and solder the open end of the GND wire to the base of the 1/8" phono jack.
√ Slide a ¾" length of heat shrink tubing over the PTT and TX wires.
√ Plug both jacks into the HT and the DB-9 connector into the TNC.
√ Separate the TNC from the HT, stretching the GND wire out.
√ Lay the TX wire up to the base of the capacitor and cut and strip the wire to length.
√ Lay the PTT wire up to the base of the resistor and cut and strip the wire to length.
√ Tin the leads of the PTT and TX wires.
√ Solder the wires to their respective components. Note: there is no need to twist the wires and leads together, just let the solder flow around the wires.

√   Solder the Audio Input wire to the tip of the 1/8" phono jack.
√   Slide the heat shrink tubing up and cover the exposed soldered connections.
√   Use hot glue to cover the solder cups of the DB-9 connector.

Do the next steps in quick succession so that glue doesn't get cold before closing the housing.

√   Place the bolts into the DB-9 housing.
√   Pour some hot glue into the bottom half of the DB-9 housing.
√   Place the DB-9 connector and its wires into the housing.
√   Pour some hot glue into the top half of the DB-9 housing.
√   Close and bolt the housing halves together.
√   Backfill the housing with hot glue.
√   Label the housing as Radio Port.

Procedure to make the GPS Cable
√   Cut three #24 AWG stranded wires to a length of 12". Note: use a meaningful color scheme; the ground wire should be black.
√   Strip ¼" of insulation from the ends of the wires.
√   Get the second DB-9 connector and housing ready.
√   Separate the NMEA Input and second Ground wire from the other wires in the first DB-9 connector.
√   Slide ¼" length of heat shrink tubing on both wires.
√   Solder the GND wire (black) to pin 5 of the male DB-9 connector.
√   Solder the NMEA Input and a second wire to pin 2 of the male DB-9 connector (TX from the GPS).
√   Solder the remaining wire to pin 3 of the male DB-9 connector (RX from the GPS).
√   Slide the heat shrink tubing over the solder connections and shrink.
√   Use hot glue to cover the solder cups of the DB-9 connector.

Do the next steps in quick succession so that glue doesn't get cold before closing the housing.

√   Place the comm port bolts into the DB-9 housing.
√   Pour some hot glue into the bottom half of the DB-9 housing.
√   Place the DB-9 connector and its wires into the housing.
√   Pour some hot glue into the top half of the DB-9 housing.
√   Close and bolt the housing halves together.
√   Backfill the housing with hot glue.
√   Label the housing as GPS.
√   Cover the label in clear heat shrink tubing.

Read Chapter Four, Section 1.4.2 on how to wire up the GPS35.

Wire the Computer Port
The connections to the Computer Port are:
Flight Computer
ADC Channels

The flight computer connection lets the flight computer send messages to the TNC. The ADC channels allow the TNC to telemeter two voltages to ground stations during the mission. Additional ADC ports are available if you have the courage to solder to the pins of the 68HC11 microcontroller inside the KPC-3+.

List of Materials
- Seven lengths of #24 AWG stranded wire, each 12" long, three of them black
- Seven short lengths of heat shrink tubing
- 25 pin Male, D-subminiature connector (DB-25)

Wiring Access to TNC I/O
√ Strip ¼" of insulation from one end of three wires, making one of them black.
√ Solder the black wire to pin 7 (GND).
√ Solder one wire to pin 2 (RX).
√ Solder the remaining wire to pin 3 (TX).
√ Slide heat shrink tubing on the wires (except for the black wire) and cover the solder joint.

The other ends are connected to a flight computer. Note: if there is no flight computer at this time, roll up the wires and cover them in a short length of heat shrink tubing.

Wire Up Access to the TNC's ADCs

There are two analog-to-digital converter (ADC) channels on the KPC-3+ that are easily accessible. Three other channels are available, but require a more substantial hack, or modification, to the KPC-3+. The ADC channels have eight bits of resolution and can digitize a maximum voltage of five volts. The term resolution means that the voltages inputted to the ADC will be converted to a digital value that is eight bits in size. The largest eight-bit number is 255. So any voltage, not exceeding five volts, is converted to a digital value between 0 and 255. The digital value of the voltage is linearly proportional to the voltage. This means that zero volts is converted to a 0 and that five volts is converted to a 255. If 2.5 volts is inputted to the ADC, a digital value one half of the maximum of 255 is returned (this is 127 or 128, depending on the exact voltage). To convert the digital value back into the voltage, use this formula:

```
Vx = N/51
```

Where: V_X is the unknown voltage
N is the digital value returned by the ADC

This equation only works for ADCs with eight bits of resolution. It is derived by arranging the terms in a ratio of proportionality between the unknown voltage and five volts with the returned digital value and 255.

Ideally, to get the maximum resolution of the data, use voltage sources that vary from zero to five volts. If your voltage source cannot generate voltages as high as five volts, then you can use an op-amp like the LM411 to increase the maximum voltage. Note that this also increases the lowest voltage. To lower the lowest voltage, you may be able to bias the output voltage. This can become needlessly complicated, but it is an option. If your voltage source can generate voltages higher than five volts, then use a voltage divider that reduces the maximum voltage of the sensor or battery to five volts.

The two channels described here are called AN0 and AN1 and are available on both the DB-25 (computer port) and DB-9 (HT port) ports on the back of the KPC-3+. There are three steps to activate the KPC's ADC ports on the Computer Port.

√ Set Jumpers
√ Make Interface Cables
√ Activate KPC-3+ Telemetry

The first two steps are described in this section. The firmware change is described in the next section.

Setting ADC Jumpers
To set the ADC jumpers, open the KPC-3+ case and locate jumpers J8 and J10 (located at the back of the PCB). Change both the shorting blocks on the center pin and pin 2. J8 activates AN0 on the DB-25 connector and J10 activates AN1 on the DB-25 connector. After changing the jumpers, AN0 becomes pin #18 of the DB-25 connector and AN1 becomes pin #11 of the DB-25 connector. Voltages connected to these pins have their grounds connected to pin #7 of the DB-25 connector.

Procedure to Wire the ADCs
  √   Strip ¼" of insulation from one end of the remaining wires (two are black wires).
  √   Solder one end of the ground wires (black) to pin #7 (they share with pin with the ground of the GPS receiver).
  √   Solder one end of an analog voltage wire to pin #11 (AN1).
  √   Solder one end of the other analog voltage wire to pin #18 (AN0).
  √   Document which color wire went to which pin.
  √   Slide the heat shrink tubing over the exposed soldered ends and shrink in place.
  √   Pair a ground wire to an ADC channel wire and cut them to the same length.
  √   Do the same for the remaining two wires.
  √   Use hot glue to cover the solder cups of the DB-25 connector.

Do the next steps in quick succession so that glue doesn't get cold before closing the housing.

  √   Place the comm port bolts into the DB-25 housing.
  √   Pour some hot glue into the bottom half of the DB-25 housing.
  √   Place the DB-25 connector and its wires into the housing.
  √   Pour some hot glue into the top half of the DB-25 housing.
  √   Close and bolt the housing halves together.
  √   Backfill the housing with hot glue.
  √   Label the housing as Computer Port.

Terminate the ADC cables with a means that suits your application. Two options are to use Powerpole® connectors or headers that fit your flight computer.

Wiring the Power Connectors
Two power connections are available on the KPC-3+. I recommend making both of them, even if you only plan to use one of them. When using both of them, the KPC-3+ can be set to switch power supplies when the original supply voltage has dropped too low. Three steps are required to wire in the power connectors.

  √   Add the 9-volt battery snap
  √   Add the external power plug
  √   Set KPC-3+ jumpers

Internal Power
The KPC-3+ does not have a factory installed battery snap. You must add one.

List of Materials
  •   9-volt battery snap (use the heavy-duty battery snap from Radio Shack, 270-324)

Procedure
- √ Open the KPC-3+ case.
- √ Locate the battery snap pads.

- √ Look in the KPC-3+ Manual for directions. Instructions are located under the section, Installing Your KPC-3+ in subsection Internal Power, from a Battery. Currently the nine-volt battery snap is soldered to pads located in the back left of the TNC's PCB.

- √ Solder the red 9V battery snap lead to the + pad and the black lead to the – pad. Glue a sheet of foam rubber onto the inside of the lid, over the battery's position. The foam rubber places pressure on the battery once you bolt the lid back onto the TNC. The pressure keeps the battery from bouncing around inside the case, possibly causing mischief. Do not close the case at this time.

External Power
On the back of the KPC-3+ is a power plug jack. This is the location to solder the external power to the TNC.

List of Materials
- 2.1 mm power plug (RS #274-1532)
- Two 24" lengths of #22 gauge, strained wire (one with red insulation and the other with green insulation)
- One pair of Powerpole®s
- One miniature SPST toggle switch
- Two ½" lengths of ¼" diameter heat shrink tubing
- Two ½" lengths of 1/8" diameter heat shrink tubing
- Two labels with "TNC Power" written on it
- 1½" diameter clear heat shrink tubing, ½" long

Procedure
- √ Unscrew the housing from the power plug.
- √ Strip ¼" from one end of both wires.
- √ Strip ½" from the other end of both wires.
- √ Solder the ¼" end of the red colored wire to the center pin of the power plug.
- √ Solder the ¼" end of the green wire to the outer pin of the power plug.
- √ Slide one piece of heat shrink tubing on each wire and cover the exposed soldered connection.
- √ Cover the sealed power plug connections with a tiny amount of hot glue.
- √ Close out the power plug housing and squirt some hot glue into the back, filling the interior.
- √ Crimp and solder the Powerpole® pins on the other (1/2") ends of the wires.
- √ Snap on the plastic housings of the Powerpole® connectors, making sure you match up the color of the housings with the color of the wires.
- √ Backfill the housings of the Powerpole® connectors.
- √ Wrap a label over the back half of the Powerpole® housings, indicating they are for TNC power.
- √ Cover the label with the clear heat shrink tubing and heat the tubing.
- √ Find the center of the cable and cut the red wire.
- √ Strip ¼" of insulation from both ends of the red wire.
- √ Tin the wires and the pins on the SPST switch.
- √ Slide short lengths of heat shrink tubing on the red wires.
- √ Solder the red wires to the SPST switch pins.

√   Cover the soldered connection with the heat shrink tubing.
√   Label the switch as TNC PWR.

Set KPC-3+ Jumpers
√   In the KPC-3+ Manual is a diagram of the TNC PCB. Locate jumpers J1 and J2. After setting these jumpers, the TNC will be tested and then closed up.

Procedure
√   Place J1 ON and J2 OFF (this lets the highest voltage power the TNC).

Test
√   Press the KPC-3+ power button to Off.
√   Place both the 9-volt battery into the TNC and onto the external power cable.
√   Power up the TNC.
√   Pull power from the external power cable.
√   Check that the TNC did not turn itself off.
√   Apply power to the external power cable.
√   Pull power from the 9-volt battery snap.
√   Check that the TNC did not turn itself off.
√   Shut off the KPC-3+.
√   Close the TNC's case.

4.1.2. Programming the KPC-3+

When first powered up, the KPC-3+ performs a detection for the current baud rate by asking the user to press an * character. When you can read the message, you respond by pressing an * (shift 8). Next the KPC-3+ asks for your call sign. The KPC-3+ is now ready to be programmed, but is in the NEWUSER mode. Type INTFACE TERMINAL to get into the terminal mode. Now you're in position to really mess up your KPC-3+!

Command List
The following is a list of TVNSP-developed firmware changes to make to the KPC-3+ to configure it for near space tracking. Carefully enter these commands, and press ENTER after each one. You must decide upon your disconnect message, call sign, remote login password, and your near spacecraft's name to proceed.

```
ABAUD 4800
CD SOFTWARE
CMSG DISC
CTEXT "your disconnect message"
DIGI OFF
HEA OFF
MYREMOTE "your call sign"
RTEXT "a password for remote login"
UNPROTO APRS VIA WIDE3-3
MYALIAS NONE

BEACON E 5
BTEXT "Your near spacecraft's Name"

TELEMETRY 12

GPSHEAD 1 $GPGGA
BLT 1 E 00:01:00 START 00:00:00
```

```
LTP 1 GPSPO VIA WIDE3-3

GPSHEAD 2 $GPRMC
BLT 2 E 00:01:00 START 00:00:15
LTP 2 GPSPO VIA WIDE3-3

GPSHEAD 3 $PGRMV
BLT 3 E 00:01:00 START 00:00:30
LTP 3GPSPO VIA WIDE3-3

GPSHEAD 4 $GPBS2
BLT 4 E 00:01:00 START 00:00:45
LTP 4GPSPO VIA WIDE3-3

GPSPORT 4800 NORMAL
INTFACE TERM
```

Now, power down the KPC and restart it. No message will appear on the PC as the GPS is waiting for data from the GPS receiver.

4.1.3. General Commands

Here are some details about the following commands.

```
ABAUD 4800
```
This sets the default communications baud rate for the KPC-3+ to 4800 baud. Set your terminal program to this baud rate before trying to communicate with the KPC.

```
CD SOFTWARE
```
The carrier detect is handled by firmware inside the TNC, rather than by the audio signal coming from the HT. Carrier Detect is the detection of someone else using the same frequency. Carrier Detect prevents your transmissions from stepping on someone else's transmissions.

```
CTEXT "your disconnect message here"
```
The specified message is sent to packet stations trying to connect.

```
CMSG DISC
```
The CTEXT message is sent to packet stations trying to connect to the TNC before they are disconnected.

```
DIGI OFF
```
Prevents packet stations from digi-peating through the main telemetry system. If you want to allow digi-peating during a mission, then use a second TNC on a separate frequency.

```
HEA OFF
```
Places the header and packet message on the same line. The header consists of the destination information and a time stamp. Text from the near spacecraft takes less space this way.

```
UNPROTO APRS VIA WIDE3-3
```
Packets sent from the near spacecraft are not sent to a specific address, they are sent to everyone on the ether. There is no acknowledgment and therefore packets are not resent if someone doesn't receive a proper packet. All packets are sent to an address of APRS and are repeated a total of three times (max) by digi-peaters.

```
MYALIAS NONE
```

Allows a station to digi-peat through the KPC-3+ if they use the call sign defined in the MAYALIAS command. Since we don't want digi-peating through the TNC, there is no alias defined.

`BEACON E 5`
Send the beacon every five minutes. Beacons are used to identify the station, in this case the near spacecraft, transmitting the packets.

`BTEXT "Your near spacecraft's Name"`
The beacon text is the name of the near spacecraft. Other messages can be placed here, for instance, your near space program name or a message for this particular flight. A total of 128 characters can be used in the text message.

`TELEMETRY 12`
Send the analog and digital values of the TNC every 120 seconds (or two minutes). The values of most concern are the AN0 and AN1 values, which are the most easily accessed analog channels. The other digital and analog values are more difficult to access from outside the TNC and are not covered above. Note that telemetry has the following format:

`T#nnnn,AN0,AN1,AN2,AN3,AN5,D1D2D3D4D5D6D7D8`

Where:

`T#nnnn` is the number of the telemetry transmission and is incremented after each transmission.
Example: `T#0132`

`AN0 to AN5` (there is no AN4) are the digitized values of the analog voltages on the KPC-3+'s microcontroller.
Example: `123,375,523,078,496`

`D1D2D3D4D5D6D7D8` are the eight digital values on the KPC's microcontroller.
Example: `11011001`

LT Buffer Commands
The following three commands are set up for each LT (location text) buffer. Each LT buffer is programmed to collect a single GPS sentence and transmit it at a specified time and to a specified station. Use the next three commands for every LT buffer (up to a maximum of four) you want to set up in the KPC. LT buffers can be for data from a GPS receiver or the flight computer, if you have enough ports available on the KPC.

`GPSHEAD 1 $GPGGA`
Store the $GPGGA sentence in LT buffer 1.

`GPSHEAD 2 $GPRMA`
Store the $GPRMA sentence in LT buffer 2.

`GPSHEAD 3 $PGRMV`
Store Garmin's 3-D velocity sentence in LT buffer 3.

`GPSHEAD 2 $GPBS2`
Reserve LT buffer 4 for flight computer messages.

`BLT 1 E 00:01:00 START 00:00:00`

Beacon the contents of LT buffer 1 every 60 seconds, starting at the beginning of the minute. The APRS map shows data from the last received GPS sentence. New data overwrites old data. Giving the beacons different start times lets you see text on the APRS map before it is over written. Do not use the clear command with BLT. With the clear command, data in the LT buffer is erased after each transmission. Without the clear command, the last known location of the near spacecraft is transmitted. This may be useful should the GPS fail during descent.

`BLT 2 E 00:01:00 START 00:00:15`
Same for LT buffer 2, except LT buffer 2 packets are transmitted at 15 seconds after the minute.

`BLT 3 E 00:01:00 START 00:00:30`
Same for LT buffer 2, except LT buffer 2 packets are transmitted at 30 seconds after the minute.

`BLT 4 E 00:01:00 START 00:00:45`
Same for LT buffer 2, except LT buffer 2 packets are transmitted at 45 seconds after the minute.

`LTP 1 GPSPO VIA WIDE3-3`
Specifies that the contents of the LT buffer #1 are to be sent with a maximum of three hops through digi-peaters. GPSPO indicates that the Balloon Icon is to be displayed in APRS.

`GPSPORT 4800 NORMAL`
Tells the KPC-3+ that data from the GPS receiver follows the NMEA standard (4800 baud, N81).

`INTFACE TERMINAL`
Sets the KPC3 into command mode upon power up. When in command mode, a flight computer can send data through the Computer Port. This does not affect the GPS on the Radio Port.

This completes the modifications and programming for the KPC-3+. It's ready to be installed into an airframe at a later time.

Next we'll take a look at another tracker – the MIM.

4.2. APRS Micro Interface Module (MIM) Flight Computer

Micro Interface Module (MIM)
– *Photo provided by Dr. Bob Twiggs.*

The MIM is a 1" by 2" PCB built around a PIC microcontroller. The PIC is programmed to accept text data, break it into packets, generate CRCs for the packets, key the HT, and convert the text into audio tones. Not bad for a day's work. The MIM is not assembled by the user, but is instead purchased as a complete module. The only hardware change to make to the MIM is connecting it to the outside world. The firmware changes involve programming the MIM as to when and what to transmit. Unlike the Tiny Trak, the MIM transmits the complete GPS sentence programmed into it. The MIM can even be fooled into transmitting data looking like a GPS sentence.

4.2.1. Theory of Operation

The MIM has the following connections:

Pad Function	Location on PCB
Power and ground	Top of the MIM
Five ADC inputs	Top left of the MIM
Eight digital inputs	Top right of the MIM
Four HT connections	Left middle of MIM
Three serial connections	Bottom right of MIM

The MIM is programmed through its serial port, the same serial port used to connect the GPS receiver. In addition to sending GPS sentences, the MIM also digitizes five voltage sources, up to five volts each, at a resolution of eight bits, and the status of eight digital switches.

Connections to the MIM are soldered to the pads on the PCB. If these wires do not have a base to act as a strain relief, they eventually pull loose from the MIM's solder pads. The MIM Flight Computer is designed to prevent this. The MIM is mechanically and electrically mounted to the PCB with bolts and short lengths of wire. Then all connections to the MIM are made through ports on the PCB instead of the MIM solder pads. There are holes drilled into the corners of the PCB for attachment to a sheet of Coroplast™ (forming the avionics pallet).

4.2.2. Mounting the MIM to the Flight Computer PCB

There are two steps to mounting the MIM to the PCB, mounting it mechanically and connecting it electrically. Each step is covered in a separate section below.
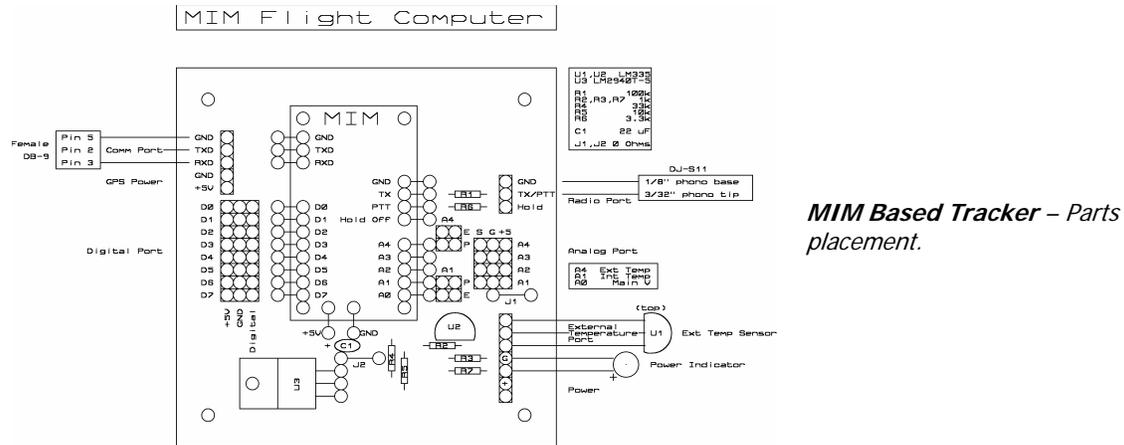
MIM Based Tracker – *Parts placement.*

Mechanically Mounting the MIM to the PCB
There are four holes in the corners of the MIM for mounting it to a base. Usually stand-offs are used to raise the MIM above its mounting base. I have always found it nerve wracking to use small stand-offs. So in place of standoffs, I recommend using a sheet of foamed neoprene rubber. Using it place of standoffs is less expensive and easier for my 42-year old fingers. However, you can use stand-offs in place of the foam if you desire.

Materials Needed to Mechanically Mount the MIM to the PCB
- 3mm neoprene foam rubber*
- Nylon zip ties
- Four mounting bolts and nuts ½" long (use #1 hardware) **

* Foamies® brand neoprene foam manufactured by Darice Inc. is available at crafts stores.
** I have found that two bolts, if mounted in diagonal corners, works well enough. The wires used to electrically connect the MIM to the PCB along with two bolts are sufficient to secure the MIM to the PCB.

Procedure to Mechanically Mount the MIM to the PCB
- √ Measure and cut a rectangle of neoprene foam to fit the MIM.
- √ Press the foam against the underside of the MIM, creating an impression of the MIM's crystal.
- √ Trim out a rectangle of foam where the crystal housing is located.
- √ Replace the foam and, with a sharp point, punch small holes into the foam where the MIM's mounting holes are located.
- √ Position the MIM on the PCB, with the foam between the MIM and the PCB.
- √ Bolt at least two diagonal corners of the MIM to the PCB.

Electrically Connecting the MIM to the MIM PCB
At this stage, the solder pads on the MIM are electrically connected to the PCB.

Components Needed to Electrically Mount the MIM to the MIM PCB
- Tweezers
- Wire

Wire Notes: The MIM PCB has solder pads matching those of the MIM. The MIM is mounted to the MIM PCB with "L-shaped" wires soldered between the MIM's pads and the pads of the MIM PCB. Use either components leads, if you have a lot of them lying around, or cut leads from thin gauge solid, smaller than #24 AWG, wire stripped of insulation. After selecting a source of wire, follow the steps below.

Procedure to Electrically Mount the MIM
- √ Cut the leads to a length of 3/4" long.
- √ Bend a right angle in the leads ½" from the end.
- √ Tin the solder pads of the MIM.
- √ One at a time, place a wire "L" onto a solder pad and through the corresponding PCB pad. Note: remember to use just a tiny amount of solder to the MIM pads and apply the solder quickly. Too much heat can make the copper pads lift from the MIM.
- √ Solder each wire "L" to the MIM.
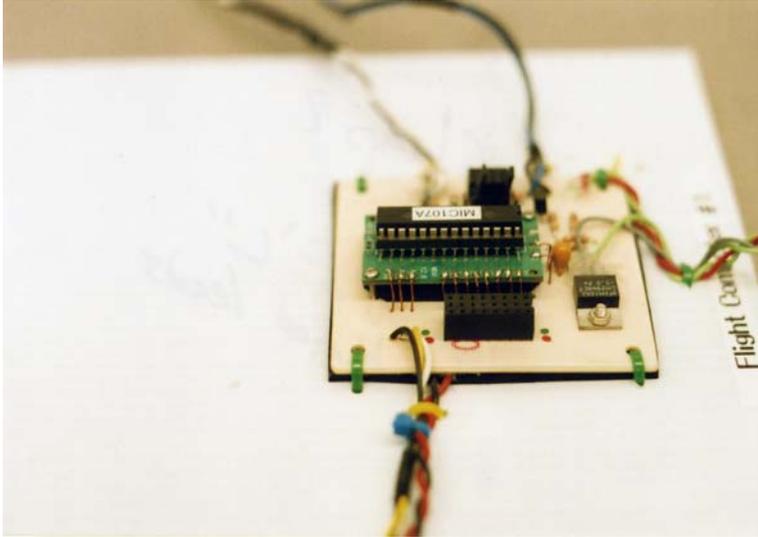
"L" Leads Close-up - Leads are made from bare copper wire.

Note: This will drive you crazy, so be sure to have lots of spare time. And please, don't come looking for me if this step drives you over the edge.

Note: There are three solder pads related to power on the MIM. One solder pad is for ground and must be used. The other two are for positive power and only one of these is used. Since five volts will be made available for the MIM, the PCB only uses the pad marked +5V.

After the "L"s have been soldered to the MIM, flip the PCB over and solder the other ends of the leads to the PCB. Trim the excess leads.

4.2.3. Procedure for Assembling the MIM PCB

After having mechanically and electrically mounted the MIM, solder the following components to the PCB:

Materials to Complete the PCB
- Double row female receptacles, 1/10" between centers (12 holes total)
- Single row female receptacles, 1/10" between centers (12 holes total)
- Double row of male headers, 1/10" between centers
- Two shorting blocks
- Two LM335 temperature controlled zener diodes
- One LM 2940T-5 low dropout voltage regulator
- 22 uF tantalum capacitor
- One 2.2k resistor
- Two 1k resistors
- One 10k resistor
- One 33k resistor
- One 100k resistor
- One 3.3k resistor
- Two zero ohm resistors or jumper wires
- One SPST or SPDT toggle switch
- Two Powerpole® connector kits
- 9-Position Male, D-Subminiature Connector, Solder-type (RS# 276-1537)
- DB-9 jacket kit

- Wire, #22 or #24 gauge stranded
- Heat shrink tubing for the above wires
- One Two-conductor, 3/32" phone plugs (RS# 274-290B)
- One Two-conductor, 1/8" phone plugs (RS# 274-286A)
- Two 0.02" thick polystyrene plastic pieces measuring 0.75 inches by 1.25 inches
- 1½" diameter clear heat shrink tubing, ½" long
- Coax-style DC Power Plug 4.0mm X 1.7mm
- Subminiature toggle switch

Procedure for Completing the PCB

Resistors and Jumpers
Bend resistor leads to a length of 0.4" with a lead bender. After soldering the resistors, clip the extra leads. Use either 0 ohm resistors or short lengths of insulated wires for the jumpers. For extra security against shorts, keep the jumper wires insulated for as much of their length as possible.
- R1
- R2
- R3
- R4
- R5
- J1
- J2

Capacitors
The capacitor has a 0.1" spacing between leads. Use a tantalum capacitor for C1 and note its polarity. After soldering the capacitor, clip the extra leads.
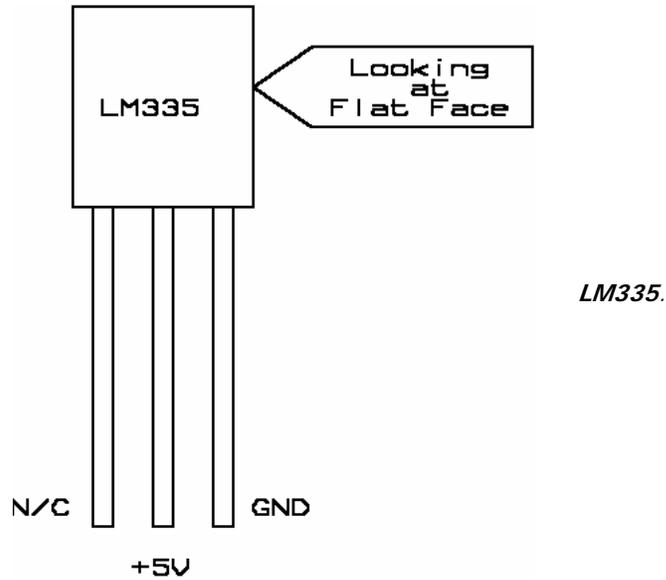
- C1

Semiconductors
U1 is soldered to a 12" long cable while U2 and U3 are both soldered to the PCB. Note the proper orientation of U1 and U2. Bend the leads of U3 (voltage regulator) back before soldering it to the PCB. Bend the leads where they get thicker. The voltage regulator is bent so that its heat sink is flush against the PCB. After soldering U3, bolt its heat sink to the PCB. After soldering the semiconductors, clip the extra leads.

- U2
- U3

Directions for Cabling U1 (LM335)

```
┌─────────────┐        ┌─────────────────┐
│             │       ╱│    Looking      │
│             │      ╱ │      at         │
│  LM335      │◄────    │  Flat Face      │
│             │      ╲ │                 │
│             │       ╲│                 │
└──┬───┬───┬──┘        └─────────────────┘
   │   │   │
   │   │   │
   │   │   │
   │   │   │
 N/C   │  GND
      +5V
```

LM335.

- √ Cut the leads of U1 to a length of ½".
- √ Cut three lengths of 22 AWG stranded wire to a length of 12".
- √ Strip ¼" of insulation from one end of each wire and ½" of insulation from the opposite ends.
- √ Tin the ½" ends of the three wires.
- √ Tin the leads of U1 (LM335).
- √ Lay the tin end of one wire against a tinned lead of U1 and heat the contact with a soldering iron until the solder melts and connects the lead to the wire.
- √ Repeat on the other two leads.
- √ Cover the exposed leads with heat shrink tubing.
- √ Solder the ¼" ends of the wires to the PCB – watch the polarity of U1 (a top view of U1 is illustrated).
- √ Twist or wire tie the U1 cable.

Male Headers
- √ Cut two pieces of two-wide male headers, with 1/10" between centers to a length of 2 pins. You will have two pieces of two by two male headers.
- √ Solder them to the PCB.
- √ Female Receptacles
- √ Cut two identical lengths of each of the single and double row female receptacles. One set is cut to a length of eight holes and the other set is cut to a length of four holes.
- √ Solder the receptacles to the PCB.

PCB Power Connector
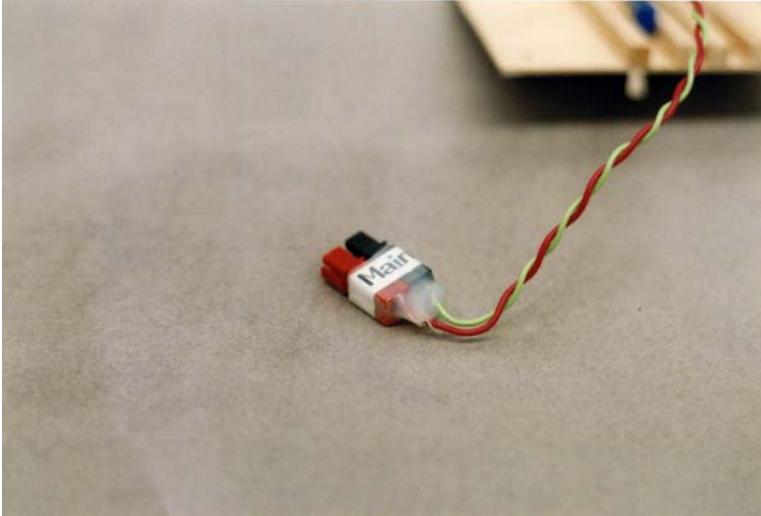
Completed Powerpole® *- After crimping wires, they are soldered and inserted into housing. Housing is backfilled with hot glue and then labeled. Label is protected with clear heat shrink tubing.*

√   Cut about 18" of two pieces of stranded wire.
√   Solder the red wire to the pad marked + Power.
√   Solder the black wire to the pad marked GND Power.
√   Slide two 1" lengths of heat shrink tubing over both the red and black wire.
√   Strip 1" of insulation from the other end of the red and black wire.
√   Fold the stripped wire over.
√   Crimp the wires in a Powerpole® connector pin.
√   Fill the crimp with solder.
√   Snap the crimps into their Powerpole® jackets.
√   Fill the interior space with hot glue.
√   Slide the jackets together and wrap the HT label around them.
√   Cover the jacket with clear heat shrink tubing and heat the tubing.
√   Backfill any remaining gaps.
√   Cut the red wire about two-thirds of the way between the coax power connector and the Powerpole®, closer to the Powerpole®. Note: be sure there is heat shrink tubing on both sides of the cut wire.
√   Strip ¼" of insulation from both ends.
√   Slide a 1" length of heat shrink tubing over both wire.
√   Slide thin heat shrink tubing over each wire.
√   Solder the wires to the pins on the back of the subminiature toggle.
√   Slide the thin heat shrink tubing over the soldered pins.
√   Twist the wires together to form a "Y" shaped cable.
√   Keep the "Y" together by shrinking the tubing on each arm of the "Y".

Test continuity between the +5V Powerpole® and the ground Powerpole®. If there is continuity, then you have soldered in a short. Check your connections.

LED Power Indicator
√   Cut at least 12" of two wires (the LED cable).
√   Strip ¼" of insulation from one end of each wire and ½" from the other end.
√   Solder the black wire to the pad labeled G on the PCB diagram.
√   Solder the other wire to the pad to it's right
√   Slide a single 1" length of heat shrink tubing on both wires to cover both wires on the LED leads.

√   Slide a 1" length of narrow heat shrink tubing on each wire to cover the soldered joint.
√   Clip the LED leads to a length of ½".
√   Tin the LED leads and wires.
√   Solder the wires to the LED leads.
√   Cover the solder joints with the heat shrink tubing.
√   Cover the individual wires and LED leads with the larger heat shrink tubing.
√   Shrink all tubing down.

DJ-S11 MIC, Audio, and Power Connectors
The first, and easiest, connection to make is the HT cable. Since I recommend your near space capsule use an Alinco DJ-S11, I have documented the proper connections for the DJ-S11.

MIC and Audio

√   Strip back ¼" of insulation from one end of a black wire and a colored wire.
√   Solder the black wire to the GND pad of the HT pads and the colored wire to the TX/PTT pad of the PCB.
√   Solder the other end of the GND wire to the base of the 1/8" phono jack.
√   Plug the Ground plug into the HT and stretch the wire out taut.
√   Plug the 3/32" plug into the HT.
√   Stretch out the colored wire to the center connector of the 3/32" plug.
√   Measure the proper length of the wire, then cut and strip its end.
√   Solder it to the tip of the 3/32" phono jack.
√   Plug the phono jacks into the DJ-S11.
√   Squirt a little hot glue between the jacks, without getting any on the HT.
√   Put a thin coat of hot glue on one piece of polystyrene.
√   Press the first sheet of polystyrene onto one face of the glued connectors.
√   Put a thin coat of hot glue on the second piece of polystyrene.
√   Flip the HT over to its other side and press the second rectangle of plastic onto the combined connectors.
√   When the glue in the DJ-S11 plug has cooled, remove the plug from the HT.
√   Fill the voids in the HT plug with the warm hot glue.
√   Let the unified connector cool.
√   Trim the edges of the HT plug with a sharp Exacto knife.
√   Finish the housing by covering it with heat shrink tubing.

Power
√   Cut two wires, both 18" long (use one red and one black wire).
√   Remove ½" of insulation from one end of both wires.
√   Solder the red wire to the center connector of coax power plug.
√   Solder the black wire to the ring connector.
√   Slide a length of heat shrink tubing over the positive wire, covering the soldered connection.
√   Squirt a drop of hot glue between the soldered connections.
√   Screw on the plastic cap and fill the interior space with a little bit of hot glue.
√   Strip 1" of insulation for the other ends of the wires.
√   Double over the exposed wire.
√   Crimp Powerpole® connectors on the wires.
√   Slide the crimps into their jackets, using the proper colored housings to indicate positive and ground.
√   Slide the Powerpole® jackets together.
√   Wrap the jackets with a label marked HT.

√   Cover the jacket and label with clear heat shrink tubing.
√   Cut the red wire about two-thirds of the distance away from the coax power plug.
√   Strip ¼" of insulation from the ends of the wires.
√   Slide heat shrink tubing over the wires.
√   Solder the wires to the pins of a toggle switch.
√   Cover the soldered connection with heat shrink tubing.

DB-9 Connector
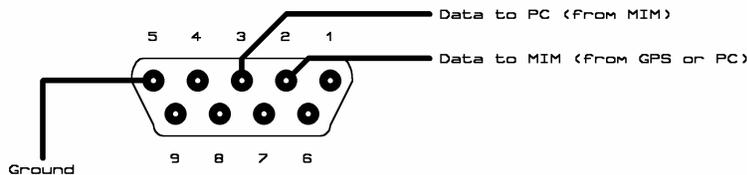
DB-9 Connections - *Look carefully on DB-9 and you will find labels for each solder cup (numbers may only be on one side of DB-9).*

Since the MIM will spend most of its time connected to the GPS receiver, use a male DB-9 connector on the MIM serial port. This will necessitate the use of a gender changer when programming the MIM.

√   Strip ¼" of insulation from both ends of three wires.
√   Solder three different colored wires to the serial pads of the MIM, using a black colored wire for the GND pad.
√   Slide on ½" lengths of heat shrink tubing.
√   Solder the other ends of the wires to the following pins of the DB-9 connector:
√   GND   Pin 5
√   TXA   Pin 2
√   RXA   Pin 3
√   Slide the heat shrink tubing over the exposed soldered connections and shrink the tubing.
√   Use hot glue to further cover the wires and DB-9 pins.
√   Cover the DB-9 with a cover kit and backfill with hot glue.

4.2.4. Notes on Design

The MIM based flight computer draws 31 mA of current without the GPS35 and 160 mA with the GPS35.

A Short Note About Digital Ports
Many digital connections, those where you only report either a high or low state, require pull-up or pull-down resistors. The MIM has pull-up resistors built into the PCB. So switch closures should connect the MIM's digital ports to ground. When the switch is opened, the digital port will read a digital 1.

A Short Note About Voltage Regulators
Many voltage regulators require an overhead of two volts. For example, if you use a LM7805 voltage regulator to provide five volts to a circuit, then you need to supply the voltage regulator with seven volts to operate. The LM7805 is ideal for a nine-volt battery if you want an inexpensive voltage regulator. The two-volt overhead I referred to is called the dropout voltage. When the supply voltage drops below the output voltage plus the dropout voltage, the voltage regulator stops supplying voltage.

There are several alternatives to the LM7805. The alternative used here is the LM23940T-5. It operates like the LM7805, but has only a 0.25 volt drop out. This makes it ideal for a six-volt supply voltage. By the way, the lower the supply voltage, the lower the volts the voltage regulator has to drop, and therefore the more efficient the regulator and the lower the amount of waste heat generated by the regulator.

Other alternatives are the switched regulator and those with a charge pump. Those are newer and more expensive voltage regulators. I've decided to save them for my next book, that is to say, after I have completed more research on them.

4.2.5. Procedure to Mount the PCB to the Coroplast™ Base (Avionics Pallet)

Now that all the wires are soldered to the MIM PCB, it's time to mount the PCB down to the Coroplast™ base. Afterwards tie the MIM cables to the Coroplast™ base as a strain relief.

Materials to Make the Avionics Pallet
- Sheet of Coroplast™
- Neoprene foam
- Nylon wire ties
- Drill bit to punch holes

Procedure to Make the Avionics Pallet
- √ Cut a sheet of Coroplast™ to fit the airframe.
- √ Lay the foamed neoprene sheet under the PCB.
- √ Mark the size of the PCB and locations of its mounting holes on the neoprene
- √ Carefully cut out and punch holes in the neoprene.
- √ Lay the PCB on top of the Coroplast™ and mark the location of the mounting holes.
- √ Carefully punch the holes into the Coroplast™.
- √ Measure ½" away from the Coroplast™ holes and make a second set of holes.
- √ Lay the PCB and neoprene on top of the Coroplast™.
- √ Use nylon wire ties to tie the PCB down to the Coroplast™.
- √ Lay the cables on the Coroplast™ and mark the location of holes for nylon wire tie strain reliefs on the Coroplast™.
- √ Carefully punch holes in the Coroplast™ and tie the cables down to the Coroplast™ to provide strain relief.

4.2.6. Software Changes

I recommend programming the MIM with the following settings:

```
MYC your call sign-11
VIA WIDE3-3
PTT 0
MYS O (see note)
TXD 21 (default)
PER 6
POS 10
STR GPGGA
TELE 10 5
B 20
BT (name of your flight computer)
```

```
CW 30
CWI your call sign-11
```

4.2.7. General Comments

```
MYC your call sign-11
```
This field codes the call sign the MIM transmits under. Use the 11 SSID to identify the near space tracker as a balloon (display the balloon icon).

```
VIA WIDE3-3
```
The path, WIDE3-3, limits packet transmissions to just three hops through digi-peaters. Consult with your local APRS community for guidance.

```
PTT 0
```
This activates the press-to-talk of the HT by bringing the PTT button to ground (active low). This is the default and appropriate for most HTs.

```
MYS O (the APRS balloon symbol)
```
My Symbol is a second method to indicate the appropriate symbol to display on APRS. The symbol "O" (not zero) is the balloon icon. This field is not required if the SSID of 11 is used, but does take precedence over the symbol coded in the SSID. Other symbols available include the following

- MYC Icon
- E   Eyeball
- K   School
- R   RV
- U   Bus
- [Jogger
- b   Bicycle
- _   Weather Station

Not that I'm encouraging it, but wouldn't catch someone's attention to see a jogger icon at an altitude of 100,000 feet? Consult the APRS Protocol Reference for more information on symbols.

```
TXD 21 (default)
```
This field specifies the delay between keying the HT and sending the audio tones in tens of milliseconds. So, the default of 21 means to delay sending tones for 0.21 seconds after keying the HT. Increase this value if the first part of the packet is clipped.

```
PER 6
```
PERIOD sets the time base for all other telemetry functions. As such, it acts as a multiplier for times settings for the following functions:

- Position
- Telemetry
- Beacon
- CW
- Auto (valid only if the MIM is used as a MIC-E, which it isn't on the near space tracker)

```
POS 10
```

Indicates how often position reports are transmitted in seconds and multiplied by PER. By setting PER to six and POS to 10, position reports are transmitted every six times 10 seconds, or once a minute.

`STR GPGGA`

STR determines which GPS sentence (string) is to be transmitted. If the MIM is connected to a BASIC Stamp 2 microcontroller, STR can be set to an invalid GPS sentence type, like GPBS2, and the MIM will transmit data sent to it by the microcontroller if the data is prefixed with GPBS2. The issue of applying this is that the sentence really needs to be a valid APRS field. The author has experimented with sending $GPGGL, CR, /"data" as a means of accomplishing this. Look for more notes in the sequel to this book.

`TELE 10 5`

This field indicates how often telemetry is transmitted and how many analog channels to include. The first number is the number of seconds between telemetry transmissions in seconds, and multiplied by PER. In the recommended commands, telemetry is transmitted every 10 times six seconds. The second digit indicates how many of the analog channels are to be transmitted with each telemetry report. Only a 2 or 5 can be used in this field.

`B 20`

This field determines the time between beacon transmissions in seconds when multiplied with the PER setting. In this example, beacons are sent every six times 20 seconds, or every two minutes.

`BT (name of your flight computer)`

The text for the beacon (Beacon Text) is set in this field. Up to eighty characters can be specified for the beacon. Use a meaningful name for this text. Since the avionics pallet can be moved between several different airframes, I do not recommend programming the name of the near spacecraft into BT, unless you want to reprogram the MIM every time it moves to a new airframe.

`CW 30`

This field determines how frequently the CW ID is transmitted. The number specified is the time in seconds between transmissions multiplied by the PER setting. In this example, the call sign is transmitted every 300 seconds, or every 5 minutes. The CW call sign is useful for DFing a lost near spacecraft.

`CWI your call sign-11`

This field indicates the text to be transmitted with each CW ID. Up to twelve characters can be specified, enough for a call sign and SSID.

4.2.8. Example of Telemetry

The following is an example of the telemetry transmitted by a MIM. This example is from a TVNSP near space mission at GPSL 2001 at Manhattan, Kansas.

```
KD4STH-11>APRS,WIDE,3-3:$GPGGA,135020,4329.3433,N,11624.2788,W,1,11,1.1,819.7,M,-
18.3,M,,/GPS FIX
```

This one is a "standard" APRS packet that gives the complete GPS sentence. After KD4STH-11, which is my balloon's call sign, is the destination for the packet (APRS). As I understand, this means I'm sending the packets to anyone who wants to receive them. At the very end is the /GPS FIX. This is a message from the MIM saying that it is getting GPS updates. If the GPS had died, the messages would be /LAST FIX (which is something you don't want to see occur at 100,000 feet).

Good To Know: Upper-air Soundings with Radiosondes

Up and Away - *A radiosonde is released in front of the filling building.*

Twice a day, the National Weather Service (NWS) launches radiosondes that measure the temperature, pressure, humidity, and wind profiles of the atmosphere. NWS Radiosonde launches are a part of our country's participation to the World Meteorological Organization's (WMO) World Weather Watch program. Under WMO's WWW, upper-air stations spread throughout the world determine the upper-air profile of the Earth at twelve-hour intervals. NWS launches take place at 102 radiosonde stations across North America, some Pacific islands, and in the Caribbean. The total of 102 launches every twelve hours means the NWS launches over 74,000 radiosondes each year. Currently radiosonde launches are the only tool capable of measuring the temperature, pressure, humidity, wind speed, and wind direction of the atmosphere from sea level to over 100,000 feet.

The earliest upper-air soundings in the US began in 1749 and were based on observing tethered kites. As radio technology became available, radiosondes replaced kite observations, tethered balloons, and airplane based observations. Radiosonde launches began in 1937-1938 by the then Weather Bureau. Initially, radiosonde launches and observations were a laborious by-hand process. By the 1980's, with the advent of desk top PCs, the automated radiosonde program of today was born.

The device sent up on the balloon is called the radiosonde, and its observation of temperature, pressure and humidity is called a radiosonde observation. When adding the calculated wind speed and direction, the data becomes a rawinsonde observation.

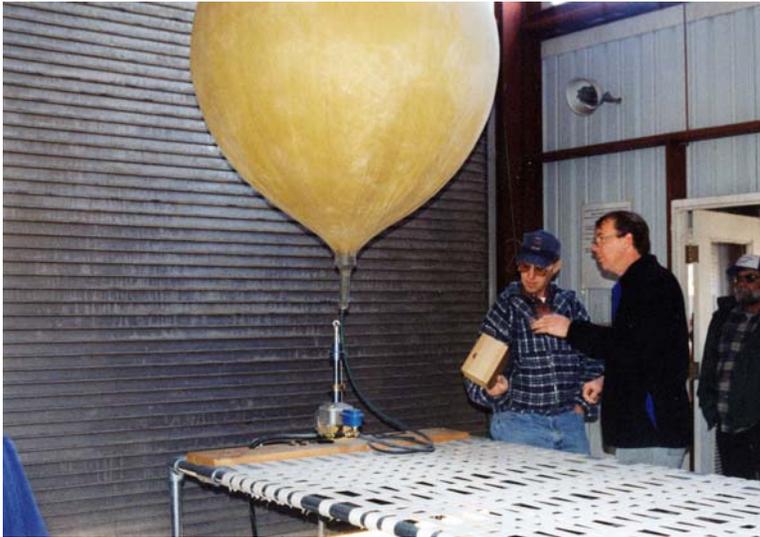In the upper-air sounding system are as following elements:

- Flight Subsystem
- Surface Subsystem

Flight Subsystem
The flight subsystem closely matches our near spacecraft, with the only major difference being the nature of the payload. The parts of the Flight Subsystem are:

- Balloon
- Flight Train
- Radiosonde

Balloon

Filled Balloon - Amateur radio operators look over a filled balloon.

Our near spacecraft uses the same balloons as the NWS. We even order them from the same supplier (but the Federal government orders in bulk and must get a heck of a discount). On my visits to the Boise NWS office, I have observed them using 1000-gram balloons. The lifting gas of choice at the NSW is hydrogen. Launching over 74,000 radiosondes a day means you have to economize. While potentially explosive, hydrogen is much less expensive than helium. Hydrogen can be manufactured from water as needed, while helium is a limited resource, like oil and natural gas. In Antarctica, natural gas is used as a lifting gas because it is less expensive than hydrogen in that part of the world. The downside of using natural gas is its lower buoyancy.

Flight Train

The flight train of a radiosonde consists of a string (the load line), train regulator, light system (for night launches), and parachute. Flight trains are between 70 and 120 feet long (with 85 feet the recommended length) so that the radiosondes do not swing too greatly but are still far enough away from the balloon where it can't interfere with the radiosonde's measurements. The train regulator is a ratcheting let-down device that increases the distance between the balloon and the radiosonde. Let-downs are used in high wind conditions where a long flight train may let the radiosonde become damaged during the initial ascent. Over several minutes, the let-down unreels string from a spool. When launched at night, small light sticks are attached to radiosondes to help meteorologists track the radiosonde for the first few minutes of the ascent. This becomes necessary if the radio tracking equipment needs help locking onto the ascending radiosonde. A plastic parachute, often bright orange in color, is attached to the flight train to slow the descent of the radiosonde after balloon burst. Radiosondes launched where they will recover over the ocean are not required to carry a parachute, as their descent is over unoccupied locations.

Radiosonde

Sonde on Desk *- The Vaisala Radiosonde being prepped for launch. The battery is on the notebook.*

The most used radiosonde today is Viasala's RS-80 radiosonde. This radiosonde fits on the palm of your hand and runs from a water-activated battery. The meteorological sensors of the RS-80 are a temperature sensor, humidity sensor, and pressure sensor. The temperature sensor is mounted outside the radiosonde body on a small plastic boom. The humidity and pressure sensor are mounted inside the radiosonde body where they cannot be affected by precipitation during the ascent. Data from these three sensors is collected and encoded on a radio carrier for transmission to the Ground Subsystem. Radiosondes transmit at 100 mW power and at a frequency of 1680 MHz. A frequency of 1680 MHz is in the middle of higher of the two primary Meteorological aids bands of 400.15 to 406.00 MHz and 1675 to 1700 MHz.

Surface Subsystem
The Ground Subsystem consists of the following parts:

RDF Wind-finding Antenna
Receiver and Sensor Processing Unit

RDF Wind-finding Antenna
Also called a Radiotheodolite, it is housed inside a dome on top of the inflation building. The antenna is motor driven on two axes and automatically tracks the radiosonde by keeping the antenna pointed at the strongest signal. The positions of the two axes are sent to the Receiver and Sensor Processing Unit where they are used to calculate the position of the radiosonde as function of time, and hence, the wind speed and direction at altitude.

Receiver and Sensor Processing Unit
Consisting of a rack of electronics and software on a PC, the receiver and sensor processing unit filters noise out of the radiosonde telemetry and decodes it like a modem or TNC to determine the radiosonde's current temperature, humidity and pressure. The data created becomes three text files that are sent to the NWS for further dissemination to the WMO.

A Radiosonde Launch

Out to Launch - *A meteorologist from the N.W.S. getting ready to release a radiosonde.*

Contact your local radiosonde station for a tour of their facility. During your visit you will see the balloon filled with hydrogen gas inside the inflation building where wind and precipitation can't interfere. The gas delivery system has a balloon lift based cutoff system that is adjustable with weights and fills the balloon to the lift desired without human intervention. Strict control of balloon lift is necessary to set the radiosonde's ascent rate to the value expected by the sensor-processing unit. After filling the balloon, the radiosonde's battery is unwrapped from the package that it and the RS-80 are shipped in, and the battery is soaked in water to start its chemical reaction. The radiosonde is checked for proper radio function and the flight train is assembled. At the appointed time (either 0000 hours or 1200 hours UTC) the flight subsystem is released. Because of its lightweight nature, the meteorologist in charge of the radiosonde launch literally throws the flight subsystem into the air.

Only 20% of the radiosondes launched are ever recovered and sent back to the NWS for refurbishment. Currently the NWS is in the process of transitioning to a new radiosonde system.

The NWS' Upper-air Observations Program maintains a website at `http://ua.nws.noaa.gov/` where you can get more information and download a copy of their manual, the Federal Meteorological Handbook No. 3, Rawinsonde and Piball Observations.

Near Space Humor

Fourteen Near Space Bumper Stickers

1. Have APRS, Will Travel
2. Got Helium?
3. 100,000 Feet? Been There, Done That
4. Conquering Near Space, One Syntax Error At A Time
5. Will Chase Balloons For Food
6. Amateur Near Space: Not Just Amateur Science, It's An Adventure!
7. If I Were A Weather Balloon, I'd Be At 100,000 Feet By Now
8. 100,000 Feet and Bust!
9. 0 to 100,000 Feet in 120 Minutes
10. Near Space Recovery, The Ultimate Road Rally
11. Eat, Sleep, Chase Balloons
12. I'd Rather Be Near Space Chasing

13. Helium, It Does A Balloon Good
14. There's No Place Like Near Space

* Jacques Alexandre Cesar Charles was an early balloonist. In the winter of 1783 he ascended in a balloon with the Robert brothers from Paris. He was so excited by what he had experienced that he demanded a second launch that very evening. Thus, was he the first human to see the sun set twice in the same day.

(The Invention of Clouds, by Richard Hamblyn – Farrar, Straus and Giroux 2001)