

# CHAPTER EIGHT

## Near Space Experiments

*"Boy, if you want to read conspiracy theories about Roswell, just type Weather Balloon and Radar Reflector into Google."  
-Dan Paulson (KD7OST)*

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### **1.0 General Construction Comments**

#### **1.1 Introduction**

This chapter suggests a series of entry-level experiments to perform in near space. Some experiments require mechanical and electrical construction while others only involve processing of data after a typical mission. Experiments in this chapter include: measuring atmospheric conditions, cosmic ray studies, sky brightness, several life science experiments, and some technology tests. At the end are directions for editing data from TNC logs.

#### **1.2 Construction Recommendations**

Here are additional suggestions on designing near space experiments.

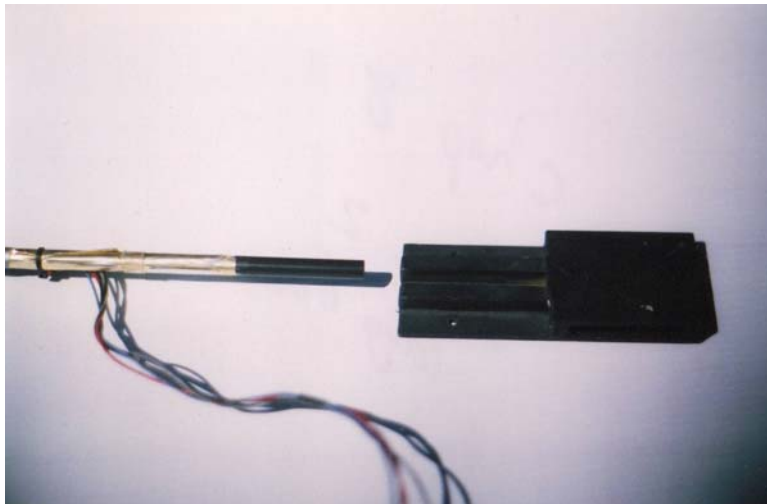
##### **1.2.1 Booms**

Chapter Five Section Three explains one method for constructing composite booms on quad panels. While the design is for square and perpendicular booms, there is no need for the boom to be rectangular in shape or perpendicular to the quad panel. Adapt the boom to fit the experiment. Modify booms into scan platforms for experiments requiring positioning during the mission. Heavier

experiments require stronger servos (i.e. servos with more torque). Torque is measured in units of inch-ounces. Every ounce a servo can move when that ounce is mounted at the end of a one-inch arm means a stronger servo. Large servos with 140 in-oz of torque are readily available at hobby shops like HobbyTown (servos this powerful are used to control sails on RC sailboats). Ideally a servo this powerful handles an 8.75-pound experiment mounted one inch away from the servo or a one-ounce experiment mounted 11.6 feet away from the servo (or any combination of ounces and inches to equal 140). Balance experiments about their center of rotation to decrease the strain on the servo moving the experiment around.

### 1.2.2 Very Long Booms

Some experiments are better mounted some distance away from the airframe. However, heavy experiments mounted some distance from the center of the near spacecraft create a torque on the stack. It's important to reduce the weight of experiments on long booms. One way to keep the weight of booms low is to use a kite tube in place of a composite boom. Kite tubing is available in either graphite or fiberglass (both types are a kind of composite) and are available from Into The Wind. Short lengths of kite tubing are extended with the use of ferrules, short lengths of either metal or fiberglass connecting tubes. Use an adhesive like Hot Stuff (a CA) to glue the ferrule to the kite rods. A platform like the design below is suitable for holding the tubing boom to the surface of a composite boom. The mount can be removed from the boom for other flights.



***Long Boom** - A four foot fiberglass kite spar slides into a slot in the platform to a boom.*

Another construction idea is to build a truss structure from kite tubing. In this design, smaller diameter dowels form a series of triangles within the boom structure. Use a Dremel or drill press to drill the holes in the tubing. Cut smaller diameters of kite tubing to length and epoxy them into the holes, making the truss structure. An example of can be seen in my first near spacecraft, the Isaac Asimov.



*The Isaac Asimov - My first near spacecraft. Note the truss structure of the booms.*

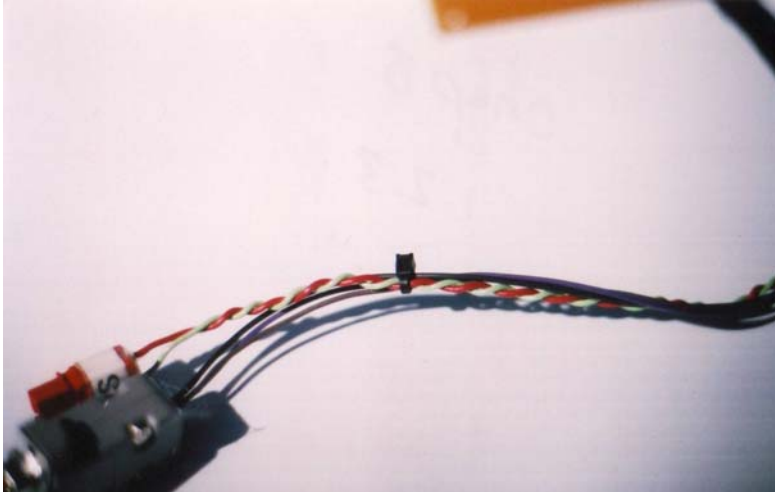
### 1.2.3 Organizing Cables

Organizing cables accomplishes three objectives. The first is to keep the cables from tangling or getting caught on the near space capsule. The second is to identify the function of cables so that an accident, like connecting ground wires to the five-volt pin of an expansion port of a flight computer, doesn't occur. The last is that neatly bundling cables gives the experiment a neater overall appearance.

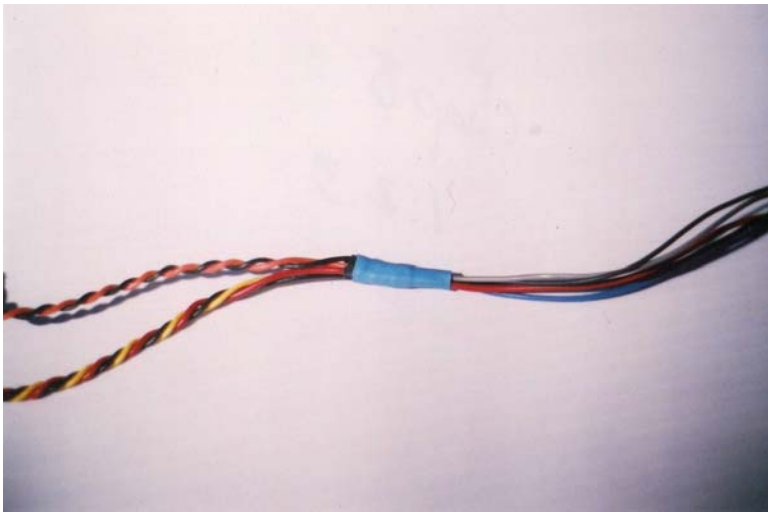
#### **Bundling Cables**

Three simple ways to bundle cables together are: twisting wires together, using short lengths of heat shrink tubing around cables, or tying wires into cables with nylon wire ties. Twisting wires together reduces the noise in signal cables through common-mode rejection, so it is a good practice when wires pass close to radios. When using heat shrink tubing to bundle cables, carefully and briefly apply the heat to avoid damaging the insulation of the wires in the cable. When bundling wires with nylon wire ties, do not tie nylon wire ties so tight that they cut into the insulation of the wires being bundled. Nylon wire ties are not appropriate at sites where cables are required to flex at the site of the tie. Repeated flexing causes the nylon tie to cut into the insulation. Instead, use a length of heat shrink tubing. Nylon ties are best used where the cable needs to be immobilized.





*Various Ways to Control Wire –  
Top Photo – Twisting  
Middle – Zip Tie  
Bottom – Heat shrink*



### **Labeling Cables**

Two simple methods to label cables and headers are through insulation colors and adhesive labels. When using colors to signify the function of wires, pick a standard and stick with it. A good standard is to use green or black wires for ground and red for power. Ground wires can be divided into two subcategories, with black wires for digital grounds (for signals, for instance) and green wires for analog ground (like power ground, for instance). Power wires can be further divided according to voltage with a different bright color for each voltage.

Adhesive labels are best used to label the function of an entire cable, for instance, a Geiger counter cable. When using an adhesive label to signify the function of a cable, write the function on the label before adhering it to the cable. Avery makes several formats of sticky labels that are useful. One source of labels is floppy diskette labels. Depending on the label design, they will have colored parallel lines drawn on them. Cut the label into strips and apply them to the cable. However, probably the best option is to use a label maker. These stand-alone printers are available in office supply stores. The text to print on the label is typed on their built-in keypad and the label printed thermally to adhesive, colored Mylar tape. The result is a very neat and legible label. A labeler used by the author is the Casio EZ-Label Printer.

In time the adhesive in labels dries out, letting the labels fall off their cables. To prevent labels from falling off the cable and to protect the lettering, cover the label with a short length of clear heat shrink tubing after adhering the label to the cable. Labels not only identify cables, they can also identify housings at the end of cables. Measure clearances before applying heat shrink over a plastic housing.

### 1.2.4 Controls For Experiments

Remember your sixth grade science class? You were taught to use a control on each experiment. Without a control for comparison, the true effects of the experimental variable cannot be determined. Where appropriate or possible, be sure to design and use a control for each experiment flown into near space. There are times when additional controls may be useful or needed. For instance, with a first control on the ground, a second control could be carried inside the near spacecraft and the original experiment carried outside the airframe. A control could involve sending an identical experiment into near space, but wrapped in aluminum foil to protect it from solar UV.

Controls provide one additional benefit. With so many conditions to be tested in near space, controls justify launching more flights into near space. So keep those controls coming!

## 2.0 Altitude Determination

### 2.1 Introduction

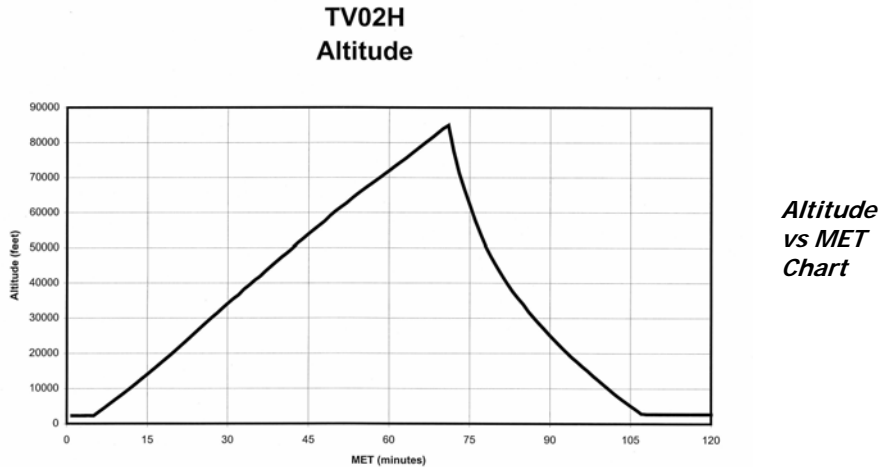
In most cases, the sensor values measured during a near space mission are graphed in relationship to the altitude. The GPS \$GPGGA sentence is commonly used to determine the altitude. There are proprietary sentences indicating altitude, but these change from GPS manufacturer to manufacturer, so they will not be discussed. Consult the *Good To Know* section of Chapter Four for information on the various GPS sentences, including the \$GPGGA sentence. Consult the manual that comes with your GPS model as to the availability of other proprietary sentences indicating altitude. The \$GPGGA sentence indicates altitude in units of meters. For most Americans, the meters unit is not meaningful. In this case the units are converted to feet.

#### 2.1.1 Processing The Spreadsheet

To convert from the altitude in meters into altitude in feet, use the following spreadsheet equation

$$+A3*3.28084$$

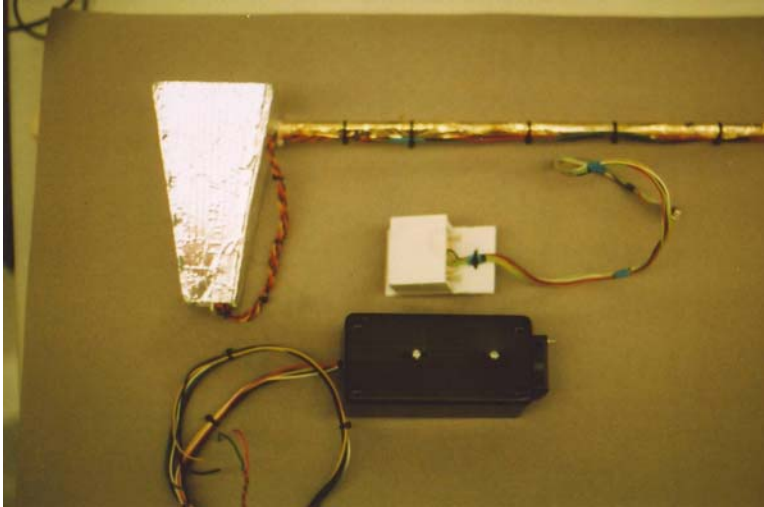
This equation assumes the A Column contains the altitude field of the \$GPGGA sentence and that the data begins in Row 3. Change A3 to the appropriate row and column. A popular graph shows altitude as a function of Mission Elapsed Time (MET). Read Section 11 of this chapter on editing the Time column of the spreadsheet to get MET. Section 11 also shows how to create the chart of Altitude over MET for MS Excel.



### 3.0 Environmental Sounders

Everyone wants to know what near space is like this time of year. How cold is it? Is the air dry? What is the atmospheric pressure like? Temperature, pressure, and relative humidity are three variables that a near spacecraft can measure by carrying a mini-weather station. These are the same three environmental conditions that National Weather Service (NWS) radiosondes measure twice a day all over the world. Combined with data from a GPS, a temperature, pressure, and relative humidity profile can be generated for the atmosphere at the time and location of launch. Besides a profile, you can determine how environmental conditions change as a function of altitude and determine whether the atmosphere is stable. In addition, measurements taken at different times of the year can be compared and annual changes in the atmosphere can be found. When you make measurements of various layers of the atmosphere or ocean, you are making a sounding. Hence the devices described in this section are called environmental sounders.

The Simple Sounder, the first experiment to be described, measures both the temperature and relative humidity of the atmosphere during a mission. The Mini Weather Station, the next experiment described, adds pressure measurements to complement temperature and humidity. Stand-alone pressure sensors are described next. Stand-alone pressure transducers are used when a single pressure transducer is not accurate across the entire range of pressures experienced during a near space mission. The last topics are how to mount, calibrate, and use the sounders.



**Environmental Sounders –**

*Top – Simple Sounder mounted inside a ram air cup to force air over the temperature sensor.*

*Middle – Mini Weather Station in a white coroplast box to shield it from direct sunlight.*

*Bottom – This sounder has a fan mounted on the side of the box to prevent sensor self-heating.*

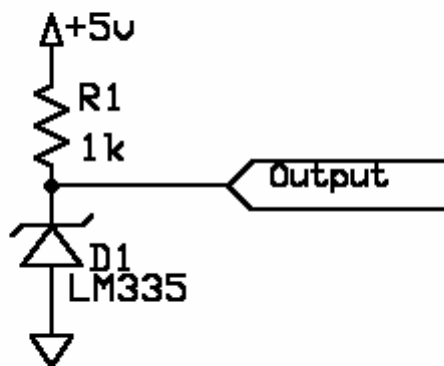
**3.1 The Simple Sounder**

The simple environmental sounder contains just two sensors. It measures air temperature with an LM335 voltage controlled zener diode and measures relative humidity (RH) with a HS1101 capacitive humidity sensor. Both sensors are relatively inexpensive and easy to interface. Like the LM335, the output from the HS1101 does not require amplification.

**3.1.1 Simple Sounder Theory Of Operation**

**The LM335 for Temperature Sensing**

The LM335 is a zener diode whose temperature coefficient is optimized. Zener diodes are wired up according to this schematic.



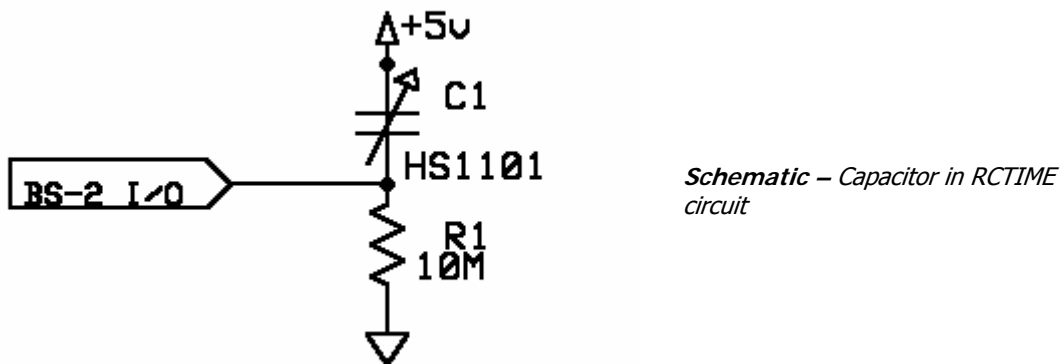
*LM335 Schematic*

As long as the applied voltage is greater than the breakdown voltage of the zener, the voltage measured across the zener diode remains the same, even as the applied voltage changes (that is, until the current flowing through the zener exceeds its power rating, at which point the zener is destroyed). So if a 3.6-volt zener is supplied with five volts, as in the diagram above, 3.6 volts of the 5.0 volts

will be dropped to ground by the zener, while the resistor supplying the voltage must drop the other 1.4 volts. The breakdown voltage of a diode is not constant, but changes slightly with temperature. In the case of the LM335, it is very sensitive to its temperature -- as the LM335's temperature increases, so does its breakdown voltage. The breakdown voltage of the LM335 is equal to its temperature in Kelvin divided by 100. The output voltage LM335 is the input to an ADC channel on the CC/PS.

### The HS1101 for Humidity Measurement

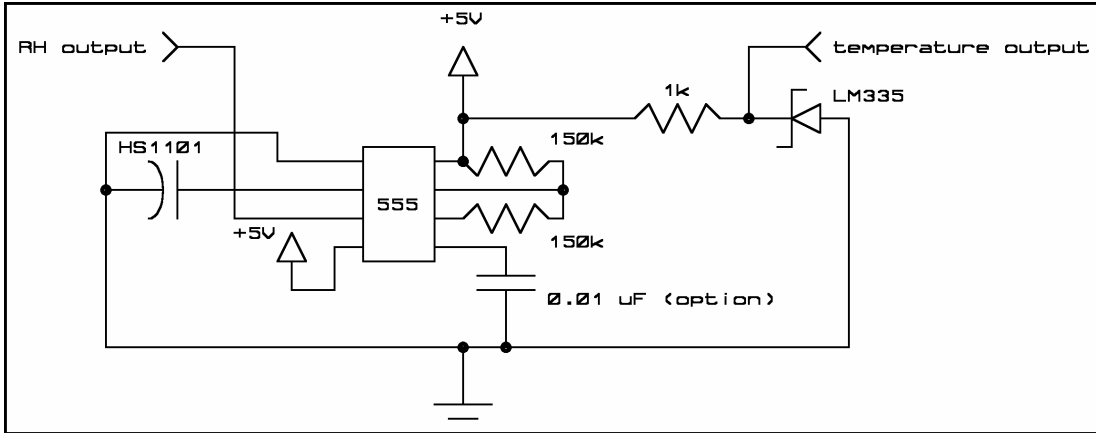
In the HS1101, the capacitance of the RH sensor is varies linearly with the change in the relative humidity. The capacitance of the HS1101 is determined by how long it takes for the sensor to charge through a 10M resistor connected to ground. This procedure works because the other side of the HS1101 is connected to +5V and both plates of the HS1101 begin with +5V.



The RCTIME command of the BS2p determines how much time is needed to charge the HS1101. Five volts is provided to one side of the relative humidity sensors by a +5V pin on the flight computer I/O port. An I/O pin of the BS2p in the flight computer charges the other side of the RH sensor to five-volts (giving both plates of the capacitor in the HS1101 the same charge) and then lets the capacitive sensor discharge to ground through the fixed 10M resistor. The time required for the capacitor in the HS1101 to drop from a level of +5V to a level of +1.4 V (the transition to a logic low) is returned in the variable passed with the command. Because of the variations in resistance, the HS1101 requires calibration for accurate results.

The schematic for the Simple Sounder, which uses the LM335 and HS1101, appears below.





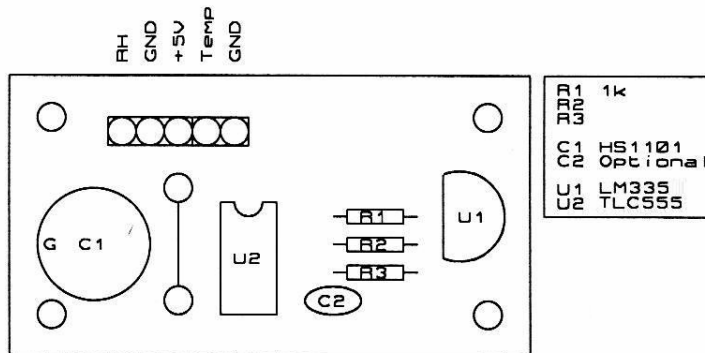
*Simple Sounder Schematic - Measures relative humidity with the HS1101 and temperature with the LM335.*

### 3.1.2 Simple Sounder Materials

- 1k ohm resistor
- 10M ohm resistor
- HS1101 capacitive RH sensor
- LM335 temperature-controlled zener diode
- Stranded wire, #22 or #24 AWG, at least three different colors
- Cable termination for your flight computer ports
- Simple Environmental Sounder PCB
- TLC 555

### 3.1.3 Simple Sounder Procedure

## Simple Sounder Temperature and RH Board



*Simple Sounder Parts Layout - HS1101 humidity sensor (C1) and LM335 temperature sensor (U1).*

There are three broad steps to making the environmental sounder. Soldering components to the PCB, making the power and data cable of the sounder, and making a Coroplast box for the electronics of the sounder. The last step has several different variations, depending on how you want to mount the sounder and is described in section 3.4.

### **Soldering The PCB**

Note: The components HS1101 and LM335 are sensitive to their orientation. The HS1101 is a two-pin device. On the underside of the HS1101 (component C1) there is a green ring around one of its pins. This pin is soldered to the hole labeled G in the component layout diagram. The diagram of the LM335 (component U1) shows its proper orientation. There is no particular order to solder the components, just watch that C1 and U1 are inserted in their proper orientation. After soldering the components, make sure all the soldered joints are smooth and shiny. Cut excess lead length after soldering components into the PCB.

### **Making The Cables**

Before building the sounder's cable, decide how to mount the sounder. A typical location for the sounder is outside the N/C, mounted to a boom. Three possible options are,

1. In a Coroplast tube mounted on a boom next to the N/C
2. In a Coroplast ram cup mounted away from the N/C
3. In a Coroplast tube with fans blowing air across the sensors

Once a mounting option has been selected, then measure the distance the cable must run from the sounder to the CC/PS inside the N/C. Then increase that length by 50%. Cut five lengths of #22 or #24 AWG stranded wires for the cable. Color code the wires as follows: one black wire for digital ground, one red wire for power, one green wire for power ground, and two miscellaneous other colors for sensor voltages. Strip the ends of the wires back about one quarter of an inch. Solder the wires to the PCB. Temporarily bundle the wires together to form a cable. Terminate the cables in a connector appropriate for your flight computer. Each device in the Complete Sound operates from +5V. Therefore, all the cables should terminate at the ADC ports. The ground for power and the sensors can be connected together. Even though all the grounds are shared, the author still prefers to bring all ground wires to the ADC port.

## **3.2 The Mini Weather Station**

Adding air pressure measurements to the Simple Sounder results in a Mini Weather Station, enabling your near spacecraft to measure the "Big Three" -- temperature, humidity, and pressure.

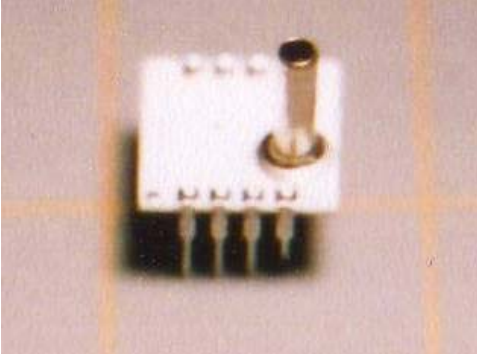
### **3.2.1 Mini Weather Station Theory Of Operations**

#### **The LM335 for Temperature Sensing**

The LM335, which will again be used for temperature sensing, has already been described in detail in subsection 3.1.1.

#### **The SM5812 for Pressure Sensing**

The SM5812 is a micromachined silicon pressure sensor. It consists of a thin silicon diaphragm over a vacuum contained within its silicon die.



*The SM5812 Pressure Sensor*

The resistance of the diaphragm is dependent on its strain, which changes as the pressure on the other side of the vacuum changes. This pressure sensitive resistor is part of a Wheatstone Bridge. The Wheatstone Bridge allows the device to detect tiny changes in the resistance of the silicon diaphragm as changes in the current flowing through the center of the Wheatstone Bridge. In addition, there is circuitry on the SM5812 to amplify and condition the signal generated by the silicon pressure sensor. The output of the SM5812 is a voltage that varies based on the atmospheric pressure.

### **The HIH3610 for Humidity Readings**

The HIH3610 is a capacitor with platinum electrodes. As water vapor flows into its dielectric (the layer between capacitor plates), the capacitance of the device changes. On-chip circuitry converts the changing capacitance into a voltage that varies linearly with the percent relative humidity. The output of the HIH3610 is ratiometric, meaning that as its supply voltage changes, so does the output voltage when the relative humidity remains constant. At a constant 5.0V supply, the HIH3610 produces a voltage between 0.95 V at 0% RH to 4.07V at 100% RH. The capacitance of the HIH3610 does vary to a small extent with changes in temperature. The equation to calculate % RH from voltage is given by,

$$\%RH = [V - V_s(0.16)] / (V_s * 0.0062)$$

Where  $V_s$  = supply voltage

Which simplifies to

$$\% RH = (V - 0.8) / (0.031)$$

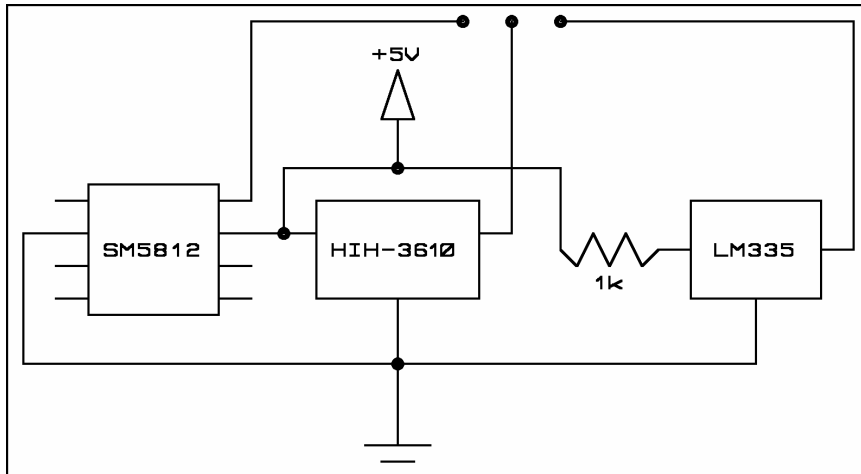
When the supply voltage is 5V, and V is the voltage from the sensor

Temperature compensation is provided with the following equation

$$\text{True RH} = (\%RH) / (1.0546 - 0.0216T)$$

Where %RH was calculated above

And T is the temperature in degrees F



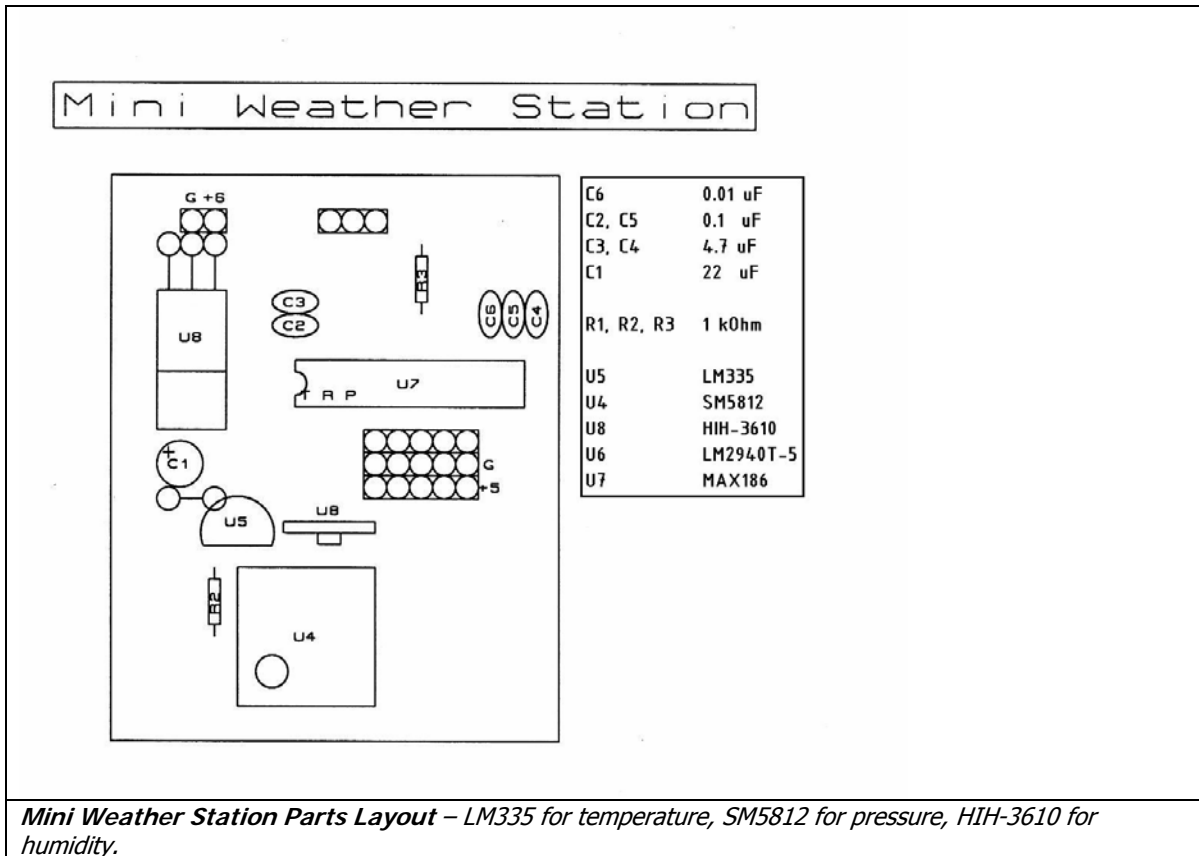
*Mini Weather Station Schematic – Pressure (SM5812), humidity (HIH-3610), and temperature sensors (LM335) in one circuit.*

### 3.2.2 Mini Weather Station Materials

- LM335 Temperature Controlled Zener Diode
- SM5812 Amplified Pressure Sensor
- HIH-3610-001 Relative Humidity Sensor
- 1k resistor (1/4W)
- Eight #24 AWG stranded wire, preferably 5 or 6 different colors
- Termination for the ends of the wires to match the flight computer's ADC ports
- Mini Weather Station PCB

### 3.2.3 Mini Weather Station Procedures

There are three broad steps to making the environmental sounder. Soldering components to the PCB, making the power and data cable of the sounder, and making a Correplast box for the electronics of the sounder. The last step has several different variations, depending on how you want to mount the sounder, and is described in section 3.4.



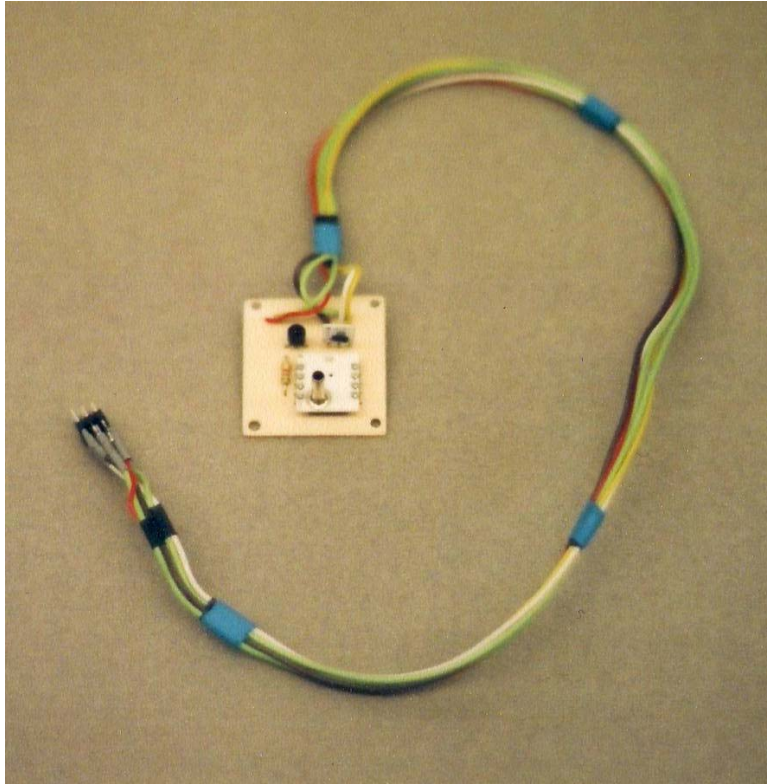
### Soldering The PCB

The components SM5812, HIH3610 and LM335 are sensitive to their orientation. The HIH3610 is a three-pin device. On one face of the HIH 3610 is its circuitry encased in a small blob of black plastic. The other side is bare ceramic. The plastic blob is illustrated in the top silk diagram as a rectangular bump on component U3. The diagram of the LM335 (component U5) shows its proper orientation (note the flat face in component U5 in the silk diagram). The single port of the SM5812 is drawn as the circle in the lower left hand corner of device U4. There is no particular order to solder the components, just watch that U5, U4, and U8 are inserted in their proper orientation. After soldering the components, make sure all the soldered joints are smooth and shiny. Cut excess lead length after soldering components into the PCB.

### Making The Cables

Before building the Mini Weather Station's cable, decide how to mount the Mini Weather Station. A typical location for mounting is outside the N/C, mounted to a boom. See subsection 3.1.3 for directions on determining the proper lengths of the wires for the Complete Sounder Cable.

- √ Cut eight lengths of #22 or #24 AWG stranded wires for the cable.
- √ Color code the wires as follows: three black wires for digital ground from each sensor, one red wire for power, one green wire for power ground, and three miscellaneous other colors for the sensor voltages.
- √ Strip the ends of the wires back about one quarter of an inch.
- √ Solder the wires to the PCB.
- √ Temporarily bundle the wires together to form a cable.



*Mini Weather Station - Finished unit containing pressure, relative humidity, and temperature sensors.*

Terminate the cables in a connector appropriate for your flight computer. Each device in the Mini Weather Station operates from +5V. Therefore, all the cables should terminate at the ADC ports. The ground for power and the sensors can be connected together. Even though all the grounds are shared, the author still prefers to bring all ground wires to the ADC port.

### 3.3 Stand-alone Pressure Sensors

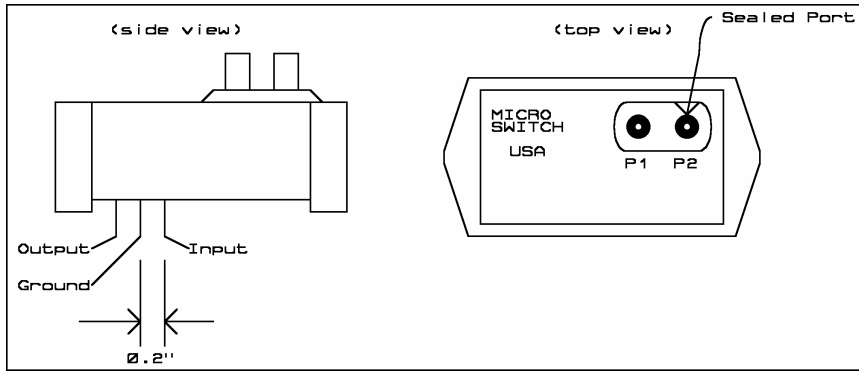
Pressure sensors that are accurate over the range of pressures experienced in a near space flight are neither readily available nor inexpensive. So instead, fly multiple pressure sensors, each geared to a particular pressure region.

This section covers the Honeywell 140PC Pressure Transducer and Silicon Microstructures SM5812 pressure sensors. There is another popular pressure transducer, the Motorola MPX series, which will not be covered in this section due to the difficulty in interfacing to this device. The MPX requires the use of a differential op-amp or a 16-bit ADC to digitize its low output voltage.

#### 3.3.1 Theory Of Operation

The theory of operation for many pressure transducers we use in amateur near space are described in subsection 3.2.1.

#### **Honeywell 140PC**

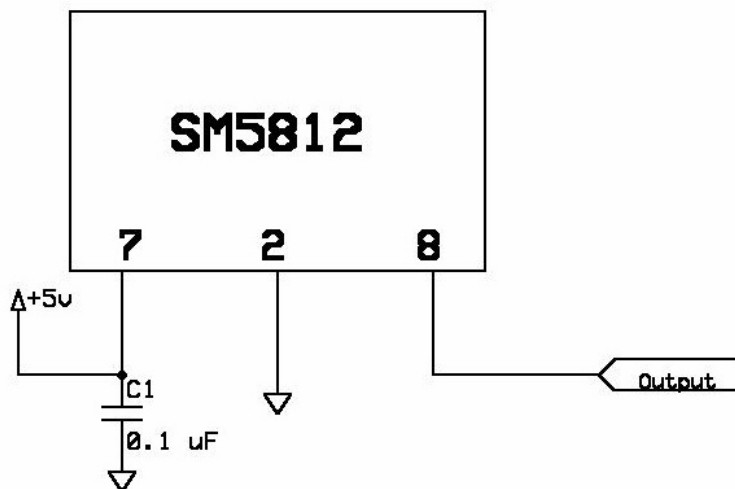


*The 140PC - The proper model contains a sealed tube that is just visible in Port P2.*

The Honeywell 140PC is a pressure transducer which measures approximately 1" X 2" X 2". The three pins on the bottom are for power, ground, and signal. The power and signal both share the ground. The three pins of the 140PC have a spacing of 0.2 inches. The 140PC is available in three models. The model of interest measures absolute pressure (the other two measure gauge and differential pressure). If you get your hands on a 140PC, a nine-volt source can be used to operate it because of its excitation voltage of eight volts (it's easier to get nine volts than eight volts). The output voltage is linearly proportional to pressure if it's given eight volts. If excited with more than eight volts, then the extra voltage above eight volts must be subtracted from the output voltage first. As an example, if nine-volts is used to excite the 140PC, then the one additional volt must be subtracted from the output before determining the true output voltage and hence the current pressure. To increase the accuracy of the 140PC, monitor its input voltage during the mission to determine how much voltage to subtract from the output reading (unless the input voltage is regulated, it will drop during the flight, changing the output voltage when there is no change in pressure). The output voltage of the 140PC is greater than the maximum input voltage of the MAX186 ADC used in the flight computers described in this book. Therefore a voltage divider must be wired into the output. Other than keeping its port clear of obstructions, there are no mounting concerns. The 140PC can be left inside the near spacecraft, as the internal pressure is the same as the external pressure.

### Silicon Microstructures SM5812

The SM5812 has already been described in detail under subsection 3.2.1. The schematic is shown in the figure below.

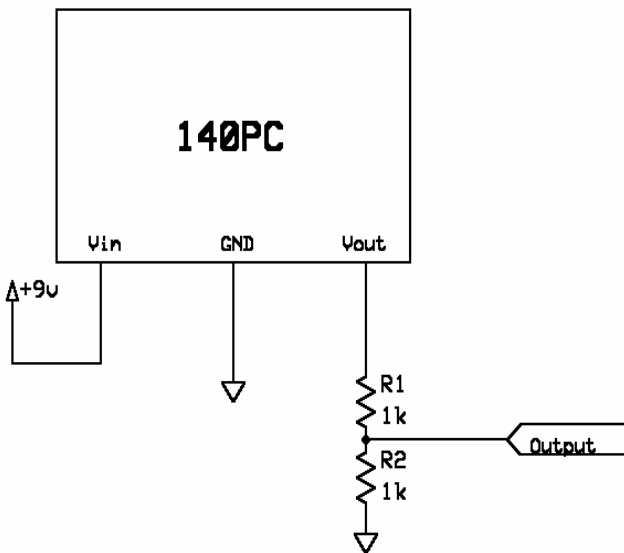


*Schematic – SM5812*

### 3.3.2 Stand-alone Sensor Materials

- SM5812 or 140PC Pressure Transducer
- Two 1k resistors<sup>A</sup>
- #24 AWG stranded wire (three colors)
- PCB for either the 140PC or SM5812
- Correplast sheet
- Neoprene foam, 3mm thick
- Nylon wire ties

### 3.3.3 Stand-alone Sensor Procedure



*Schematic - 140PC and voltage divider*

- ✓ Cut four 12" lengths of wire and strip ¼" of insulation from both ends of all wires
- ✓ Solder the 140PC or SM5812 to the PCB
- ✓ For 140PC, bend the leads of two resistors to a length of 0.4 inches
- ✓ Solder resistors R1 and R2 onto the PCB
- ✓ Cut three lengths of #22 or #24 AWG stranded wires for the cable  
Note: Color code the wires as follows: black or green wire for ground, red wire for power, and a different color for signal.
- ✓ Strip the ends of the wires back about one quarter of an inch
- ✓ Solder the wires to the PCB
- ✓ Temporarily bundle the wires together to form a cable
- ✓ Terminate the cables in a connector appropriate for your flight computer.
- ✓ Cut a sheet of neoprene foam to fit the dimensions of the PCB
- ✓ Cut a sheet of Correplast a little larger than the PCB
- ✓ Position the PCB on the Correplast and punch holes for the nylon wire ties  
Note: Each hole in the PCB gets two holes in the Correplast, one for the hole in the PCB and one outside the dimensions of the PCB
- ✓ Stack the PCB on the neoprene foam and then the Correplast



- √ Lock the stack together with nylon wire ties
- √ Punch additional holes in the Coroplast to make a strain relief for the cables

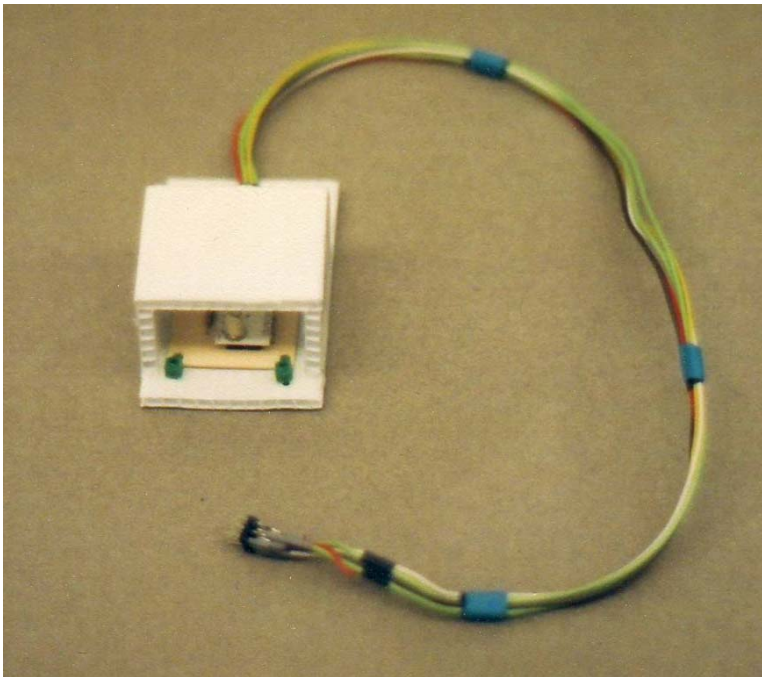
### 3.4 Mounting Environmental Sounders

The preferred location of a sounder is outside of the near spacecraft, preferably on a boom, like an antenna boom (where the boom can provide double duty without adding the weight of a second boom). From there, the cable from the environmental sounder runs inside the capsule and is plugged into the CC/PS expansion or ADC port. The sounder should be packaged inside a white plastic box to shield the sensors from direct exposure to the sun's light and heat. Until I learn more, avoid using aluminum, which may be reflective to visible light, but is difficult for infrared to escape. As a result, the sounder may heat up inside an aluminum box (why do we wrap potatoes in aluminum foil, if aluminum doesn't retain heat?).

#### 3.4.1 Building A Coroplast Box

There are several styles of coroplast boxes suitable for Sounders. The good points of coroplast include: it's lightweight, quite strong, cuts easily with an Exacto knife, and glues together well with hot glue. Building the coroplast box consists of several steps:

- √ Cut foamed neoprene to shape to insulate the underside of the Sounder PCB.
- √ Select a style for the Sounder box.
- √ Cut the coroplast to shape and punch PCB mounting holes in it.
- √ Glue the coroplast box together and wrap it in a white Uline tape for additional strength.
- √ Install the Sounder PCB and neoprene foam to one face of the coroplast box and tie them down with nylon zip ties.



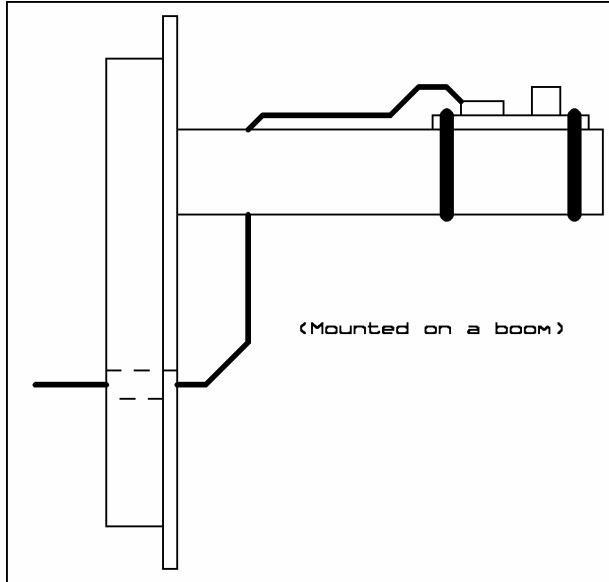
*The Mini Weather Station –  
Housed in a protective coroplast  
box.*

Measure the dimensions of the Environmental Sounder PCB and cut a sheet of foamed neoprene to fit the underside of the assembled PCB. Use a sharp pencil to punch holes in the neoprene that line up with the mounting holes in the PCB. These holes are where the nylon zip ties pass through. Select one of the mounting options listed below (or design one of your own). Measure the dimensions of the

Sounder and its neoprene foam to determine the size of the coroplast box. Keep in mind that the assembled coroplast box must be larger than the Sounder so that air can flow around it.

### 3.4.2 The Simple Mount

A simple tube shaped Coroplast box would have dimensions as illustrated below.



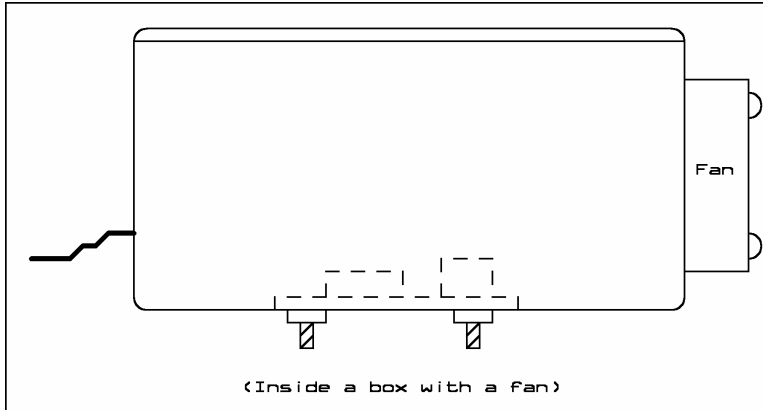
*Sounder Mounted on a Boom -  
Make a housing to protect the  
circuit.*

Note that the box is basically a square tube that shields the Sounder from direct exposure to the Sun. The larger base in the design allows the Sounder box to be mounted to a boom with a pair of rubber bands.

### 3.4.3 Fan Mount

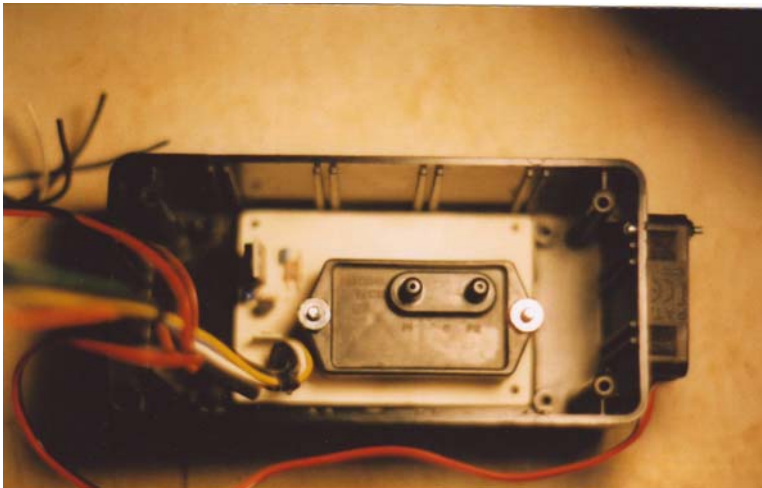
Temperature sensors like the LM335 (that generate their own heat) depend on the air around them to prevent self-heating from affecting the measurement. As the altitude increases during a mission, the amount of air around the LM335 decreases, reducing the air's effectiveness at removing generated heat. Air can be forced over the sensor with a fan (which requires battery power) or through the balloon's upward ascent. The next two designs incorporate airflow in their design.

If fans are mounted to a Coroplast tube, then the Coroplast box must be larger than the Simple Mount to accommodate the mounting of the fans. The dimensions cannot be determined until the dimensions of the fans are known. To keep the current requirements and physical size of the Sounder small, use CPU cooling fans (these are smaller, lighter, and run off of five volts).



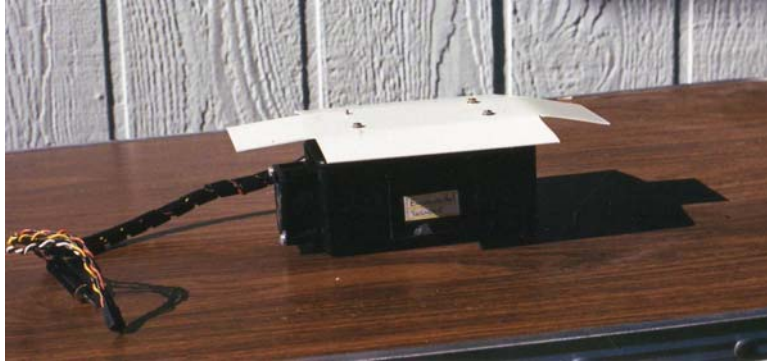
**Fan Mount** - If using a fan, use a separate battery for the fan, as it may draw a lot of current.

One or two fans can be used to blow air over the LM335. Cut the correplast such that the bolts mounting the fans to correplast can pass through the openings. This way there is no need to punch additional holes into the correplast (take advantage of what is already there). If using two fans, then position one fan on each of the openings of the Correplast box. Note which direction the fans blow air (the direction is usually marked on the side of the fan housing) and arrange the fans to blow air in one side of the Sounder box and out the other side. Be sure to mount the Sounder PCB to the correplast box before bolting the CPU fans.



**140PC Pressure Transducer Inside a Fan Box** – The 140PC is mounted to a circuit board and inside a plastic project box. Note the fan on the right side of the plastic box.

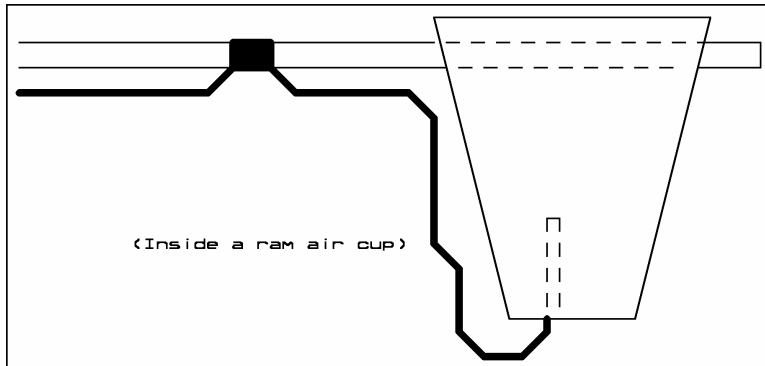
Solder the fan wires together, matching their colors. Extend the lengths of the wires so they reach the interior of the near spacecraft, where their battery is located. Terminate the wires in the appropriate connector for your near space program (like using Anderson Power Poles). Wire a toggle switch into the wires connecting the fans to the positive side of the battery. The switch allows you to power the fans just before launch and to run them off their own battery. Bundle the fan wires to the cable that already exists for the Sounder PCB.



*Closed Fan Box – The fan is visible on the left side of the photo.*

### 3.4.4 Ram Air Cup Mount

To avoid using additional batteries for the Sounder, a ram air cup can be used in place of a fan. During ascent, the ram air cup scoops up air and forces it to flow faster over the LM335. If using a ram air cup for the sounder, then the Coroplast box can have dimensions as outlined below



*Mounting the Sounder Inside a Ram Air Cup*

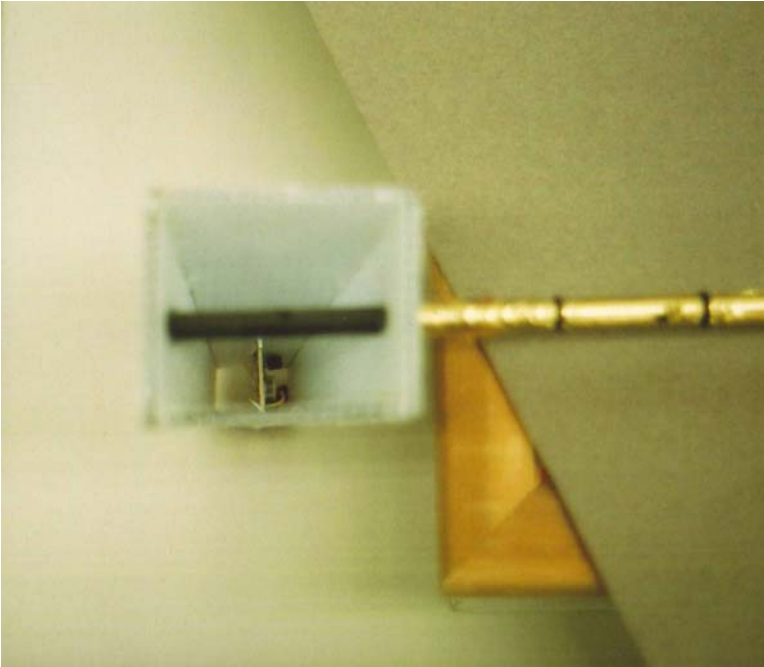
This design requires a fiberglass boom to mount the ram air cup away from the near spacecraft and into faster flowing air. In the ram air cup design, the Sounder PCB is glued into two narrow slits cut into the base of the ram air cup. Very little hot glue is needed to secure the Sounder PCB to the ram air cup.

#### Mounting The Ram Air Cup To The Fiberglass Boom

For lightweight, but a strong boom, use a 1/4" fiberglass tube for the ram air cup boom. The fiberglass boom is available from Into The Wind, in Boulder Colorado, as a kite spar.

- √ Drill out two 1/4" holes just below the top of two opposing sides of the ram air cup
- √ Test fit the fiberglass rod before proceeding
- √ Plug in the hot glue gun and let the glue hot
- √ Push the fiberglass rod most of the way back into the ram air cup  
Note: The rod must be pulled back far enough to expose the rod's surfaces that make contact with the Coroplast of the ram air cup.
- √ Apply a thin bead of hot glue to the fiberglass rod and finish pushing it into the ram air cup
- √ Finish gluing the cup, both inside and outside the cup, with a fillet of hot glue
- √ Secure the Sounder cable to the fiberglass rod with either nylon zip ties or thin bands of heat shrink tubing

Note: Use enough ties or tubing to keep the cable from flopping around, or around every 4-6 inches.



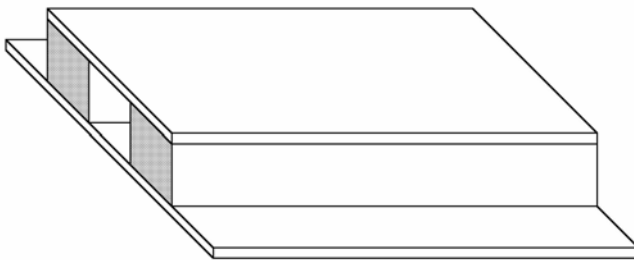
*Inside a Ram Air Cup - The temperature and RH sensor PCB is mounted at the small end of the ram air cup.*

### **Mounting The Fiberglass Boom To An Experiment Boom**

The end opposite the ram air cup must be secured to a near spacecraft in one way or another. Described here is the method the author has used to mount a long fiberglass boom to an already existing experiment boom.

#### **Materials**

- 1/8" thick plywood
- Two feet length of 1/4" square basswood
- Epoxy
- 6-32 mounting hardware
- Experiment boom

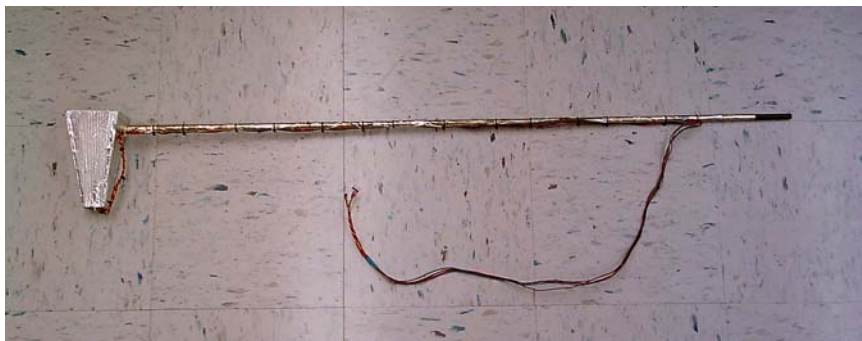


*Boom Mount*

## Procedure

Basically you are going to assemble a two-layer fiberglass boom trap that is mounted to an experimental boom. The trap is bolted to the experimental boom with 6-32 hardware. The fiberglass boom then slides into the boom trap where it remains secure through the ascent and descent. The fiberglass boom can pull out of the trap, but this has not been observed to happen until landing. The cables from the sounder in the ram cup at the end of the fiberglass boom keeps the sounder from falling away from the near spacecraft.

- √ Measure the width of the experimental boom; this will be the width of the boom trap
- √ Cut a piece of 1/8" plywood the width of the boom and a length of six inches (the trap bottom)
- √ Cut a second piece of plywood that is as wide as the first, but only half the length (the trap top)
- √ Cut two lengths of 1/4" basswood six inches long (the trap spines)
- √ Find the center of the long dimension of the trap bottom
- √ Draw two parallel lines to the center, 1/8" away from the center, or 1/4" apart  
Note: This is where the fiberglass boom sits in the trap
- √ Epoxy the basswood spines to the trap bottom, forming a trench down the long dimension of the trap bottom that is just wide enough to slide the fiberglass boom into
- √ Epoxy the trap top to the top of the spines, and flush with one end of the trap bottom
- √ Test fit the fiberglass boom, it should slide into the trench between the spines and inside the pocket formed by the trap top and bottom
- √ Clamp the four pieces of wood together until the epoxy sets
- √ Cut four additional pieces of 1/4" basswood, long enough to reach from the spines to the outside edge of the trap top and bottom
- √ Epoxy these pieces to the front and back of the trap top, stabilizing and strengthening it's connection to the spine pieces
- √ Place the trap on top of the experiment boom and drill four mounting holes for the 6-32 hardware (about 1/8" holes) through the trap and the experiment boom
- √ Bolt the trap to the experiment boom and slide the fiberglass boom into the trap  
Note: There should be enough friction to keep the end of the fiberglass boom secured inside the trap. If the fit is loose, place a narrow strip of tape along the last three inches of the fiberglass boom.



*Completed Boom*

## 3.5 Using Environmental Sounders

### 3.5.1 Calibration

For each of the sensors in the Sounders in this section, a graph of sensor voltages to environmental conditions yields a straight line. In calibrating the sensors, you will determine the Y-Intercept of that

line and its Slope. With these two values for a graph line, you can calculate the value for any reading by the following equation.

$$V = (R - O) * S$$

Where

V is the value we want to calculate

R is the reading from the sensor

O is the Y-Intercept (an offset for the sensor)

S is the slope for that sensor

Fortunately, we understand most of the sensors well enough to give the proper equation. However, for the HS1101 humidity sensor, the calibration process is essential. The accuracy of the other sensors benefit from calibration, but are close enough that it isn't necessary right away.

### Calibrating Temperature Sensors

#### The LM335

The LM335 is very accurate when you purchase it. The third lead of the LM335 (the one we're not using) is used to adjust the output voltage of the LM335. This adjustment improves the accuracy of the LM335. If a simple voltage divider, with one resistor being a trimmer potentiometer, is connected to this lead, then the proper offset voltage can be added to the LM335. I recommend keeping it simple and using software to increase the LM335's accuracy rather than adding a voltage offset. Use an accurate thermometer when determining the temperature offset of an LM335 and make all measurements away from direct exposure to sunlight.

Digitize the output voltage of the LM335. If using the MAX186, then the digitized value returned by the ADC is in units of 1/100th of a volt. If a different ADC is used, then the units of the converted voltage may be different. To determine the units, divide the maximum input voltage of the ADC by the highest number counted by its bits of resolution. The highest number countable by the bits of resolution is equal to  $2^R - 1$ , where R is the number of bits of resolution in the ADC. So if using an eight-bit ADC with a maximum input voltage of 5 volts, then the units of the converted voltage is  $5/(256 - 1)$ , or 0.019 volts. For the rest of this example, I'm assuming you're using the MAX186.

- √ Connect the Sounder to a flight computer
- √ Write and download a program to digitize and debug the LM335 voltage every couple of seconds
- √ Place the LM335 and thermometer next to each other and away from sources of heat
- √ Let the program run long enough to produce a stable LM335 value
- √ Average several of the LM335 readings
- √ Convert the LM335 readings into temperatures with the following equation
  
- √ Reading to Voltage  
 $\text{Reading} * \text{Volts/Reading}$   
 (From the above notes)
  
- √ Voltage to Temperature, three steps here
  - √ Volts to Kelvins.  
 Multiple the average voltage by 100
  
  - √ Kelvins into Celsius  
 Subtract 273 from the temperature in Kelvins

- √ Celsius to Fahrenheit
  - Add 40 to the temperature
  - Multiply the results by 1.8
  - Subtract 40 from the result
- √ Compare the LM335 temperature to the thermometer temperature, note whether there is a correction to add or subtract from the LM335
- √ Repeat this process at a lower temperature (seal sensor in a plastic bag and soak inside an ice bath)
- √ Average any corrections

Note: Ideally, the correction at any temperature is the same. If this is not true, then make several temperature comparisons at different temperatures and plot the results to create a graph of temperature correction to different temperature. Ideally, the plot is a straight line. Apply the same procedure as outlined for the HS1101 to determine simple, linear equation for the LM335's temperature correction.

Document the necessary correction for the LM335 where it won't get lost

## Calibrating Relative Humidity Sensors

### The HS1101

The capacitance of the HS1101 is linear with respect to the relative humidity. With fixed resistors in circuit with the HS1101, the results of the RCTIME command are also linear with respect to relative humidity. In a perfect world, the results of the RCTIME command can be calculated from the RC time constant of the HS1101 and its resistor. But it's easier if we just calibrate the sensor by taking measurements at several relative humidities and graphing the results. As long as a new air mass does not replace the current one, the greatest change in relative humidity occurs between morning and afternoon, where the cool morning temperature generates the highest relative humidity of the day and the warmer afternoon temperature generates the lowest relative humidity of the day. A relative humidity indicator and flight computer are needed to calibrate the relative humidity sensor. Program the flight computer to make measurements of relative humidity every minute and debug the result. Record the relative humidity and the average of several RCTIME values during the morning and later in the afternoon. Beware that tiny air currents create microclimates and can vary the relative humidity. Your presence also makes a difference as your body is continuously perspiring. So make the measurements in a quiet location. It only takes two points to define a line, however, to get the best-fit line, make several other measurements of RCTIME results and relative humidity at different times of the day.

- √ Create a new spreadsheet
- √ Enter the RCTIME results in the first column and the relative humidity in the second column
- √ Click the Chart button
- √ Select, XY (Scatter), Scatter with data points connected by lines without markers
- Note: Since there are only two columns in the spreadsheet, the default of Excel works well
- √ Click the Finish button until the chart is completed
- √ Right click the series line in the graph
- √ Click Add Trendline...
- √ Under the Type tab, select Linear Regression
- √ Under the Options tab, click Display equation on chart
- √ Click the OK button
- √ Click View in the menu
- √ Click Zoom
- √ Click 100%



- √ Click the OK button
- √ Scroll the slider bars until you can read the equation in the upper-right hand corner of the graph
- √ Record the equation

Note: The X-axis is the RCTIME results, the Y-axis is the Relative Humidity.

### **The HIH3610**

The HIH3610 outputs a voltage that is linearly related to the relative humidity. There is no need to calibrate it to achieve acceptable accuracy. However, the above procedure can be followed if you desire to see that the sensor is linear. Keep in mind that some un-linearity you may see in the graph will result from the relative humidity indicator you use to perform the calibration.

### **Calibrating Pressure Transducers**

#### **140PC and SM5812**

Both the 140PC and SM5812 outputs a voltage that is linearly related to the air pressure. There is no need to calibrate either one to achieve acceptable accuracy. However, the procedure for calibrating the HS1101 can be followed if you desire to see that either of the sensors is linear. Remember that some of the un-linearity observed in the chart may be due to errors in the pressure sensor used to calibrate the 140PC or SM5812.

Unlike relative humidity, pressure variations on the surface are too small to effectively calibrate pressure transducers with a range as large as the 140PC and SM5812. They require either a vacuum pump or a flight to calibrate. It's faster and more convenient to calibrate a pressure sensor if you have access to a vacuum pump. The author was able to calibrate a 140PC at the Physics Department of Kansas State University.

#### **With A Vacuum Pump**

There is only one vacuum port on the SM5812, so there is no question about where to connect the vacuum hose. However, the 140PC has two ports. Look in them and notice which port has a rounded clear cap inside of it. This is the sealed port and forms the vacuum reference for the sensor. To pump down the 140PC, connect a vacuum hose to the other port. Connect the output of the 140PC to a channel of the CC/PS ADC Port. Download a program into the BS2p to digitize that channel and report the value. Write the routine into a program loop with a five second pause inside the loop. Now the CC/PS will report the pressure reading every five seconds. Take your first reading at surface air pressure. Record both the atmospheric pressure and the pressure reading from the ADC. Label the reading as  $R_g$  and the pressure as  $P_g$ . Monitor the air pressure inside the vacuum pump and the 140PC as you begin to pump it down. Take several measurements of voltage and pressure and record the readings in a spreadsheet.

#### **Without A Vacuum Pump**

The calibration of the 140PC with near space flights requires several flights (remember, anything justifying repeated flights is a good thing). Data from each flight must be averaged to yield an accurate calibration. In the Standard Atmosphere Model, the atmospheric pressure decreases by a constant factor for every fixed change in altitude. As an example, the atmospheric pressure changes by a factor of two for every 18,000 foot change in altitude or by a factor of 90% for every 50,000 foot change in altitude. The presence of high and low pressure systems influences this change in pressure, so it's best to launch at times when the near space stack will ascend through air between highs and lows. In any case, it's best to average the results from several flights. Consult the *Good To Know* section of Chapter Six for a table of pressure and altitude according to the Standard Model (which is needed for calibrating the 140PC without a vacuum pump).

- √ Create a spreadsheet with three columns,
  - Altitude (A Column)
  - Standard Pressure (B Column)
  - 140PC Reading (C Column)
- √ After a mission, record the altitude and voltage reading from the 140PC
- √ Look up the standard pressure for each altitude and add them to the Standard Pressure column
- √ At this point either add new values from a new mission, or process the spreadsheet and find the pressure equation

### **Adding New Values**

- √ After the next mission, create new rows for the new altitudes and pressure readings (seldom, if ever, will two flights record pressures at the same altitude)
- √ Record the new altitudes and 140PC voltages
- √ Look up the standard pressure for each altitude and add them to the Standard Pressure column

### **Processing The Spreadsheet**

- √ Click Chart Wizard button
- √ Under Chart Type window, click XY (Scatter)
- √ Under Chart sub-type, click bottom right example (Scatter with data points connected with lines without markers)
- √ NEXT button
- √ Series Tab
- √ Under SERIES window, click the REMOVE button to delete all the series
- √ Now click the ADD button (to add the series we want)

Each series needs a name, X values, and Y values  
(X is horizontal, Y is vertical axis)

- √ Click the button in the X VALUES: window
- √ Select the first cell in the 140PC Reading column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the 140PC Reading column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
  
- √ Click the button in the Y VALUES: window
- √ Select the first cell in the Standard Pressure column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Standard Pressure column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
- √ Click the Finish button until the chart is completed
- √ Right click the line in the graph
- √ Click Add Trendline....
- √ Under the Type tab, select logarithmic regression

- √ Under the Options tab, click Display equation on chart
  - √ Click the OK button
  - √ Click View in the menu
  - √ Click Zoom
  - √ Click 100%
  - √ Click the OK button
  - √ Scroll the slider bars until you can read the equation in the upper-right hand corner of the graph
  - √ Record the equation
- Note: The X-axis is the 140PC readings (digitized voltages) and the Y-axis is the Standard Pressure

### 3.5.2 Determining Environmental Conditions

There is seldom a need to create a chart of environmental data after balloon burst. The data collected during descent covers the same region as collected during ascent, but with less resolution (the near spacecraft descends faster than it ascends). Where descent data is most useful is when looking at wind chill effects, primarily on the airframe interior.

#### Temperature

##### Spreadsheet Calculations

These directions assume the air temperature reading is located in column A. Change this reference as necessary.

- √ Change the digitized value into units of Kelvins with this equation  
= +A3/10
- √ Convert Kelvins into Celsius with this equation  
= +B3-273
- √ Note: you can stop here if you want to work in the SI system (metric), however, most Americans wouldn't touch the metric system with a three-meter pole (which is very close to a ten foot pole).<sup>B</sup>
- √ Convert Celsius to Fahrenheit with this equation  
= ((+C3 + 40)\*1.8) - 40
- √ Alternatively, you can enter the following equation, which combines the elements of the three above equations  
(((+A3/10)-273)+40)\*1.8)-40

#### A Note, Why Does This Conversion Work?

A Fahrenheit degree is 1.8 times larger than a Celsius degree (which makes the Fahrenheit degree more precise than the Celsius degree). As long as 0 degrees F was equal to 0 degrees C, then all we would have to do is multiple the temperate in Celsius by 1.8 to get the temperature in Fahrenheit. It turns out that the temperature in Celsius matches the temperature in Fahrenheit at a temperature of minus 40 degrees. So a temperature of minus 40 degrees Fahrenheit is the same temperature as minus 40 degrees Celsius. By adding 40 to the temperature in Celsius, the temperature scales are being adjusted to make their equal temperatures occur at 0 degrees. Then we can multiple the results for the conversion factor of 1.8. Afterwards slide the temperature scales back by 40 degrees to get real world temperature scales.

Insert a new column and label it Lapse Rate. Its unit is degrees/1000 feet. The lapse rate is determined by dividing the change in air temperature by the change in altitude. To calculate the change in both the altitude and temperature, subtract the current reading from the previous reading. Use the following spreadsheet equation

$$= (+A4 - A3) / (+B4 - B3) * 1000$$

Where

A column is assumed to be the temperature column

B column is assumed to be the altitude column

Change the references as needed for your spreadsheet

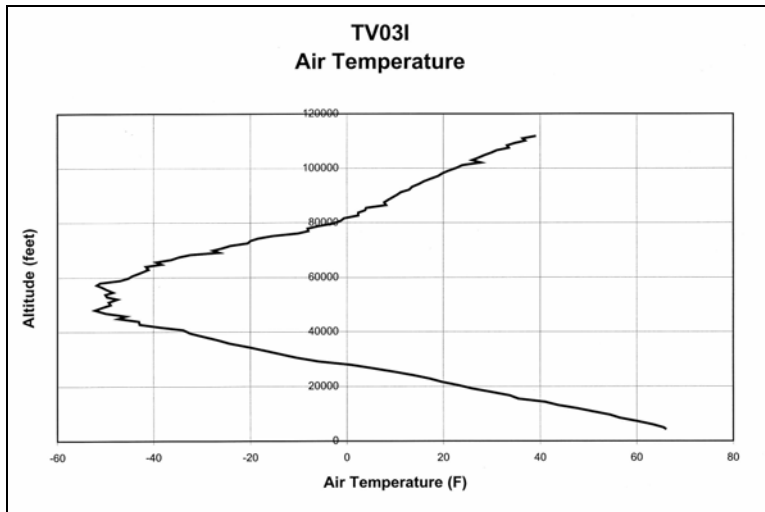
Insert a new column. This column is the stable lapse rate. This column indicates the expected air temperature assuming only that the adiabatic lapse rate is in effect. Label the new column, Stable Lapse Rate and its unit is degrees/1000 feet. This column lists the two adiabatic lapse rates only from the ground to the tropopause. The first lapse rate is the lapse rate when the air temperature is greater than the dew point (dry adiabatic lapse rate). The other lapse rate comes into effect once the air temperature drops below the dew point (moist adiabatic lapse rate). There is a complete explanation of lapse rates in Chapter Nine, in the *Good To Know* Section. You need to know the dew point at the time of launch to complete this column.

For every cell with a corresponding air temperature above the dew point, put the value 5.4 into the cell. In cells with a corresponding air temperature below the dew point, put the value 3 into the cell. Remember to stop at the tropopause, as stability is not an issue in the stratosphere.

You now have three useful columns of information regarding the air temperature, the measured air temperature, the calculated lapse rate, and the expected lapse rate. From these three columns generate two graphs to determine the temperature profile of the atmosphere during the near space mission, the altitude of the stratosphere, and the stability of the troposphere.

### Temperature Profile Chart

Create a graph that compares the altitude to the measured air temperature. The product should look like this:



*Air Temperature vs Altitude*

These steps will create the Air Temperature Profile chart

- √ Look over the Altitude column to find the row number of the highest altitude (remember this row number)
- √ Click Chart Wizard button
- √ Under Chart Type window, click XY (Scatter)
- √ Under Chart sub-type, click bottom right example (Scatter with data points connected with lines without markers)
- √ NEXT button
- √ Series Tab
- √ Under SERIES window, click the REMOVE button to delete all the series
- √ Now click the ADD button (to add the series we want)

Each series needs a name, X values, and Y values (X is horizontal, Y is vertical axis).

- √ Click the button in the NAME: window
- √ Click the name of the column (which you wrote at the top of the column)  
Note: Name should be Air Temperature Profile
  
- √ Click the button in the X VALUES: window
- √ Select the first cell in the Air Temperature column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down until the message window says you are near the row with the highest recorded altitude
- √ Press and hold the SHIFT key
- √ Click the cell in the Air Temperature column at the row with the highest altitude  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
  
- √ Click the button in the Y VALUES: window
- √ Select the first cell in the Altitude column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down until the message window says you are near the row with the highest recorded altitude
- √ Press and hold the SHIFT key
- √ Click the cell in the Altitude column at the row with the highest altitude  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
  
- √ Click the NEXT button
  
- √ Under Titles Tab
- √ Enter name of chart in Chart Title window
- √ e.g. Type name of mission and what was measured.
- √ Note: At this time, do not add a space between the name of the mission and the characteristic measured, the space is added later when the Main Title is formatted (e.g. TV03Eair Temperature)
- √ In the Value (X) Axis: window, type Temperature (degrees F)
- √ In the Value (Y) Axis: window, type Altitude (feet)
  
- √ Under Axes tab
- √ Value (X) axis and Value (Y) axis should already be clicked

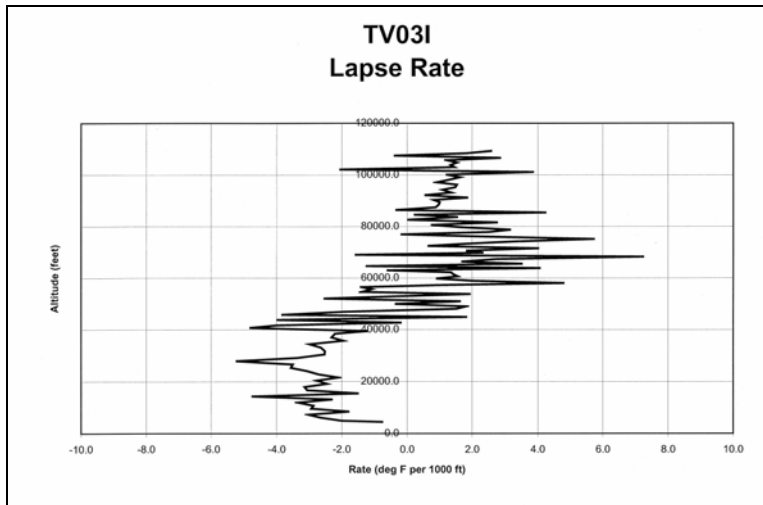
- √ Under Gridlines Tab
- √ Click the Major Gridlines square under Value (X) axis:
- √ Click the Major Gridlines square under Value (Y) axis: if it is not already clicked
  
- √ Legend Tab
- √ Unclick the Show Legend button (it's not needed when a single characteristic is graphed)
  
- √ Data Labels Tab
- √ The NONE option should be selected
  
- √ NEXT button
  
- √ Click option to Save As New Sheet
- √ Type ascent rate (or other meaningful name) into name window
  
- √ Click FINISHED button
  
- √ Additional modifications to Chart
  
- √ Right click center of Plot Area. Away from data line or axis
- √ Click Format Plot Area.....
  
- √ Under Border Options
- √ You can leave this alone, but I prefer to click under the Color window (a button with a pull down menu), the Black square
  
- √ Under Area Options
- √ Click the NONE option (this gets rid of the gray background)
- √ OK button
  
- √ Left Click Chart Title
- √ Right Click
- √ Click Format Chart Title.....
- √ Font tab
- √ Under Size window, select a larger font, like 20
- √ OK button
- √ Left click between name of mission and characteristic
- √ Press the ENTER button to break the title into two rows of text
  
- √ Left one of the Axis Titles
- √ Right Click
- √ Click Format Axis Title.....
- √ Font tab
- √ Under Size window, select a larger font, like 14
- √ OK button
- √ Repeat for other axis title
  
- √ Left click the series on the chart
- √ Right click
- √ Click Format Data Series.....
- √ Under Patterns tab

- √ Click option button in Color: window
- √ Click black square
- √ Click option button in Weight: window
- √ Click next heavier weight (if desired)
- √ OK button

Note that the air temperature drops as the altitude increases until the near spacecraft enters into the stratosphere. The knee in the air temperature graph indicates the altitude of the stratosphere. Second, note the altitude at which the air temperature drops below the dew point. If there is sufficient moisture in the atmosphere at this altitude, clouds can be expected to form just above this altitude. Finally, compare this graph to ones generated at different times of the year.

### Lapse Rate Chart

This graph compares the altitude to both the Calculated Lapse Rate and the Stable Lapse Rate. The product should look like the chart below.



*Lapse Rate Chart*

This chart requires two series, the Calculated Lapse Rate and the Stable Lapse Rate. To create this chart, follow the same directions used to generate the Air Temperature Profile, above, except,

After deleting the series,

- √ Name the first series Calculated Lapse Rate by clicking on the name of the column
- √ Replace the X-column with the Calculated Lapse Rate (do not select cells above the maximum altitude)
- √ Be sure to click the Name window for the series and select the cell with the text Calculated Lapse Rate in it
- √ Click the ADD button to create a second series for the chart
- √ Name the second series Stable Lapse Rate by clicking on the name of the column
- √ Replace the X-column with the Stable Lapse Rate (do not select cells above the maximum altitude)
- √ Be sure to click the Name window for the series and select the cell with the text Stable Lapse Rate in it
- √ Leave the Y Axis alone

- √ Legend Tab
- √ Leave the Show Legend button clicked
  
- √ Right click the Calculated Lapse Rate series in the chart  
Note: You can identify this one by its fluctuation in values
- √ Click Format Data Series
- √ Under Line options, click Style
- √ Select the solid line (top option in pop-menu)
- √ Under Color option, select the black square (upper left)
  
- √ Right click the Stable Lapse Rate series in the chart  
Note: You can identify this one by its constant values
- √ Click Format Data Series
- √ Under Line options, click Style
- √ Select the dashed line (2nd, 3rd, 4th, or 5th option)
- √ Under Color option, select the black square (upper left)  
Note: This is assuming you only have a black and white printer
- √ Complete the rest of the chart as you did the previous one

At altitudes where the Calculated Lapse Rate is to the left of the Stable Lapse Rate, that is, where the Calculated Lapse Rate is smaller than the Stable Lapse Rate, the atmosphere is stable. Where the Calculated Lapse Rate is to the right of the Stable Lapse Rate, the atmosphere is unstable. It's not uncommon to find the atmosphere is stable at some altitudes and not at others.

The Chapter Nine *Good To Know* Section explains lapse rates, atmospheric stability, and the construction and use of the sling psychrometer (which is used to measure the dew point at the time and location of launch).

### Relative Humidity

#### Spreadsheet Calculations

- √ Insert a new column, just after the HS1101 or HIH3610 readings
- √ Label the column, Relative Humidity
- √ Its unit is percent

### For the HS1101

In the first cell, enter the equation as determined by the calibration process of the HS1101

### For the HIH3610

In the first cell, enter the equation

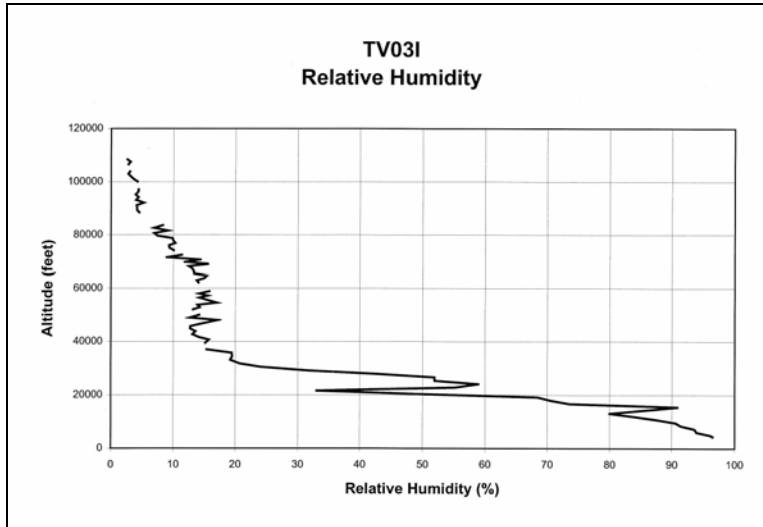
$$= ((+A3 / 1000) - .8) / .031$$

The equation assumes the HIH3610 readings are located in column A. Change this reference as needed.

- √ Select the third cell in the Relative Humidity column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Relative column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste



## Relative Humidity Chart



*Relative Humidity Chart*

To create this chart, follow the same directions used to generate the Air Temperature Profile, above, except,

- √ After deleting the series,
- √ Replace the X-column with the Relative Humidity (do not select cells above the maximum altitude)
- √ Leave the Y-Axis alone

You should note the air gets drier at high altitudes

Compare the relative humidity of this mission to missions at other times of the year

## Atmospheric Pressure

### Spreadsheet Calculations

- √ Insert a new column, just after the Pressure Sensor readings
- √ Label the column, Air Pressure
- √ Its unit is mb (millibars)

### Equation for the 140PC

- √ Enter the equation as determined by the calibration process

### Equation for the SM5812

- √ Enter the following equation for millibars (mB)  

$$= ((+A3/1000)-0.5)*253.25$$
- √ or the following equation for pounds per square inch (PSI)  

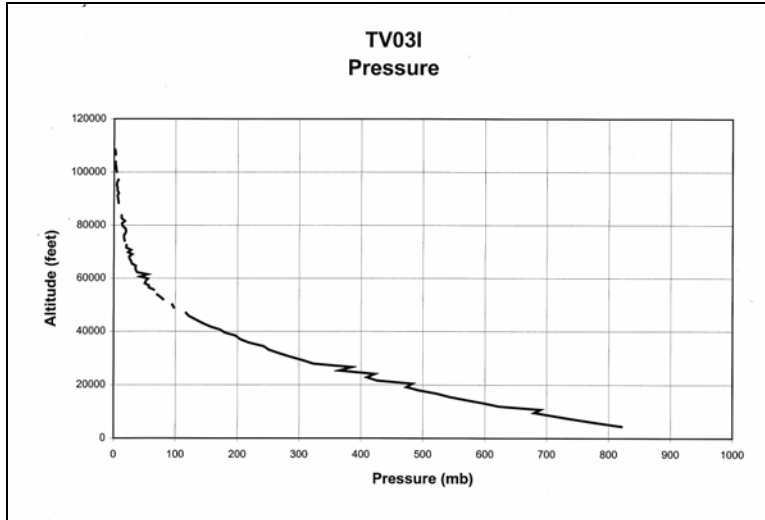
$$= ((+A3/1000)-0.5)*3.675$$

Note: This equation assumes the voltage reading of the SM5812 is located in the A Column of the spreadsheet and that values begin in the third row. Change A3 to the appropriate row and column.

- √ Select the third cell in the Pressure column (the cell containing the equation)  
 Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down

- √ Press and hold the SHIFT key
- √ Click the last cell in the Pressure column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

### Pressure Chart



*Pressure Chart*

To create this chart, follow the same directions used to generate the Pressure chart, above, except,

- √ After deleting the series,
- √ Replace the X-column with the Pressure (do not select cells above the maximum altitude)
- √ Leave the Y-Axis alone

You should note the air pressure decreases logarithmically with increasing altitude. To see this, convert the pressure axis (X-axis) to the logarithmic scale by this process.

- √ Right click the X-axis
- √ Click on X-Axis properties
- √ Click Format Axis
- √ Click Scale Tab
- √ Under Value (X) axis scale, make sure the minimum value is set to 1 (not zero)
- √ Check the Logarithmic option at the bottom of the window
- √ Click the OK button

Note the series forms a nearly straight line early in the mission.  
Save this chart for comparison to future missions

Another option is to find a good logarithmic fit for the pressure

Note: Return axis to linear by unclicking the Logarithmic scale option

- √ Right click the series line
- √ Click Add Trendline....
- √ Under the Type tab, select Linear Regression
- √ Under the Options tab, click Display equation on chart
- √ Click the OK button

Save this chart for comparison to future missions

Compare pressures from different flights and look for the presence of high and low pressure systems or cold and warm air masses.

## 4.0 Winds at Altitude

The winds of near space can be characterized with the help of the capsule's GPS receiver. The \$GPRMC sentence gives information on capsule heading and speed. We can assume the balloon and capsule move with the winds, therefore allowing us to determine the wind speed and direction as a function of altitude.

All you need is your spreadsheet and the GPRMC sentences from the flight. A sample GPRMC sentence is shown below.

```
$GPRMC,172744,A,4340.3022,N,11641.5445,W,15.9,139.4,171101,15.4,E,A*0C
```

The two fields of interest are underlined in the above example. The first field is the speed of the GPS receiver (15.9 knots in this example) and the second is its heading (139.4 degrees true north in this example).

In place of the GPRMC sentence, the speed and heading are also available through a posit from the Tiny Trak. The Tiny Trak posit has this format.

```
KD4STH-9>APT202,WIDE3-3,qAR,KOYG-7:13934.12N/10355.75W-110/017/A=045495/Near  
Space Tracker #1
```

The two fields of interest are underlined in the above example. The first field is the heading of the GPS receiver (110 degrees true north in this example) and the second is its speed (17 knots in this example).

In the following directions, we are assuming the GPS is firmly attached to the balloon and not in free-fall.

If the speed and heading are made available as part of a TNC log, then consult Section 11 for directions on processing the TNC log. The rest of these directions assumes the data was part of the flight log recorded on the flight data recorder.

To convert knots into miles per hour, multiply knots by 1.15. Miles per hour can be converted to feet per second by multiplying miles per hour by 1.47. Alternatively, knots can be converted directly into feet per second by multiplying knots by 1.69.

### 4.1 Spreadsheet Calculations

- √ Insert a new column, just after the GPS Speed column
- √ Label the column, Air Speed
- √ Its unit is mph

Enter the following equation into the first cell of the new column

```
+A3 * 1.15
```

Note: To convert the GPS Speed into kilometer per hour, use the following spreadsheet equation

$$+A3 * 1.85$$

The two above equations assume the GPS Speed is in the A Column of the spreadsheet and that values begin in the third row. Change A3 to the appropriate row and column.

- √ Select the third cell in the Air Speed column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Air Speed column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

The Direction column indicates heading of the near spacecraft, and not the direction of the wind. To correct this, the directions must be reversed. If the heading is greater than 180 degrees, then 180 must be subtracted from the heading. If the heading is less than 180 degrees, then 180 must be added to the heading.

#### 4.2 Spreadsheet Calculations

- √ Insert a new column, just after Direction column
- √ Label the column, Wind direction
- √ The units is degrees true north

Enter the following equation into the first cell of the new column

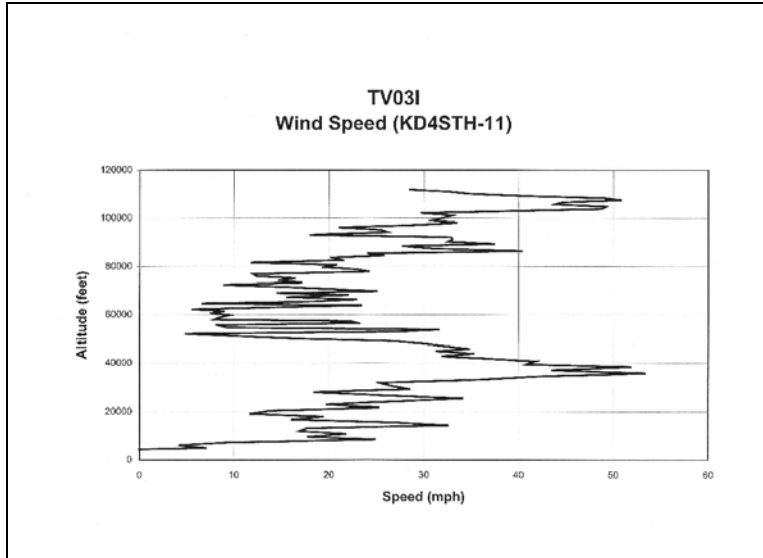
$$=IF(+A3<180,+A3+180,+A3-180)$$

The above equation assumes the Heading is in the A Column of the spreadsheet and that values begin in the third row. Change A3 to the appropriate row and column.

- √ Select the third cell in the Wind direction column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Wind Direction column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

#### 4.3 Wind Speed Chart

There is seldom a need to create a chart of wind speed after balloon burst. The data collected during descent covers the same region as collected during ascent, but with less resolution.

*Wind Speed Chart*

To create this chart, follow the same directions used to generate the Pressure chart, above, except,

- √ After deleting the series,
- √ Replace the X-column with the Wind Speed (do not select cells above the maximum altitude)
- √ Leave the Y-Axis alone

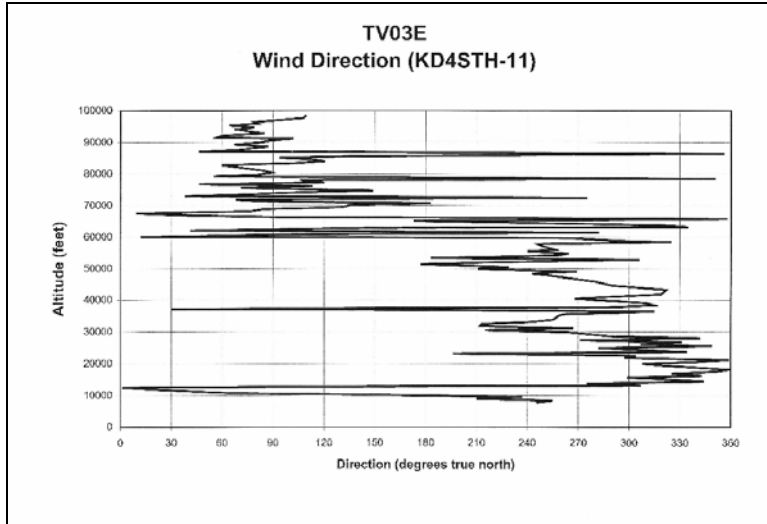
Typically the wind speed aloft increases with altitude until the near spacecraft is at the same altitude of the jet stream. If the balloon passes through the center of the jet stream, its speed can exceed a 100 mph! The jet stream is a thin river of high-speed winds aloft. The jet stream controls the movement and location of warm and cold masses of air. It's position, speed, and altitude changes over time. The following characteristics can be gleaned over several years of flights

- What is the altitude of the fastest winds?
- How deep are these winds?
- Is there a consistent, yearly variation to wind speeds aloft?

When comparing the depth of the jet stream, select a standard for determining the depth of the winds. One standard is to designate the top and bottom of the jet as the altitudes at which wind speeds are one-half the maximum wind speed observed in the jet.

#### 4.4 Wind Direction Chart

There is seldom a need to create a chart of wind direction after balloon burst. The data collected during descent covers the same region as collected during ascent, but with less resolution.



*Wind Direction Chart*

To create this chart, follow the same directions used to generate the Pressure chart, above, except,

- √ After deleting the series,
- √ Replace the X-column with the Wind Direction (do not select cells above the maximum altitude)
- √ Leave the Y-Axis alone
  
- √ After creating the chart,
- √ Left click the X-Axis
- √ Right click Format Axis
  
- √ Click Scale tab
- √ Type 0 in the minimum window
- √ Type 360 in the maximum window
- √ Type 30 in major unit window
- √ Click the OK button

It's not unusual to see wind direction change at high altitudes. At times the direction of the stratospheric winds can reverse, remaining constant for months at a time.

- Is the direction of winds aloft change in a regular pattern over the course of the year?
- Is the wind direction indicative of passing cold or warm fronts?

## 5.0 Basic Cosmic Ray Studies

Cosmic rays are primarily high energy nuclei and most of those nuclei are protons, or hydrogen atom nuclei. Some cosmic rays travel from the depths of space to the surface of Earth while others originate in the Sun. Before they reach us on the ground, though, cosmic rays must first traverse the upper atmosphere. There, collisions with nitrogen and oxygen molecules shields life from this shower of cosmic rays. A simple Geiger counter sent into near space permits you to detect individual cosmic rays. Each click of the Geiger counter is the detection of a single atomic nuclei originating from a star, either the Sun, or more likely, from a distant supernovae. The highest energy cosmic rays probably originate in other galaxies.

## 5.1 Theory of Operation

The heart of a Geiger counter is the geiger-muller (GM) tube. The GM tube contains a fill gas like helium or argon at low pressure. A voltage potential of several hundred volts exists between the cathode (negative charge) or outer jacket of the GM tube and a wire anode (positive charge) running through its center. This potential is not large enough to cause a breakdown of the gas inside the GM tube, so electrons do not separate from the fill gas. When ionizing radiation passes through the GM tube, the radiation ionizes (separates some electrons from their atoms) some of the fill gas creating a path for some electrons to flow towards the wire anode. As the electrons flow through the GM tube they collide with more of the fill gas, exciting them. The excited atoms decay back to their ground state within nanoseconds and as they do so, they emit photons (electromagnetic radiation). The photons liberate more electrons in the fill gas creating a mixture of negative electrons and positive nuclei in a chain reaction. The formation of ions discharges the GM tube within a microsecond and creates the familiar “click” of the Geiger Counter that is so popular in the 1950 B-grade science fiction movies. Because of this short discharge time, only the lightweight electrons will drift through the tube while the positively charged and much heavier helium nuclei remain nearly motionless. Eventually the presence of the positive nuclei cuts off the strong electric field around the anode wire and stops the GM tube discharge. Ionized helium now drifts towards the cathode (GM tube wall) where it wants to neutralize by collecting electrons from the tube wall. The presences of a quenching gas like chlorine or bromine ensures that the fill gas instead neutralizes by taking electrons from the quench gas instead of the GM tube cathode. Depending on the energies involved, a fill gas ion neutralizing on the cathode may end up releasing more electrons and cause multiple discharges in the GM tube, as opposed to a single discharge for each passage of ionizing radiation. The quench gas is eventually neutralized in a way that prevents multiple discharges in the GM tube. No new detections of ionizing radiation are possible while the gas inside the GM tube is ionized. The time it takes for the gas to recombine is called the Dead Time of the tube.

Some forms of radiation are more penetrating than others. Alpha particles for instance, cannot pass through a sheet of paper. To enable GM tubes to detect alphas, one end of the GM tube is covered with a thin sheet of mica. Another form of radiation is the beta particle. Betas are stopped by thin metals. Only the alpha and beta particles penetrating the alpha window of the GM tube are detected. Gamma and X radiation with energies greater than 40 kilo-electron volts (keV or thousands of electron volts) can penetrate the metal sides of the GM tube. Less energetic gamma and x radiation can only penetrate the alpha window of the GM tube. Therefore, when it comes to alphas and betas, and some weaker X and Gamma Rays, the radiation detected most by a GM tube is effected by its orientation. However the cosmic rays detected during a near space mission typically have energies at least one giga-electron volt (GeV or billions of electron volts). So most cosmic rays have sufficient energy to penetrate the stainless steel sides of a GM tube. Therefore during a near space mission, Geiger counter orientation is not a factor. The only shortcoming with Geiger counters is that they do not allow you to easily determine the energy of the detected radiation.

An excellent Geiger counter is the RM-60. The RM-60 is manufactured by Aware Electronics and is designed for PC use. The RM-60 measures 4.4” X 2.5” X 1” and weighs 0.2 pounds. The RM-60 detects pretty much every cosmic ray that enters the tube. Each cosmic ray passing through the RM-60 geiger-muller tube creates a 5V pulse that is several tens of microseconds long. Output from the RM-60 can be captured by the CC/PS and telemetered to ground stations. For the RM-60, its GM tube has a dead time of no more than 90 microseconds. If the incidence of ionizing radiation is evenly spread out, the RM-60 can ideally detect 11,111 particles per minute. The RM-60 receives its power (five volts) from the serial port of a PC or laptop. The output of the RM-60 is a five-volt pulse for each detection of radiation.



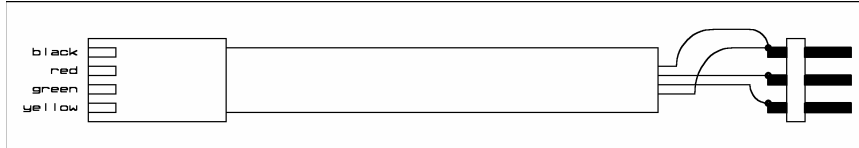
**Aware Electronics RM-60 Geiger Counter** - The phone cable was modified for my flight computer.

## 5.2 Materials

- RM-60 Geiger Counter
- Phone cable
- Header to connect to flight computer

## 5.3 Procedure

Below is the wiring diagram for connecting the RM-60 to the CC/PS.



**RM60 Cable** - Modifying a phone cable (with RJ-11 jack). The black wire of the phone cable is not used.

Begin making the RM-60 connector by cutting a six-foot long standard phone cable in half. Carefully strip back one inch of the outer jacket of insulation, exposing the four colored wires inside. The colors of the wires are black, red, green, and yellow. When connected to the RM-60, the green wire is signal, the red wire is power, and the yellow wire is ground. The black wire is not used. Strip back ½ inch of insulation from each wire, except for the black wire. Cut the black wire back to the outer jacket. Now solder or crimp a connector for your version of the CC/PS. If you crimp pins on the thin phone line wires, you'll need to double over the wires first, which means you should also strip back more insulation.





*RM60 Cable - Modifying a phone cable (with RJ-11 jack). The black wire of the phone cable is not used.*

## 5.4 Using The RM-60

### 5.4.1 Calibrating The RM-60

Each RM-60 is calibrated for X and gamma radiation by Aware Electronics in units of micro roentgen per hour. As background information, the Roentgen is a measure of the number of ionization pairs produced by x-rays or gamma rays per gram of air. To be exact, one Roentgen (1 R) equals  $2.08 \times 10^9$  ion pairs per 1 cc of air. Unfortunately, the Roentgen is defined for only x-rays and gamma rays, and does not apply to the energetic protons usually encountered in cosmic rays. However each “click” counted by the flight computer is the detection of a single cosmic ray passing through the GM tube of the RM-60.

### 5.4.2 Collecting Cosmic Ray Data

A word-sized variable is required to store the number of counts by the RM-60 without risking an overflow. From previous experience, counting pulses for ten seconds is long enough, but even counting for a minute will not overflow a word-sized variable.

The BS2p command to count the number of pulses from the RM-60 is as follows

```
RM60 CON 1
GMCount VAR WORD

COUNT RM60,10000,GMCount
```

This code assumes the RM60 is connected to I/O pin 1

The RM-60 has an alpha window in front of the detector. Cosmic rays being detected are typically coming from the sky overhead, and not from the ground. By turning the RM-60 upside down, you can filter out low energy alpha and beta particles. Another option is to place materials like lead above the RM-60 and control the position of the lead with a servo. Only particles with sufficient energy to penetrate the lead are detected with the lead in place. This becomes a crude method for determining the energy of radiation. To use this method, count pulses from the RM-60 twice each mission repetition, once with and once without a lead above the GM tube.

### 5.4.3 Spreadsheet Calculations

The primary observation to make with an Aware Electronics RM-60 is the number of cosmic rays detected as a function of altitude. In the spreadsheet is a column of GM Counts, per ten seconds. If a lead shield was carried on the mission, then the spreadsheet also includes a column of GM Counts With Lead, per ten seconds with lead.

#### Single Count Calculations

- √ Insert a new column, just after the GM Counts
- √ Label the column, Cosmic Ray Flux
- √ Its unit is counts per minutes per  $\text{cm}^2$

Note: This is calculated by multiplying the flux in ten seconds by a factor of six and then dividing the flux by the exposed area of the RM-60's GM tube. The exposed area of the tube is the difficult part to determine. If the tube is positioned on its side, then the exposed area is approximately the length of the GM tube multiplied by the diameter of the tube (approximately one centimeter by five centimeters). No matter how the RM-60 rotates, the cosmic rays still see an area of about one centimeter by five centimeters. However, in this configuration, the GM tube cannot detect alpha particles (helium nuclei). It should be noted that alphas shouldn't be able to penetrate the airframe of the near spacecraft, so any detected must have been created inside the airframe by cosmic ray collisions. I think I see another experiment here, comparing cosmic ray fluxes with identical horizontal and vertical GM tubes. See Chapter 13, Section One for notes on creating a Geiger Counter Telescope.

If the tube is oriented vertically, with the alpha window face up, then it detects alpha particles, but calculating the exposed area becomes more complex. Now the depth of the tube that cosmic rays "see" changes significantly with angle of approach. As a swag, the author assumes the tube appears to have twice the area as the face of the tube, or about twice a one centimeter circle. This makes the area  $2 * 3.14 * (0.5 * 0.5)$ , or about 1.57, as opposed to 5.00 for the horizontal tube orientation.

In the first cell, enter the equation

$$= (+A3 * 6) / (1 * 5) \quad (\text{with horizontal tube})$$

or

$$= (+A3 * 6) / 1.57 \quad (\text{with vertical tube})$$

Note: If you use a Geiger counter with a different sized GM tube, change the dimensions in the divisor.

- √ Select the third cell in the Cosmic Ray Flux column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Cosmic Ray Flux column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

#### Two Count Calculations

- √ Insert three columns, one after the GM Counts, the second after GM Counts With Lead, and the third after the second new column
- √ Label the first column, Raw Cosmic Ray Flux
- √ Its unit is counts per minute
- √ Label the second column, Filtered Energy Cosmic Ray Flux

- √ Its unit is counts per minute
- √ Label the third column, Penetrating Energy Cosmic Ray Flux
- √ Its unit is counts per minute

Convert the first two new columns to counts per minute. The third new column is the difference between the first two columns, or the cosmic ray flux capable of penetrating the lead shield.

In the first open cell of the Raw Cosmic Ray Flux, enter the equation

$$= (+A3 * 6) / (1 * 5)$$

or

$$= (+A3 * 6) / 1.57$$

- √ Select the third cell in the Raw Cosmic Ray Flux column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Raw Cosmic Ray Flux column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

In the first open cell of the second Filtered Cosmic Ray Flux, enter the equation

$$= (+C3 * 6) / (1 * 5)$$

or

$$= (+C3 * 6) / 1.57$$

- √ Select the third cell in the Filtered Cosmic Ray Flux column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Filtered Cosmic Ray Flux column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

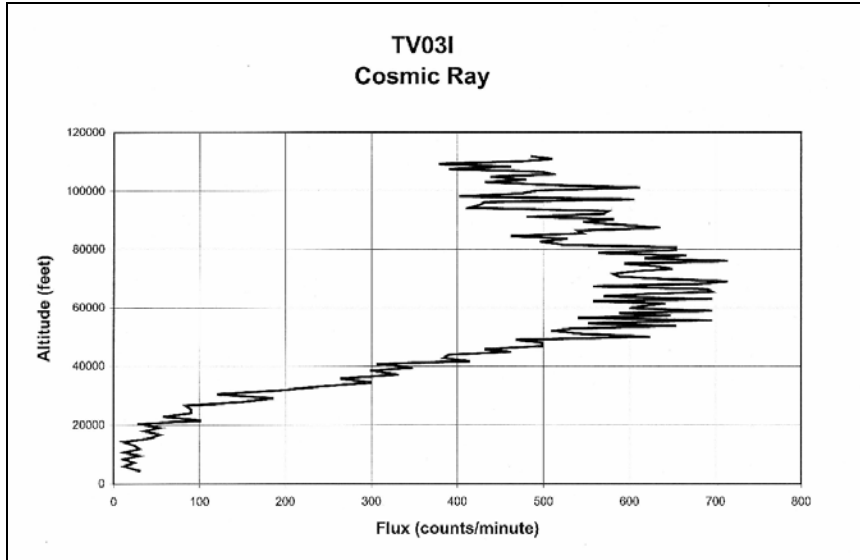
In the Penetrating Cosmic Ray Flux, enter the following equation

$$= +B3 - D3$$

- √ Select the third cell in the Penetrating Cosmic Ray Flux column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Penetrating Cosmic Ray Flux column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

### 5.4.4 Cosmic Ray Flux Chart

There is seldom a need to create a chart of cosmic ray counts after balloon burst. The data collected during descent covers the same region as collected during ascent, but with less resolution. Generate a chart of cosmic ray count per minute versus the altitude. The product should look like the following graph.



*Cosmic Ray Chart*

To create this chart, follow the same directions used to generate the Pressure chart, above, except,

- √ After deleting the series,
- √ Replace the X-column with the Cosmic Ray Flux (or Raw Cosmic Ray Flux) (do not select cells above the maximum altitude)
- √ Leave the Y-Axis alone

Note that the cosmic ray flux increases to until some altitude when it begins to decrease. The cosmic ray flux initially increases because the atmosphere filters out the lower energy secondary cosmic rays. The altitude at which the flux begins to decrease is the altitude where the fewer of the unfiltered secondaries and more of the primaries are beginning to be detected.

Over several flights, compare the maximum cosmic ray flux and the altitude of the cosmic ray flux knee. Compare these two factors with the proton count available from the website [www.spaceweather.com](http://www.spaceweather.com) or the occurrence of a solar flare before the flight.

### 5.4.5 Penetrating Cosmic Ray Flux Chart

Generate a chart that compares the raw cosmic ray flux to the penetrating cosmic ray flux as a function of altitude.

This chart requires two series, the Raw Cosmic Ray Flux and the Penetrating Cosmic Ray Flux. To create this chart, follow the same directions used to generate the Air Temperature Profile, above, except:

After deleting the series,

- √ Name the first series Raw Cosmic Ray Flux by clicking on the name of the column
- √ Replace the X-column with the Raw Cosmic Ray Flux (do not select cells above the maximum altitude)
- √ Be sure to click the Name window for the series and select the cell with the text Raw Cosmic Ray Flux in it
  
- √ Click the ADD button to create a second series for the chart
- √ Name the second series Penetrating Cosmic Ray Flux by clicking on the name of the column
- √ Replace the X-column with the Penetrating Cosmic Ray Flux (do not select cells above the maximum altitude)
- √ Be sure to click the Name window for the series and select the cell with the text Penetrating Cosmic Ray Flux in it
- √ Leave the Y Axis alone

### Legend Tab

- √ Leave the Show Legend button clicked
- √ Right click the Raw Cosmic Ray Flux series in the chart  
Note: You can identify this one because it should be a little bit higher
- √ Click Format Data Series
- √ Under Line options, click Style
- √ Select the solid line (top option in pop-menu)
- √ Under Color option, select the black square (upper left)
- √ Right click the Penetrating Cosmic Ray Flux series in the chart
- √ Click Format Data Series
- √ Under Line options, click Style
- √ Select the dashed line
- √ Under Color option, select the black square (upper left)

### 5.4.6 A Possible Complication

Cosmic rays impacting the lead sheet may create secondary cosmic rays. If so, the flux with the lead shield in place will be higher than the raw cosmic ray flux. It has been so long since the author performed this experiment that he can't remember what happened. This is all the more reason to fly and try this experiment out.

Over several flights, compare the penetrating cosmic ray flux as a function of altitude. Compare the penetrating cosmic ray flux to the proton count available from the website [www.spaceweather.com](http://www.spaceweather.com) or the occurrence of a solar flare before the flight.

Another option is to make several shields, each one thicker or more effective than the previous one. Compare the cosmic ray flux that penetrates each shielding material. Tungsten ought to be a good shielding material (this is more reasons to fly a mission, right?).

## 6.0 Photometers

As a near spacecraft ascends the sky above darkens and eventually turns black. How the sky darkens gives an indication of the amount of air remaining above the capsule, because it is this air and dust that scatters sunlight and makes the sky bright. The color most easily scattered by air molecules is blue, hence our blue skies. Sensors that indicate the amount of sunlight in the sky are referred to as photometers (meters that measure the brightness of light). There are several variations of the photometer (which is sensitive to the total brightness of light over a wide range of frequencies). One variation is sensitive to the brightness of light in a specific frequency (color) of light and is called a

spectrophotometer. Another variation that is sensitive to the brightness and polarization of light and is called a photopolarimeter. To observe the effect of sensitivity to brightness and polarization for yourself, purchase a pair of polarized sunglasses and perform the following experiment. Remove the glasses from your eyes and look at a patch of the sky 90 degrees away from the sun through one of the lens. Now rotate the sunglasses by 90 degrees and observe the brightness of the same patch of sky through the lens. Next look at a patch of the sky 180 degrees away from the Sun and repeat the same experiment. Notice that the effect of rotating the lens is the same, but the orientation of the polarization is rotated between the two patches of sky.

The ideal sensor for an amateur photometer sensitive across the visible spectrum is the photodiode, a type of miniature solar cell. Increasing light intensity on a photodiode increases the current created by the photodiode. Note that it is not the voltage that changes. Photometers based on photodiodes then must measure the current generated by a photodiode and not the voltage. Two types of photometers are described in this section, one based on the TSL230 which is an array of photodiodes on a single silicon chip and the other based on discrete photodiodes and LEDs. But first, possible confounding effects are described.

### **Possible Sources Of Error In Photometer Measurements**

There are two problems I've encountered with measuring sky brightness during a near space mission and one potential problem I haven't analyzed. They are the photometer's sensitivity to pointing, the Sun's changing elevation during a mission, and the possibility of a photometer's sensitivity changing due to its temperature.

#### **Sensitivity To Pointing**

When the photometer points towards the Sun for one measurement and away from the Sun for a second measurement, the photometer indicates a substantial change in light intensity that is not related to a change in altitude. The direction the photometer points must be taken into account for each measurement, especially when the photometer has a narrow field of view.

#### **Sensitivity To Changing Sun Elevation**

The Sun moves at least 22 degrees during the ascent of a near space mission (not all of that 22 degrees is change in elevation, some is change in azimuth). As the Sun rises higher, the amount of air that sunlight passes through decreases. Therefore the intensity of light detected by the photometer changes as the Sun rises, even if the altitude of the near spacecraft is constant the entire time. A method for accounting for changes in the Sun's position must be implemented to get the most meaningful data.

#### **Possible Sensitivity To Changes In Temperature**

As the temperature of the photometer decreases, its efficiency should increase (the same effect is seen in solar cells). A change in photodiode sensitivity affects the output generated by the photometer and creates what appears to be a change in sky brightness that turns out is independent of the actual change in sky brightness. The effects of temperature change must be taken into account more accurate photometer measurements.

Under the construction section are some recommendations for getting around these sources of error. However, they recommendations are not complete. There's lots of room for improvement for implementing photometers on amateur near space missions (which just further justifies the need for more flights).

## 6.1 The TSL230-Based Photometer

Light intensities in near space are easily determined using the TSL230 light to frequency converter. I discovered the TSL230 from a Stamp Application article written by Scott Edwards for the magazine *Nuts And Volts* (November 1996). *Nuts and Volts* is one of the magazines you should subscribe to (the other being *Circuit Cellar*). The TSL230 is a very simple sensor to interface to the CC/PS. The TSL230 makes a photometer that is sensitive to a wide range of frequencies (colors). By covering the light sensor with inexpensive color filters, a broad band spectrophotometer can be built. Its a broadband spectrophotometer because colored filters let pass a wide range of frequencies centered on their color. A dichroic filter is one way to reduce the bandwidth of the filter but also increases the cost of the photometer. A caution to be aware of is that the frequency passed by dichroic filters changes as the filter is tipped in angle to the incident light. Aside from colored filters, a polarizer filter can also cover the TSL230 making it into a photopolarimeter. No other electronic components are required to interface a TSL230 to the BS2p (didn't I say it was easy?).

### 6.1.1 Theory Of Operation

As the intensity of the light falling on a photodiode increases, so does the amount of current it produces. The TSL230 consists of an array of photodiodes. The size of the active array can be changed, as can the sensitivity of the active array. The amount of current produced by the active photodiode array in the TSL230 controls the pulse rate output of the TSL230. In the case of the TSL230, the pulse rate increases linearly with light intensity. Double the light intensity incident of the TSL230 and its pulse rate also doubles (twice as many 5V pulses per second). A flight computer determines light intensity with the COUNT command. Do not use the PULSIN command as it only measures the width of a single pulse, whereas the COUNT command averages the width of several pulses in a single measurement.

### 6.1.2 Materials

- TSL230 Frequency-to-Light converter
  - 0.1 uF capacitor
  - Eight pin socket, 0.3" wide
- #24 AWG stranded wire (three colors)
- PCB
- 3mm foamed neoprene
- Correplast sheet
- Nylon wire ties

### 6.1.3 Procedure

- √ Solder the following components to the PCB
- 8-pin IC socket
- 0.1 uF capacitor
- √ Cut three foot lengths of each wire (red for power, black or green for ground, and a third color for signal)
- √ Strip ¼" of insulation from both ends of all three wires
- √ Solder one end of each wire to the PCB
- √ Terminate the other ends of the wires as appropriate for your CC/PS
- √ Perform a continuity check and verify the connections
  - Pins 1,5,7,and 8 are connected to +5V
  - Pins 2,3, and 4 are connected to GND
- √ Press TSL230 into its socket
- √ Cut a sheet of 3mm neoprene to size of the PCB

- √ Cut a sheet of Correplast to a 2.5" square
- √ Stack the completed PCB on the neoprene and the Correplast
- √ Center the TSL230 on the Correplast
- √ Punch small holes through the neoprene and Correplast
- √ Punch an extra set of holes just outside the PCB holes
- √ Zip tie the PCB and neoprene to the Correplast and trim the zip ties

#### 6.1.4 Using The TSL230-Based Photometer

Complete the photometer case as directed in Section 6.3.

### 6.2 The Discrete Photodiode and LED-Based Photometer

#### **Photodiodes And LEDs**

Like the photodiode array of the TSL230, discrete photodiodes are sensitive to a broad range of the spectrum, including infrared. A more narrow band spectrophotometer can be built using colored LEDs. As Forrest Mims has written about (Engineer's Mini-Notebook, Environmental Projects, Radio Shack # 62-5019), LEDs not only emit a narrow range of frequencies, but they also create current when exposed to light in the band of frequency they emit. LEDs create a narrowband spectrophotometer with a bandwidth on the order of 30 to 150 nm. This is still very wide compared to a real spectrophotometer, but for the cost, it's not bad.

The best way to interface photodiodes and LEDs to the BS2p is by allowing the LED or photodiode to charge a capacitor, and then measure the time required. This design is documented in Parallax's book, *Applied Sensors*. The idea for using LEDs as frequency specific photodiodes comes from applications notes written by Parallax Inc. and Forrest Mims.

#### 6.2.1 Theory Of Operation

Photodiodes and LEDs are made from a junction of P-type doped and N-type doped silicon. Photodiodes are designed to create a hole and an electron when a photon of light strikes the PN junction. The LED is designed to function in the opposite manner; an electron injected into their PN junction creates a photon of light. However, LEDs can operate in the same manner as the photodiode and create a hole-electron pair when a photon strikes the PN junction. However in the case of the LED, the PN junction is "tuned" for a specific frequency of light (color of light) and is insensitive to light of different frequencies. If this were not so, then all LEDs would emit white light, rather than a specific color.<sup>C</sup>

In the circuit described below, light striking the photodiode or LED creates a small current, like an inefficient solar cell. The current from the photodiode or LED changes the charge on one of the plates of a capacitor. The capacitor begins with equal charges on both of its plates. The voltage across the capacitor changes as the one plate is discharged by the photodiode or LED. Through one of its I/O pins, the Basic Stamp monitors the change in voltage between the plates of the capacitor. When the voltage difference between the capacitor's plates transitions between 1.4 volts, the logic state of the Basic Stamp's I/O pin changes. The length of time required to change the logic state is recorded in a variable through the RCTIME command. The greater the light intensity, the greater the current created by the photodiode or LED. The greater the current generated by the photodiode or LED, the faster the capacitor plate discharges and the lower the returned value from the RCTIME command.

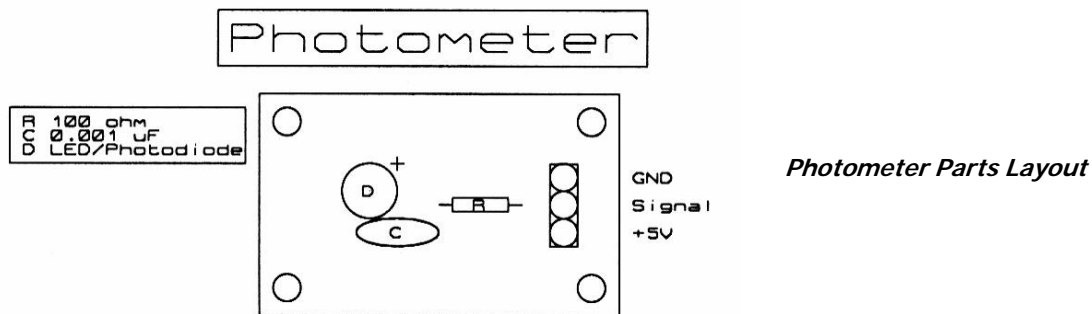
The current output from the photodiode and LED is linearly related to the light intensity. When the light intensity on the photodiode or LED is doubled, so is the current they generate which halves the values returned by the RCTIME command.



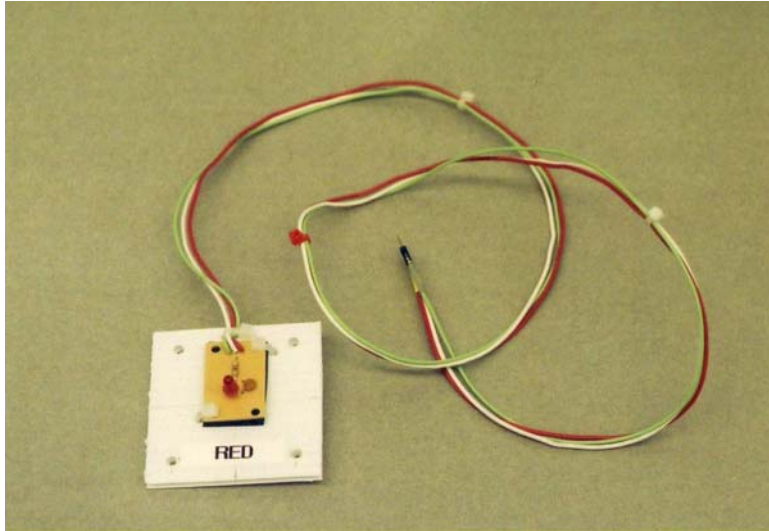
## 6.2.2 Materials

- T1¼ LED or photodiode
- 0.001 uF capacitor (may have 102 printed on it)
- or 10-15 pF capacitor if using a blue or UV LED
- 100 ohm resistor
- #24 AWG stranded wire (three colors)
- Photometer PCB
- Correplast sheet
- Nylon wire ties
- 3mm thick foamed neoprene

## 6.2.3 Procedure



- √ Solder the following components into the PCB
  - C
  - R
- √ If using the photodiode, fold the leads back so that the bubble on the photodiodes case points up.
  - D<sup>D</sup>
- √ Cut three feet of each wire (use red for power, green or black for ground, and a third color for signal)
- √ Strip ¼" of insulation from each end of all three wires
- √ Solder one end of each wire to the PCB
- √ Terminate the other ends of the wires as is appropriate for your CC/PS
- √ Cut a sheet of 3mm neoprene to size of the PCB
- √ Cut a sheet of Correplast to a 2.5" square
- √ Stack the completed PCB on the neoprene and the Correplast
- √ Position PCB so that LED or photodiode is centered on the Correplast sheet
- √ Punch small holes through the neoprene and Correplast that line up with the holes in the photometer PCB holes
- √ Punch an extra set of holes just outside the PCB holes
- √ Zip tie the PCB and neoprene to the Correplast and trim the zip ties
- √ Mark ½" inside from the four corners of the Correplast
- √ Drill 1/8" diameter holes at these four locations (these are the photometer mounting holes)



*Photometer PCB - On coroplast/neoprene base*

#### 6.2.4 Using The Discrete Photodiode-Based Photometer

Complete the photometer as directed in Section 6.3. The BS2p code for the photometer is documented in Appendix B.

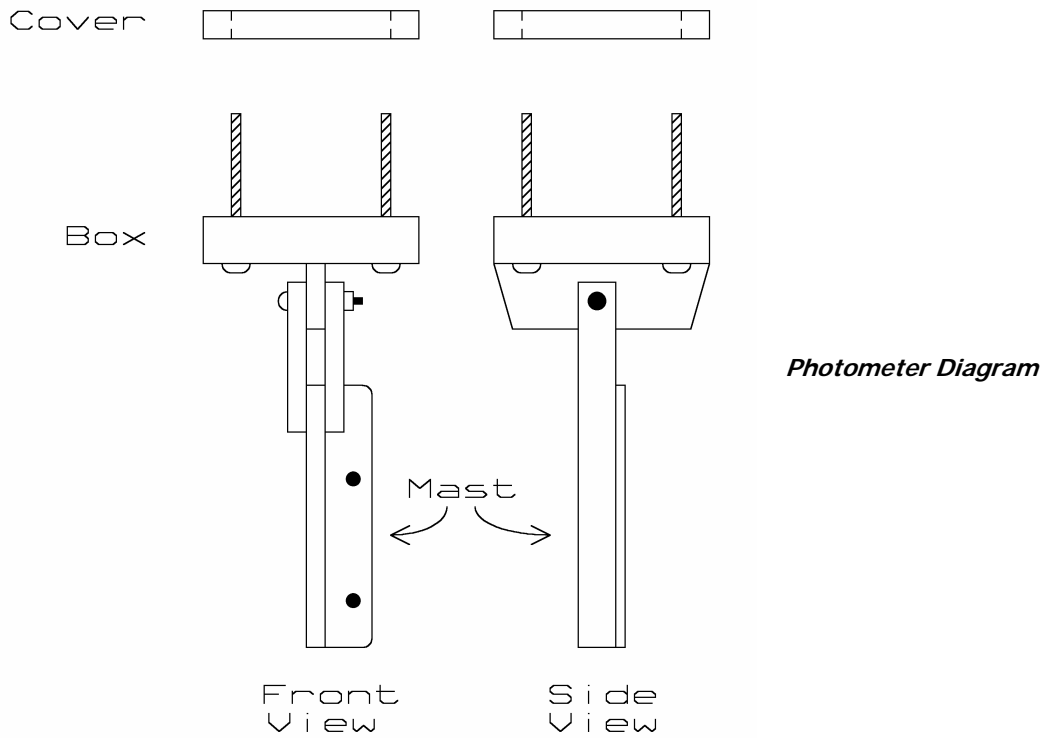
### 6.3 Completing The Photometer

The photometer PCB is now mounted such that it can clearly “see” the sky or ground without shadows or the Sun interfering. There are three parts to the photometer: the photometer box, the photometer mast, and the photometer cover. The photometer PCB is mounted inside the photometer box. Four bolts are used to secure the PCB to its box while allowing the photometer PCBs to be switched out. The photometer mast positions the photometer above or below the near spacecraft airframe. It also allows the photometer to be pointed at different elevations. Finally the photometer cover closes the photometer PCB inside the photometer box and restricts the light able to reach the photometer PCB. You should have several photometer PCBs with a photodiode and several different color LEDs. You should also have several different photometer covers. This allows you to mix and match parts for each mission.

#### Materials

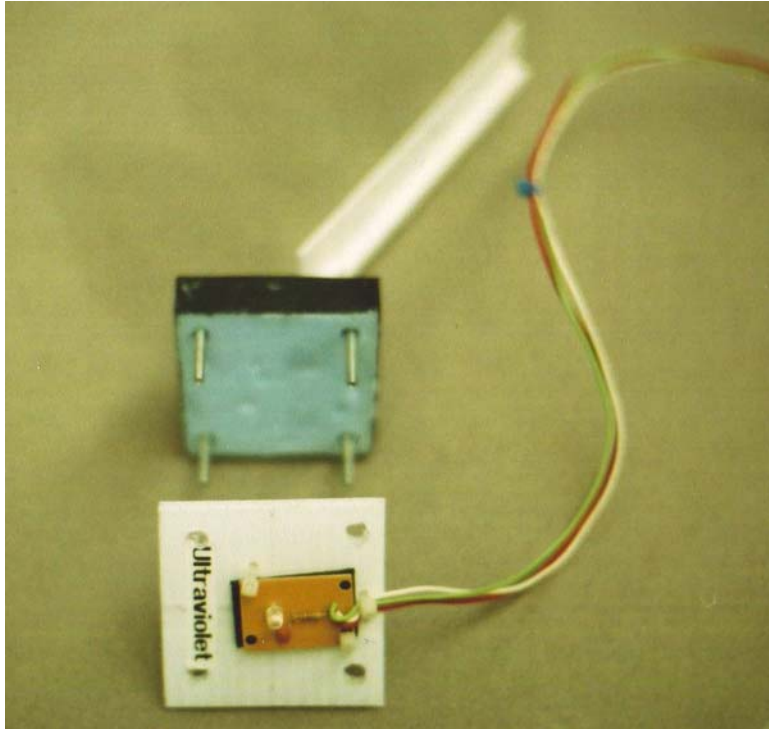
- ½” thick Styrofoam
- 1/16” plywood
- 1/4” square basswood strip
- ¼” X ½” basswood strip
- Wood glue
- Black paint
- Drill and 1/8” drill bit
- Clamps and an Exacto knife or saw
- Coroplast
- ¼” square plastic tubing
- 0.04” thick plastic sheet, at least six inches long and one inch wide
- Plastic cement
- #6-32 hardware
- ¾” rocket tubing
- Ping-pong ball

- Thin Styrofoam or foam core
- Hot glue



**Photometer Box**

Use plywood and basswood to build what is essentially a shallow box for housing the photometer circuit. You can use plastic, but the material must be opaque.



*Photometer Box*

## Procedure

### Make Photometer Face

- ✓ Cut a 2.5" square out of 1/16" thick plywood
- ✓ Cut four lengths of the 1/4" basswood to a length of 2-1/4"
- ✓ Using wood glue, glue the 2-1/4" long basswood strips to the outside edges of one of the plywood squares (this will become the top face of the photometer)
- ✓ Clamp the basswood down until the wood glue sets
- ✓ Mark the centers of the corners of the basswood strips
- ✓ Drill 1/8-inch diameter holes in the centers of the corners of the basswood strips
- ✓ Note: These holes are used to mount the photometer cover
- ✓ Find and mark the center of the photometer face
- ✓ Drill a hole in the center of the cover to admit light to the LED or photodiode (a 1/8" hole seems to work well)

Note: The LED in the photometer PCB is high enough to stick up out of the hole, the photodiode is folded over, so will reside below the cover. If the photometer is based on the TSL230, then drill a larger diameter hole

The cover is added to the photometer face later

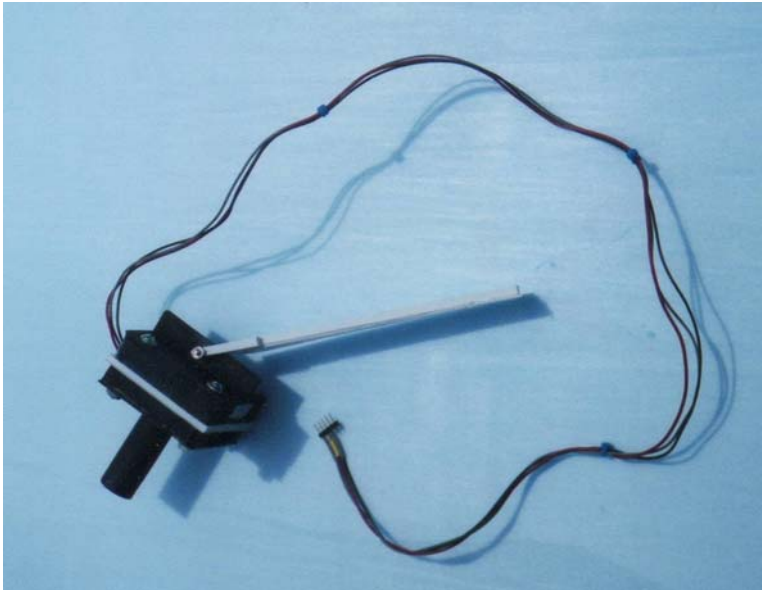
### Make Photometer Bottom

- ✓ Cut the 1/4" by 1/2" basswood to a length of 2-1/4"
- ✓ Mark the center of the strip
- ✓ Drill a 1/8" diameter hole through the center of the basswood strip
- ✓ Cut a 2.5" square out of 1/16" thick plywood
- ✓ Cut a 2.5" square out of the 1/2" Styrofoam
- ✓ Epoxy the 1/16" thick plywood to one face of the 1/2" Styrofoam
- ✓ After the epoxy sets, on the underside of the plywood, mark the middle of two opposite sides
- ✓ Glue the 1/4" by 1/2" basswood strip, centered, to the underside of the plywood, aligning the basswood on the centering marks (this makes the photometer box spine)

- √ Stack the photometer face on top of the photometer bottom
- √ Drill 1/8-inch diameter holes through the photometer bottom that line up with the previously drilled holes in the photometer face

### Photometer Mast

The mast raises or lowers the photometer box away from the airframe, where shadows can confound measurements. The mast is bolted along the edge of a quad panel.



*Photometer Mast*

### Procedure

- √ Cut a length of 1/4" square plastic tubing to 12 inches
- √ Cut two additional pieces to a length of four inches
- √ Mark two inches from one end of the longest plastic tube
- √ Glue the remaining two pieces to the sides of the longest piece, forming a two pronged fork or trident (this makes the mast prongs)
- √ Use a clamp to keep all the pieces flush and square until the glue sets
- √ Slide the fork onto the photometer box spine
- √ Drill holes in the two prongs to align with the center hole of the spine  
Note: You may need to trim the ends of the forks to allow the photometer box to rotate on the ends of the mast prongs  
Note: You may want to reinforce the joint between the mast and its prongs with a thin sheet of plastic (the author has not needed to do this, as yet)
- √ Cut a rectangle from the 0.04" plastic sheet, measuring one-inch by six-inches
- √ Glue the rectangle flush to the edge and the to the bottom of the mast (the end away from the prongs) – (this is the mast mounting plate)
- √ Align the mast mounting plate to the side of a quad panel
- √ Mark the location of the quad panel mounting holes into the mast mounting plate
- √ Drill the holes with a 1/8" diameter drill bit

### Photometer Covers

Photometer covers come in a variety of shapes and functions. The cover is designed to control the region of the sky or ground accessible to the photometer. Below are some suggestions.

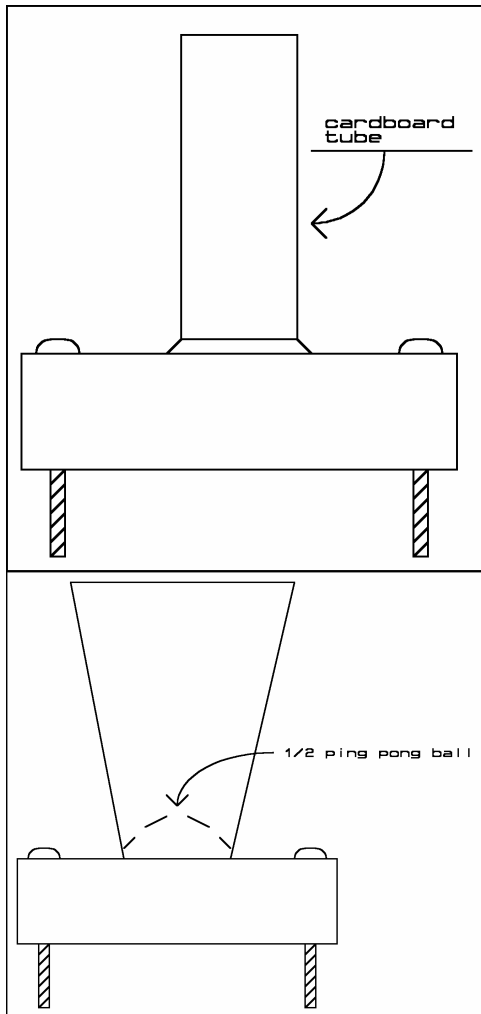
### Filters And Polarizers to Control Light

If the photometer uses photodiodes, instead of LEDs, and needs filtering for either polarized or for particular colors of light, glue the appropriate filter to the top of the photometer face. The size of the filter must be large enough to cover the opening in the photometer face but small enough not to interfere with any additional photometer cover.

If an LED is used in the photometer, then color filters are not needed (they would be a waste of weight and time). Since the LED sticks up above the photometer cover, a polarizing filter must be placed on the topside of the photometer cover.

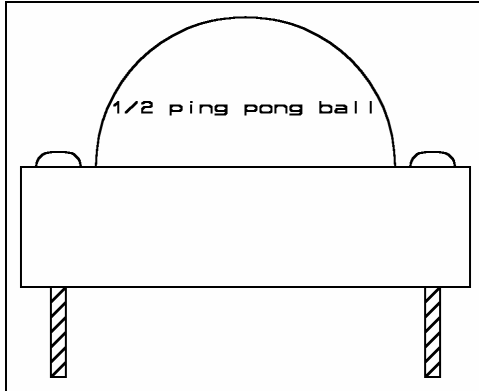
### Horns, Tubes, And Ping-Pong Balls to Control Sky Access

If the field of view of the photometer needs to be restricted, attach a tube or horn (cone) to the top surface of the photometer cover. The easiest tube is a length of rocket tube glued centered over the photometer cover. Plastic horns can be made from a plastic cup or constructed from scratch from thin plywood or foam core. Be sure to glue them centered over the photometer top.



*Tube Pointer – Attempts to limit region of sky being viewed*

*Cone Limiter – Diffuses a limited area of ground*



*Dome Diffuser – Makes photometer less sensitive to pointing direction, while integrating sky light*

To integrate the entire sky into a single brightness measurement, cover the top of the photometer with half a ping-pong ball or similar diffuser. The interior of the diffuser is more uniformly illuminated by light. It matters less where the Sun is located when the photometer circuit is inside a ping-pong ball. The ping-pong ball can also be mounted inside of a horn in an attempt to further control incident light.

The ultimate ping-pong ball diffuser may be the stack's balloon. Giving the photometer a very narrow field of view and aiming it at the center of the balloon may minimize photometer-pointing errors (sounds like an excuse for another flight to me).

#### 6.4 Using The Photometer

Now that the photometer is complete, test it for proper functioning.

##### **Calibration**

The light sensors described in this section are linear. Typically their measurements are compared to data from the ground. Unless you have a calibrated photometer, there is no realistic way to fully calibrate your photometer. If you have access to a photometer, then take a reading at launch and record it for post-flight processing.

Testing the linearity of the photometer can be accomplished with neutral density filters. Thanks to Idaho Camera, I have learned the following facts about neutral density camera filters. Using a 2X neutral density filter on a camera reduces the camera exposure by one stop, or the light intensity by half. A 4X neutral density filter on a camera reduces the exposure by two stops, or the light intensity by a factor of four. Finally, if you can find an 8X neutral density filter, it reduces the exposure by four stops, or the light intensity by a factor of eight.

Test the linearity of a photometer as follows. Download a test program into the flight computer that debugs the measurement from the photometer every five seconds. Point the photometer at a fixed location like a wall with sunlight falling on it. Make several measurements of light intensity and record them. Cover the diffuser of the photometer with one of the neutral density filters described above and make several measurements and record the result. If the photometer behaves linearly, then the count from the photometer changes by a factor of two for a 2X filter, by a factor of four for a 4X filter, and a by a factor of eight for an 8X neutral density filter.

The final calibration is to record the sky brightness just before launch. Document this step in the checklist. Pay attention to photometer orientation, if necessary.

##### **Controlling Photometer Errors**

Described below are three recommended procedures for reducing errors in photometer measurements.

### Changing Solar Elevation Errors

To remove Sun altitude errors, build a second copy of the photometer. Compare the readings from the second photometer to the readings of the first photometer. Determine what correction in counts from the second photometer is required to make its measurements match the first photometer.

Operate the second photometer on the ground while the first photometer is on a mission. This is best performed by adding the photometer and GPS receiver to a second near space capsule that is left on the ground. Record the GPS time and readings from the photometer in a flight data recorder. After the flight, compare the measurements taken by the ground-based photometer to those measurements collected by the near space-based photometer. Taken measurements often, as you need enough to match those taken during the mission.

### Changing Temperature Errors

The next effect to take into account is the possible change of sensitivity or noise in the photometer as its temperature changes. One method to determine temperature changes in the photometer is to place the photometer inside a Styrofoam cooler while making measurements. Cover the bottom and sides of the photometer in a plastic bag to avoid getting the electronics wet. Then place the photometer and a thermometer inside the cooler while taking readings. Record both the temperature and readings from each set of tests. Each set of tests involves chilling the photometer. Start with reusable ice packs to keep the interior of the cooler dry. End the test using a block of dry ice. Take several measurements as the photometer cools down.

Enter the temperature and reading into a spreadsheet and chart the results. The variation may be so minor that it's not worrying about. If not, then perform a regression on the chart and record the equation.

### Changing Position Errors

Even with a ping-pong ball cover, I have noticed a sensitivity in the photometer to its pointing direction. I recommend making several measurements at each altitude and keeping only the highest reading (the darkest patch of sky, or away from the Sun) to reduce the effects of pointing errors.

### Collecting Photometer Data

Data is collected from LED and photodiode-based photometers with the RCTIME command. Below is a sample command.

```
Photometer CON 1
Brightness VAR WORD
HIGH Photometer
PAUSE 1
RCTIME Photometer,Brightness
```

Note: This code assumes the photometer is connected to I/O pin 1

Data is collected from TSL230-based photometers with the COUNT command. Below is a sample command.

```
Photometer CON 1
Brightness VAR WORD
COUNT Photometer,Brightness
```

Note: This code assumes the photometer is connected to I/O pin 1



### Photometer Options

Photometers are not just for measuring the brightness of the sky in one region. Here are some options to consider for your near space missions.

- Mount two identical photometers 90 degrees apart and measure polarization.
- Mount two photometers side by side, but measure different the brightness of different colors (does UV brightness change at the same rate as blue?).
- Point a photometer downwards during a night launch and detect cities by their wasted light.
- Point a green and IR photometer down and try detecting plants (chlorophyll reflects lots of IR). For this experiment, it would be a good idea to carry a digital camera and record the scene below at each photometer reading.
- Perform the same experiment with different photometers and determine the “spectral signature” of cities.

### Spreadsheet Calculations

#### Single LED Photometer

In the spreadsheet there must be columns for the altitude and the photometer’s measurement at that altitude. The photometer column is called Photometer Reading and its unit is counts (counts are actually in units of two microseconds).

- √ Insert a new column after the Photometer Reading
- √ Name the column Sky Brightness
- √ Unit is ratio to ground
  
- √ In the first cell of the new column, enter the following equation  
= +A3/\$A\$3  
Note: The equation assumes the photometer reading is in column A, change as necessary.
- √ Select the third cell in the Sky Brightness column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Sky Brightness column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

#### Multiple LED Photometers On The Same Mission

In the spreadsheet there must be columns for the altitude and each photometer’s measurement at that altitude. The photometer columns are called by their color, e.g. Blue Reading. The units are counts (the counts are in units of two microseconds).

- √ Insert new columns after each of the Photometer Reading
- √ Name the columns after the color of the photometer and sky brightness, e.g. Blue Sky Brightness
- √ Units are ratio to ground
  
- √ In the first cell of each new column, enter the following equation  
= +A3/\$A\$3  
Note: The equation assumes the photometer reading is in column A, change as necessary.

- √ Select the third cell in the Sky Brightness column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Sky Brightness column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

### Multiple LED Photometers With One On The Ground

In the spreadsheet there must be columns for the altitude, time, and the photometer's measurement at that altitude. The photometer column is called Near Space Photometer Reading and its unit is counts.

- √ Insert a new column after the Near Space Photometer Reading
- √ Name the column Ground Photometer Reading and the unit is counts.
- √ Hand copy ground photometer readings that correspond to the time the near space readings were taken

- √ Insert a new column after each of the Near Space Photometer Reading
- √ Name the column Corrected Photometer Reading and make its units counts

- √ In the first cell of the Corrected Photometer Reading, enter the following equation  
= +C3/D3

Note: The equation assumes the Near Space Photometer Reading is in column C and the Ground Photometer Reading is located in column D, change as necessary.

Note: I may be mistaken; the proper equation may be to subtract the two readings.

- √ Select the third cell in the Corrected Photometer Reading column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Corrected Photometer Reading column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

- √ Insert a new column after each of the Corrected Photometer Reading
- √ Name the column Corrected Sky Brightness and make its units ratio to ground

- √ In the first cell of the Corrected Sky Brightness, enter the following equation  
= +D3/D3

Note: The equation assumes the Corrected Photometer Reading is in column D, change as necessary.

- √ Select the third cell in the Corrected Sky Brightness column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down

- √ Press and hold the SHIFT key
- √ Click the last cell in the Corrected Sky Brightness column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

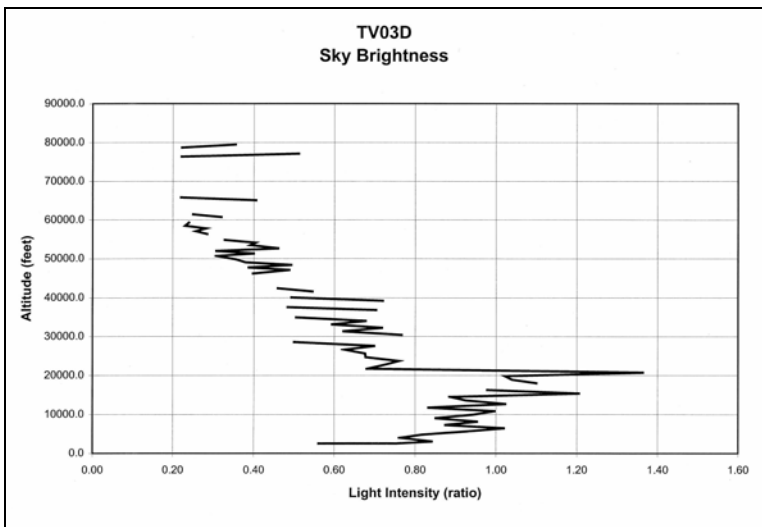
**TSL230-based Photometer**

In the spreadsheet there must be columns for the altitude and the photometer’s measurement at that altitude. The photometer column is called Photometer Reading and its unit is counts (counts are for a specific period of time).

- √ Insert a new column after the Photometer Reading
- √ Name the column Sky Brightness
- √ Unit is ratio to ground
  
- √ In the first cell of the new column, enter the following equation  
= +\$A\$3/A3  
Note: The equation assumes the photometer reading is in column A, change as necessary.  
Note: The numerator and denominator are switched in relation to the LED or photodiode-based photometers.
  
- √ Select the third cell in the Sky Brightness column (the cell containing the equation)  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Sky Brightness column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Right click anywhere in the highlighted cells
- √ Click Paste

**Single Photometer Charts**

There is seldom a need to create a chart of photometer data after balloon burst. The data collected during descent covers the same region as collected during ascent, but with less resolution. Generate a chart of sky brightness versus the altitude. The product should look like the following graph.



*Sky Brightness vs Altitude*

To create this chart, follow the same directions used to generate the Pressure chart, above, except,

After deleting the series,

- √ Replace the X-column with the sky brightness (do not use cells above the row with the maximum altitude)
  
- √ Leave the Y-Axis alone

Note that over all, the brightness is decreasing as the near spacecraft ascends. Pointing sensitivity and changing elevation of the Sun complicates the issue.

### **Multiple Photometer Charts**

Generate a chart that compares the sky brightness in several different colors as a function of altitude.

This chart requires multiple series, one for each color. To create this chart, follow the same directions used to generate the Air Temperature Profile, above, except,

After deleting the series,

- √ Name the first series after the first photometer color by clicking on the name of the column
- √ Replace the X-column with the first photometer color (do not use cells in rows above the maximum altitude)
- √ Be sure to click the Name window for the series and select the cell with the text indicating the first photometer color
  
- √ Click the ADD button to create a second series for the chart
- √ Name the second series after the second photometer color by clicking on the name of the column
- √ Replace the X-column with the second photometer color (do not use cells in rows above the maximum altitude)
  
- √ Repeat the above steps for any other photometer data. In each case, be sure to name the series after the photometer's color, as that is the name that appears in the chart's legend
  
- √ Leave the Y Axis alone

### **Legend Tab**

- √ Leave the Show Legend button clicked
  
- √ Right click the first photometer's series in the chart
- √ Click Format Series
- √ Change the line color to the color of the photometer or use a line style
- √ Repeat the above steps for each series in the chart, changing the lines to something that is meaningful or easier to distinguish

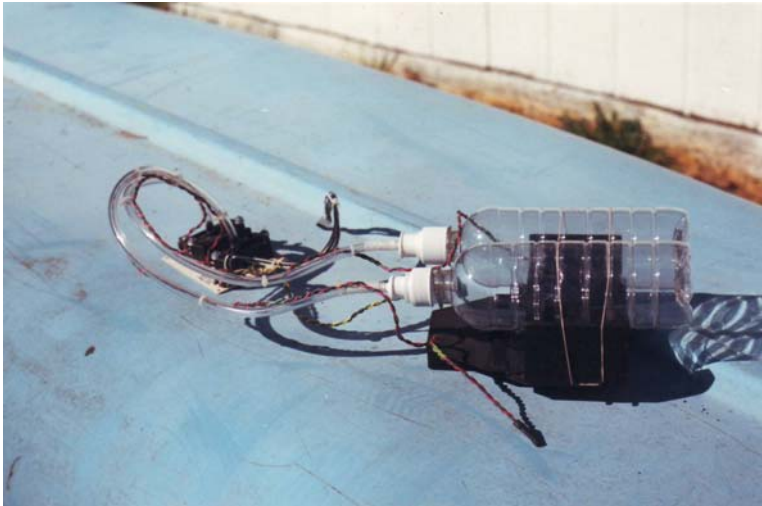
## **7.0 Simple Near Space Life Sciences**

There are several life science experiments that can be performed in near space. I'm a physical sciences kind of nerd who isn't into studying stuff that crawls around (unless it's protozoans under a microscope). Nonetheless, some of my flights have carried life sciences experiments. In this section

I describe three of them. The first experiment involves sending Roachonauts on near space missions. The remaining two biology experiments involve bacteria and plant seeds.

## 7.1 Roachonauts

Experiments can determine the effects of near space exposure on animals. However, it is strongly encouraged that you only use insects as your animal subjects. Ethical considerations should prevent most amateurs from carrying out experiments on large animals or even treating insects needlessly cruelly. When you consider the public response, cockroaches make good test subjects. If they are to make the ultimate sacrifice in the name of amateur science, then no one is going to be upset (unless there are Cockroach Huggers out there that I'm not aware of).



***Near Space Roach Motel - Two 20-oz water bottles connected to pressure and temperature sensors. It's a shame it got lost.***

### 7.1.1 Theory of Operation

The primary environmental conditions affecting cockroaches during a near space flight are cold air temperatures and low air pressure. From personal experience I can tell you that a flight to 84,000 feet does in a cockroach. I suspect it was the lack of air that did them in, but I don't have the complete answer at this time.

### 7.1.2 Materials

- Roachonaut near space habitat (20 ounce plastic pop bottle)
- Pressure monitoring system
- Temperature control and monitoring system
- Roachonaut vital sign monitoring system
- Control subjects
- ½ inch thick Styrofoam
- Hot glue
- Teflon tape
- Rubber bands
- Dowels
- Long and narrow balloon

To make the experiment a challenge, try designing a roach near space habitat that keeps the roaches alive in near space. A 20 ounce plastic pop bottle should be capable of retaining air pressure for the flight (I won't tell you my results).

My last near space habitat used a 140PC pressure transducer to monitor pressure inside the habitat. Unfortunately that capsule was lost when the flight batteries prematurely died, so I haven't continued my habitat experiments. If you do not have access to a pressure transducer that can be integrated into the habitat, then I suggest placing a small, sealed, balloon inside the habitat to monitor for air leaks. If the habitat is not air tight, then the expanding diameter of the balloon will indicate this. Directions for monitoring internal air pressure are given in the next subsection.

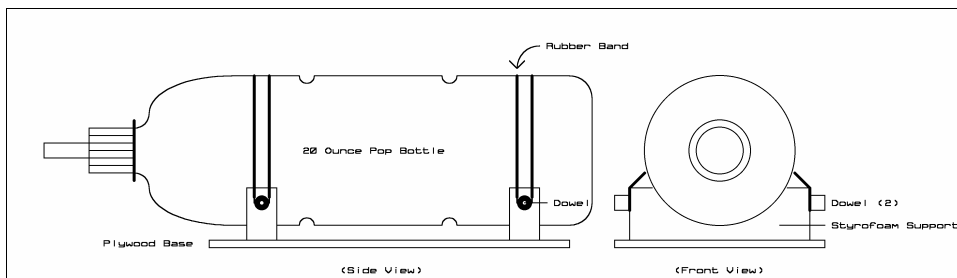
Try covering habitats with different types of insulation to monitor the effects of near space temperatures on the crew. A second habitat can be left uninsulated for a comparison. Use the temperature sensor array or Thermochron in Section 9.0 to monitor the temperature inside of habitats.

It's a good idea to monitor the vital signs of the crew during the mission. This way the lethal environmental conditions can be determined and avoided in the future. One way to monitor their life signs is with a camcorder. Roaches like to move around. When they stop moving around, the mission elapsed time, as determined from the videotape, is used to determine the lethal environmental conditions. A still camera can also serve as a means of monitoring vital signs, but without the precision of the videotape.

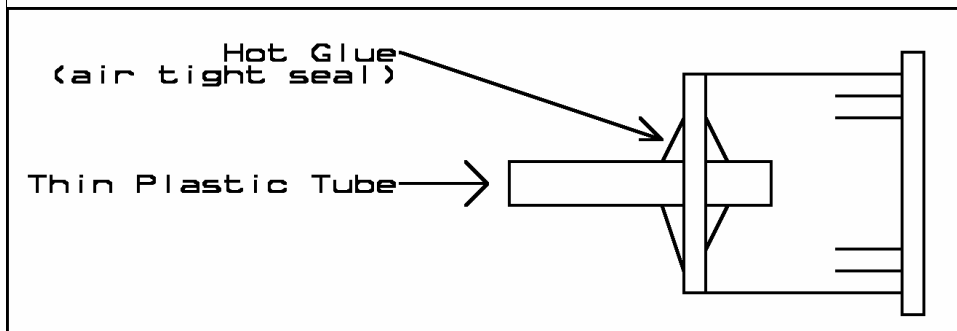
Remember your experimental controls. The crew making the trip into near space must be compared to the controls left on the ground. In addition, just as there are variations in the physical attributes of humans, there are no doubt the same types of variations in roaches. Send up several roaches in each habitat, just to make sure it isn't the above average roach that successfully completes its mission into near space.

### 7.1.3 Procedure

- ✓ Empty the contents of a few plastic 20 ounce pop bottles and keep their caps
- ✓ Thoroughly clean and dry the pop bottles and caps
- ✓ Decide on the number of habitats to launch on a single mission
- ✓ Build a habitat frame as illustrated below



**The Roach Habitat** - The bottle is held in place with a few rubber bands.



**Cap Detail** - A thin plastic tube lets air into the habitat.

Note: The habitat frame is constructed from ½ inch Styrofoam and glued together with hot glue. A pair of dowels passing through the sides of the habitat frame provides attachment points for the rubber bands that secure the habitats to the frame. They also provide attachment points for a second set of rubber bands that secure the habitat frame to a boom.

### Options For Monitoring Pressure

#### Option One, Monitoring With A Pressure Transducer

The internal air pressure of my first (and now lost) roach habitat was monitored with a 140PC transducer. Today I recommend the SM5812 pressure sensor. Please read subsection 3.3 for directions on constructing either of these transducers. As each pressure transducer is different, no dimensions are given below.

#### Materials

- Pressure Transducer
- Transducer PCB
- PVC hose with a diameter that fits the nipple on the pressure transducer
- Hot glue
- 20 ounce plastic pop bottle
- Thick walled plastic styrene tubing with a diameter large enough to fit inside the PVC hose

#### Procedure

- √ Cut a length of PVC hose long enough to reach between the cap of a bottle and a pressure transducer
- √ Purchase a plastic tube with the proper diameter to fit the PVC hose and cut it to a length of about two inches
- √ Drill a small hole in the lid of the pop bottle to fit the plastic tube
- √ Center the tubing into the hole in the cap and glue the tubing into place with hot glue  
Note: Squirt the hot glue on the inside surface of the cap, making sure not to put glue over the threads in the cap
- √ Slide one end of the PVC tubing over the cap fitting after the glue cools
- √ Slide the other end of the PVC tubing over the fitting of the pressure transducer
- √ Place the crew inside the habitat and seal it  
Note: The pressure transducer's output is connected to the flight computer's ADC and monitored during the mission.

#### Option Two, Balloon

- √ Put just enough air into a long, narrow balloon to remove the wrinkles and seal it
- √ Tie off the balloon to a length of one inch
- √ Cut away the excess balloon, leaving a thin, one-inch long balloon
- √ Place the small balloon inside the habitat
- √ Place the crew into the habitat and seal it  
Note: Record the balloon during the flight, either with video or photographs. Air pressure in the habitat is monitored by observing changes in the balloon's diameter.

### Options For Monitoring Temperature

#### Option One, LM335 From Temperature Sensor Array In The Habitat Cap

- √ Ensure the cable length of the temperature sensor array is long enough to reach the cap of a bottle
- √ Drill a 0.2-inch diameter hole in the lid of the pop bottle
- √ Slide the LM335 into the hole in the cap and glue it into place with hot glue  
Note: Squirt the hot glue on the inside surface of the cap, making sure not to put glue over the threads in the cap

- √ Leave the LM335 cable stationary until after the glue cools  
Note: I've not tested this process. It's critical to maintain an air-tight seal through the LM335 cable.

#### **Option Two, LM335 From Temperature Sensor Array On The Surface Of Habitat**

- √ Wrap two rubber bands around the habitat, each separated by about one-inch from each other
- √ Use rubber bands to hold the LM335 cable against the habitat  
Note: This is the method I used in my last habitats.

#### **Option Three, Thermochron**

- √ Place a programmed Thermochron inside the habitat before a mission

#### **Insulation Options**

On the second to last flight my habitat made, I detected a difference in internal temperature of the habitat based on the type of materials in which the habitat was covered. Use rubber bands to hold various combinations of insulation around the outside of the habitat.

### **7.1.4 Roachonaut Training**

Fortunately roaches need no elaborate or expensive training before their near space mission.

- √ Create control and experimental groups for each flight
- √ Examples of control and experimental groups include
  - Leaving a crew of roaches on the ground
  - Using different forms of insulation on cabins
  - Using different UV blockers on the cabin walls
  - Placing a cabin inside the airframe and one outside the airframe
- √ Label each cabin and record each cabin's initial condition
- √ If possible, place roach cabins in front of camcorders or cameras
- √ Record the response of roaches during their mission
- √ Retrieve the cabins after the flight and record the responses of the roaches
- √ Replace cabin caps with caps with air holes
- √ Let someone raise the roaches and observe any long term effects
- √ Fly roaches on multiple flights

One last note about using roaches as near space test subjects. Refer to these passengers as roachonauts. The news media appears to just love this. The name Roachonauts attracts the attention of the local television or radio station to your near space program.

## **7.2 Bacteria**

Another life science experiment involves bacteria and yeast exposures in near space.

### **7.2.1 Theory Of Operation**

Bacteria make a great experiment subject. Not only are there neat procedures to follow to prepare them before flight, there are also neat procedures to follow after the mission. Experimenting with bacteria involves equipment you wouldn't be exposed to performing physical science type experiments. Bacterial tests is a complementary way to incorporate other science minded individuals into a near space program.

### **7.2.2 Materials**

- Petri dishes and agar<sup>E</sup>



- A one cup measuring cup
- Metal tongs
- Eye protection
- Rubber gloves
- Bleach
- Clean wash cloth
- Cotton swabs

### 7.2.3 Procedure

There are several steps to complete when preparing near space bacteria experiments.

- √ Sterilize all the equipment and surfaces
- √ Sterilize the Petri dishes and keep them sterile
- √ Make and pour agar
- √ Inoculate the agar (pre-launch or during the mission)
- √ Culture the results of the mission
- √ Finally, when the experiment is complete, all equipment must be sterilized (did you ever see the movie, *The Andromeda Strain?*).

The procedure for preparing Petri dishes is written up in blocks, but there is not reason agar couldn't be prepared while the Petri dishes are being sterilized. In fact, that may limit the amount of contamination by reducing the time the Petri dishes must wait to be poured.

Most of this information was found on the web at websites like Science-Projects, MadSci Network, and Newton.

The Treasure Valley Near Space Program prepared Petri dishes in a kitchen. So a super-sterile laboratory is not needed to work with bacteria cultures.

#### **Make Conditions Sterile**

- √ Find a counter to work on
- √ Mix up a bleach solution (we used about half water and half bleach)
- √ Wipe the counter surface down with bleach
- √ Keep a cup of bleach solution handy

#### **Sterilizing Petri Dishes**

Note: Petri dish tops are the larger than the bottoms. When properly closed, the overhang of the top keeps airborne bacteria from falling into the agar inside the Petri dish.

Note: To limit the possibility of contamination, do not talk while sterilizing petri dishes

- √ Boil a pot of water
- √ Dip the tongs into bleach solution or boiling water (we did both)
- √ Grab a petri dish lid with the tongs
- √ Dip the lid in boiling water

Note: Do not keep the petri dishes immersed in boiling water for long as the hot water will soften and deform them.



***Sterilizing Petri Dishes - A quick dip in boiling water does the trick. Do not soak the dishes for long or they will soften and deform.***

[photo of dipping dishes]

- √ Quickly place petri dish lid on the sterilized surface, with the open face, down  
Note: This keeps falling bacteria from contaminating the interior of the petri dish.
- √ Immerse the petri dish bottom, next
- √ Place the dish bottom on the counter surface and quickly put the lid on top of the bottom
- √ Repeat the above procedure for the remaining petri dishes

### **Making Agar**

Agar is derived from seaweed and appears to the eye as a light-brown colored gelatin. Agar comes in a dry powder form that must be dissolved in water and unless the water is very hot, the agar doesn't dissolve. At this point it is not important that the agar is not sterile because it will be made sterile when dissolving it in boiling water. Some agar comes with directions on preparing it. Read them before beginning.

- √ Boil water in a pot
- √ Pour a cup of boiling water into a glass measuring cup
- √ Pour the powdered agar into the measuring cup
- √ Dip a stirring spoon in boiling water
- √ Stir to dissolve the agar  
Note: TVNSP experienced some difficulty dissolving the agar, so we microwaved the measuring cup. Other than some frothing, it worked well.



*Mixing Powdered Agar - John Knapp gets ready to microwave the agar. Be careful that it doesn't boil into a froth. You can also use a stove to heat the water.*

### **Pouring Agar Into Sterile Petri Dishes**

(<http://science-projects.com/PlatePouring.htm>)

Note: At this point, the petri dishes are sterilized and sitting on top of the bleached counter. The dish bottoms are face up and the lids on top.

- √ Have a closed and sterile petri dish and hot liquid agar at the ready
- √ Lift one end of the petri dish lid with sterilized tongs  
Note, do not turn it over where falling bacteria can land on the inside surface of the lid
- √ Pour enough liquid agar to fill the petri dish 1/3rd full
- √ Immediately close the petri dish lid
- √ Repeat these steps for any other petri dishes (you should have one control)
- √ Before the agar can solidify, rinse it out of the bottle with hot water
- √ Do not flip the petri dishes upside down as this lets dust settle in the gap between the dish and cover



*Pouring Agar - Quickly lift the lid of the sterile petri dish and pour the hot, liquid agar.*

### **Avoiding Condensation**

As the agar cools, water vapor in the agar condenses on the petri dish lids. This can be prevented or corrected after it happens; it's up to you.

### Condensation Prevention

(<http://www.fungifun.com/agar/>)

- ✓ Stack the warm petri dishes on top of each other
- ✓ Place a warm mug of water on top of the top petri dish
- ✓ Let the petri dishes cool

Note: This method worked well for TVNSP.



*A stack of petri dishes cooling-  
A mug of hot water on top of the  
dishes reduces the condensation  
inside the petri dishes.*

### Condensation Correction

(<http://science-projects.com/PlateDrying.htm>)

- ✓ Wipe the counter top with a damp paper cloth (with bleach?)
- ✓ Lay out a length of paper towels, with the inside surface of the towels face up (do not handle the towels except by their edges)
- ✓ Lay a pencil down at one end of the towels
- ✓ Quickly open the first petri dish and keep the interior surfaces of the top and bottom face down
- ✓ Lay the first half of the dish on the paper towel with one end propped up on the pencil
- ✓ Lay the other half of the petri dish on the paper towel with one end propped up on the back of the first petri dish half
- ✓ Repeat this process for the rest of the petri dishes, with each half propped up on the back of the previous petri dish half
- ✓ Let the petri dishes dry for about two hours, until the condensation is gone
- ✓ Quickly pick up the petri dishes, one by one, and close them

### Storing Poured Agar

Prepared petri dishes can be stored in the refrigerator with the lid side on the top and the agar layer on the bottom. Do not flip the prepared petri dishes upside down when storing them. Flipping them upside down exposes the opened edge to falling bacteria. A layer of condensation will develop on the lids after being stored in the refrigerator and must be removed without contaminating the agar with unintended bacteria. Follow the procedure outlined above in Condensation Correction to dry the plates properly.

At this point, the petri dish can be flown. Either inoculate them before flight for exposure tests or inoculate them during the flight looking for bacteria and fungi in near space.

### Source of Bacteria

Do not use bacteria from the garden, as there are a number of dangerous bacteria and fungi (pathogens) in soil. A safer source of bacteria is the bacteria in your mouth. However, do not get mouth bacteria into your eyes.

- √ Wipe the inside of your cheek with a clean cotton swab
- √ Lift one edge of a petri dish lid high enough to insert the cotton swab  
Note: Do not open the petri dish completely, leave the lid in place to prevent falling bacteria from landing on the agar.
- √ Wipe the damp swab across one half of the prepared petri dish
- √ Wipe the other half of the petri dish with a clean and dry swab as a control
- √ Close the petri dish
- √ Repeat this process for the control petri dish
- √ Incubate the petri dishes for a few days before their flight

#### 7.2.4 Using Bacteria

Use bacteria cultures on near space missions as soon as possible and do not let the agar dry out.

- √ Photograph the petri dishes shortly before their flight (you want good lighting)
- √ Tape petri dish lids to petri bottoms with a little masking tape  
Note: Transparent tape is too difficult to remove from plastic petri dishes.
- √ Apply strips of Velcro to the bottoms of petri dishes
- √ Create control and experiment groups for each flight
- √ Examples of control and experimental groups include
  - Petri dishes left on the ground and others sent on a mission
  - Include some sterile petri dishes on ground and near space samples  
Note: This is to test for contamination before launch
  - Petri dishes inside and outside the airframe
  - Petri dishes covered in different types of thermal insulation
  - Petri dishes covered in different UV blockers
- √ Label and record petri dish conditions
- √ Stick the petri dishes to Velcro patches on the airframe hatch  
Note: Placing the petri dish on top of the airframe accomplishes two things. First, it increases the exposure of the petri dish to solar UV and second, it limits the petri dish's exposure to the ground upon landing.



*Petri Dish - Agar-filled petri dish velcroed to the top of a module hatch.*

- ✓ Retrieve the petri dishes after the flight and record their condition with a camera
- ✓ Incubate petri dishes and observe bacteria growths
- ✓ Test bacteria for mutations

### **Incubating Petri Dishes**

(<http://www.madsci.org/posts/archives/mar99/920820551.Mi.r.html>)

- ✓ Place petri dishes underneath a gooseneck lamp
- ✓ Place a thermometer next to the petri dish(es)
- ✓ Turn on the lamp and monitor the temperature of the thermometer.
- ✓ Adjust the lamp so that the temperature is no higher than body temperature (around 100 degrees F or 37 degrees C)

### **Looking For Mutations**

Look for variations in the growing colonies

- Are their colors different?
- Are their shape and forms (morphology) different?
- Do they respond to antibiotics differently after the flight?<sup>F</sup>

### **ReFlying Bacteria**

If there are no apparent changes in the bacteria, perhaps the exposure wasn't long enough. And as we all know, more flights into near space must be flown, therefore finding future experiments is a must. Old petri dishes can be flown over again, or a sample of bacteria can be moved to a new petri dish and flown again. I'm in favor of moving bacteria samples to a new petri dish for two reasons. First this allows you to sample a single colony of bacteria and second, it's a more technical task. I apologize for forgetting where I got these directions. Someone deserves credit for these directions.

### **Materials**

- petri dishes
- Agar
- #20 AWG solid wire
- Propane torch and stand
- Pliers

### Procedure

- √ Sterilize petri dishes
- √ Make a new batch of agar
- √ Fill petri dishes with agar
- √ Let agar cool and set
- √ Cut about six inches of wire
- √ Strip off the insulation from the wire
- √ Bend one end of the bare wire into a small loop, about 1/8 inches in diameter
- √ Clean a counter top and lay down a length of paper towels (place the inside surface of the towels face up and handle the towels by their edges only)
- √ Place a sterile petri dish and a previous petri dish on the towels and ready to be opened
- √ Grab the wire by the unlooped end with pliers
- √ Start the propane torch
- √ Place the wire loop in the propane torch flame until the loop is red hot (aren't you glad you're holding the wire with a pair of pliers?)

Quickly open the previously flown petri and perform the next tasks

- √ Place the hot loop of wire into agar on the previously flown petri dish to cool
- √ Immediately wipe the cooled loop across a bacteria colony
- √ Close the petri dish and open the new petri dish
- √ Inoculate the new petri dish with bacteria by wiping the surface of the agar with the wire loop
- √ Quickly close the petri dish and label it
  
- √ Let the petri dish incubate to be sure it was inoculated
- √ Photograph the petri dish before and after the flight
- √ Fly the petri dish on the next available near space flight

### Recording Results

- √ Make a photographic record of the bacteria controls and experimental group after the flight
- √ Another really excellent option is to use the Intel Play QX3+ Computer Microscope. This microscope is designed to connect to the USB port of a PC and record images on the PC. Images up to 200 magnification can be captured on the PC and shared.



*Intel QX-3 Digital Microscope -  
An easy way to record microscopic  
images on a PC.*

### **Sterilizing Experiments**

Ideally you will use an autoclave. However very few of use have one in our kitchen where we design and build most of our near space program. Pour bleach into the petri dish to sterilize it before disposing of it in the trash.

## **7.3 Seeds In Near Space**

Planting seeds is an experiment/activity that interests young children. Aside from planting the traditional flowers, you can help young children act as scientists by planting seeds that have been exposed to near space. Having the students germinate seeds from the plants and sending those up next year can carry the experiment even further. Year after year, new generations of plant seeds can be sent into near space.

### **7.3.1 Theory of Operation**

Seeds have evolved to be tough. Near space is one way to test them in an entirely new environment. By flying seeds into near space over several missions the ability of seeds to survive space travel can be tested by elementary school students. Planting seeds and watching the resulting plants grow is a science activity we probably did in our younger days. Near space tests seeds to the following conditions: near vacuum, extreme cold, ultraviolet radiation, and to an increase in cosmic radiation.

Seeds In Near Space is an activity geared towards elementary school students. Students are exposed to following procedures: data collecting, basic math skills like addition and division, graphing, and



long range planning for future experiments. Together they add up to an exposure to the scientific method and a review of basic life skills.

Elementary students cannot design and launch a near spacecraft, but with your help they can design and fly their own experiment. Pass the word; let teachers know your program exists. Be prepared to present on your program and inform them of the necessary procedures. Finally, develop a Mission Control for students who want to see their experiment fly. Feel free to print the Seeds in Space section, located at the end of this chapter, as a handout for elementary students.

### 7.3.2 Notes For Teachers

Get a couple of flights under your belt before working with a class. When you fly their experiment, make sure a backup tracker is a part of the stack. There's nothing that will stop future flights like losing a near spacecraft and its experiment. It's fine to invite students to attend the launch and chase, but do not let students get involved with the launch, chase, and recovery unless a parent goes along. The only person who should be responsible for a student is their parent. Keep students back to avoid their accidentally getting hurt on a load line, etc. Most families will not be hams, so be prepared to use FRS radios or CBs. Keep them informed on what is going on. There's almost nothing as frustrating as chasing in a caravan and not knowing what is going on.

Work with teachers early in the school year. We teachers develop lesson plans for the entire year. The longer a teacher has been teaching, the more refined and detailed the plans. Starting early gives the teacher more time to work the flight into their classroom. You should visit with the class. Bring flight articles to the classroom so students can see what they are getting involved with. Also bring videos or still pictures to show. Some students will be very interested, to the point in fact where they may monopolize your time in class. Don't be surprised to find some students who couldn't care less. Don't focus your efforts on getting their interest at the expense of the other students. As long as they are not disrupting your presentation, let the teacher handle them.

Give the students an opportunity to test fit their experiment. Do not let them load the experiment for the first time at the morning of the launch. You may have to have the students load their experiment a day or two before the launch. Asking young students (and parents) to attend a launch so early in the morning, on a Saturday, no less, may not attract their interest. If possible, place the seeds where they can be photographed during the flight. Giving the Principal Investigators (students in this case) a photograph of their seed experiment with the Earth's curved horizon and the black of space in the background will impress them. In any case, photograph the experiment on the near spacecraft at the launch site. Give the students a copy of the photographs taken by ground crews.

Recover and protect the seeds after the flight, making sure they are not left to cook inside the car while your recovery crews enjoys their post-flight lunch. Return the seeds to the students unopened; let them open the test tubes. Students will plant the seeds after the flight. Be sure students have labeled and documented everything. Labeling cannot be overstressed!

What if there is no significant difference between the control and the experimental seeds? Have the students germinate new seeds from the plants and safely store them for a later flight into near space. Multiple generations of seeds can be sent into near space giving a classroom a very long-term project.

Aside from the seeds, give the kids a cleaned up flight log. Let them pull the temperatures of their experiment out of the data along with time and altitude. These represent other graphing activities for the students. In addition, give the class a copy of the photographs taken during the flight. If the students are capable of handling the data, give them a log of the latitudes and longitudes of the flight

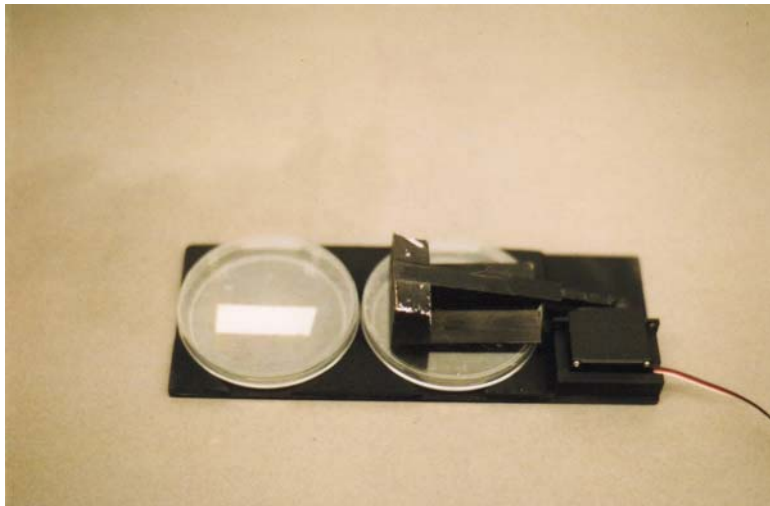
so that they can graph its flight path. If that's too much for them, give them a printed copy of the flight path and have them identify landmarks in the photographs.

## 8.0 Near Space Sampler

Are there bacteria or molds living in near space? Perhaps they're in spore form, waiting to fall on fertile ground. One way to find out is to send sterilized petri dishes into near space to sample them. Explorer I and II attempted this same experiment back in 1934 and 1935.

### 8.1 Theory Of Operation

It's very difficult for ground-based dust to climb into the stratosphere. However, high-energy events like volcanic eruptions and meteor impacts can raise dust into the stratosphere. Once in the stratosphere, dust tends to linger there for longer periods of time than it does in the troposphere, where the weather washes it out quickly. The same should apply to bacteria. Perhaps the stratosphere is very close to a sterile environment. Any microorganisms that did manage to get there for any significant length of time must contend with the increased UV flux. The collector experiment described here samples the near space environment, looking for signs of life in the stratosphere (okay, so it's not as exciting as searching for extraterrestrial life). The sampler consists of a servo-operated arm for an agar-filled and sterilized petri dish.



*Near Space Sampler – Two petri dishes on a base. The right petri dish's lid is opened by a servo-operated arm. The left petri dish is the control.*

When instructed by the flight computer, the servo rotates the sampling arm, opening the lid of the petri dish. Before the balloon bursts, the sampling arm closes the lid to protect the interior of the petri dish from contamination from talc and latex fragments from the balloon.

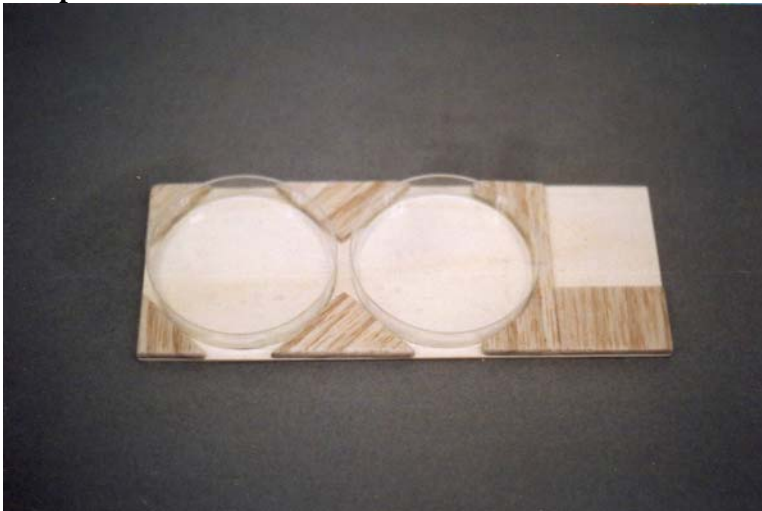
### 8.2 Materials

- Two non-sterile petri dishes<sup>G</sup>
- Sticky back Velcro
- Sheet of light plywood (1/8" thick)
- Sheet of light plywood (1/16" thick)
- Sheet of balsa (1/8" thick)
- Square plastic tube, thick walled, 1/4" by 1/4"
- 1/2" thick Styrofoam
- 1/4" by 1/2" basswood strip twelve inches long
- Parallax Standard Servo (P/N 900-00005) (Equivalent to Futaba S-148)

- Two servo-mounting screws
- Solid, #12 AWG wire
- Servo horn
- Epoxy
- Three lengths of #24 AWG stranded wire (different colors)<sup>H</sup>
- Thin heat shrink tubing to cover the #24 AWG wire

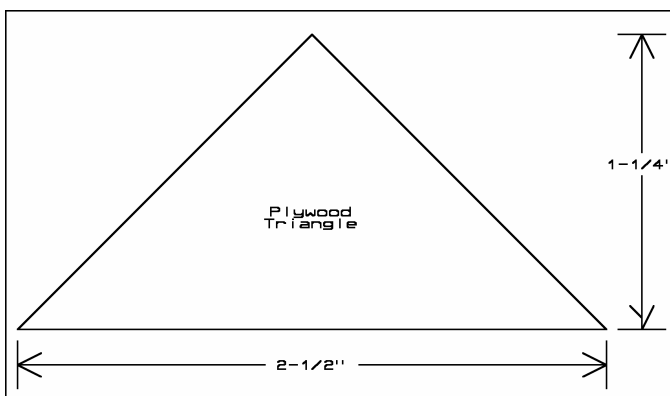
### 8.3 Procedure

#### Sampler Base



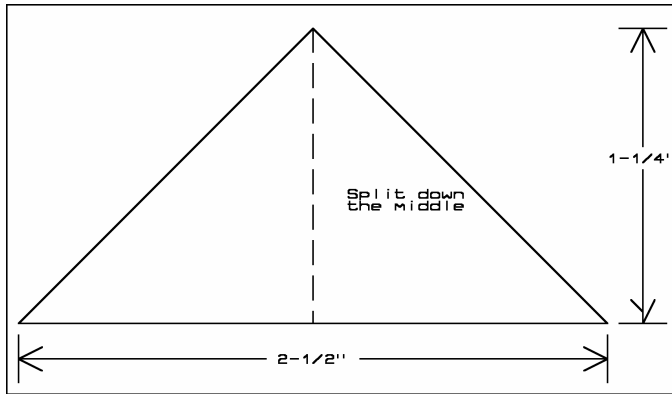
*Completed Sampler Base*

- Cut 1/8" thick light plywood to a size of 9-3/4" by 4" to form the sampler base
- Place two closed petri dishes side by side at one end of the plywood  
Note: One dish is the control and the other the experiment
- Draw circles around them, indicating their diameters
- The petri dish at the end is #2, the petri dish more centrally located is #1
- Cut four equilateral triangles of balsa wood to the dimensions illustrated below



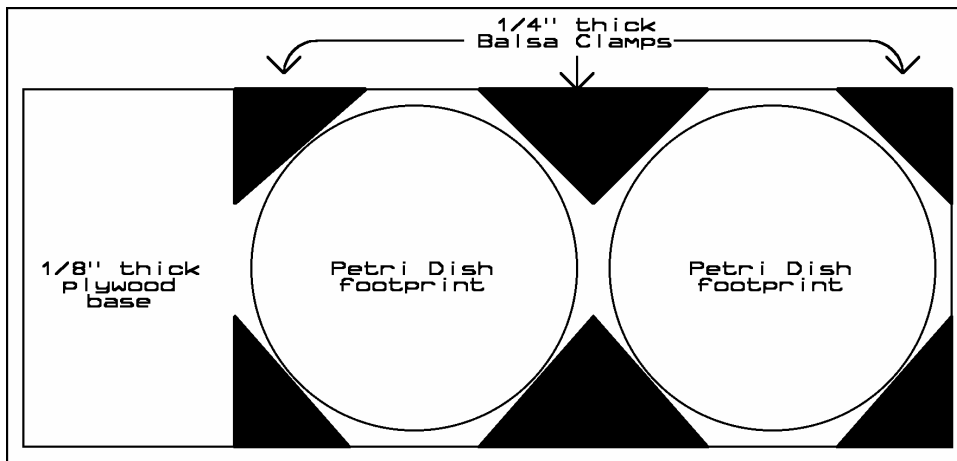
*Triangles - Cut four of these*

- √ Cut two of them in half, as illustrated in the diagram below.



*Split Triangle*

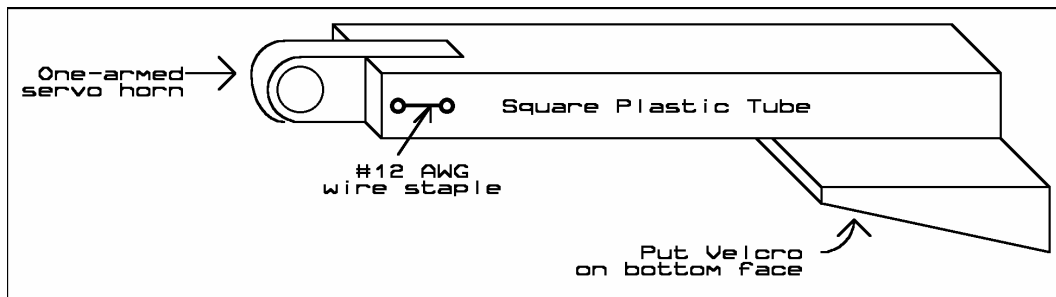
✓ Glue the triangles to the sampler base as illustrated to form “clamps” for the petri dishes



*Placing Triangles on Base – The triangles clamp the petri dishes in place*

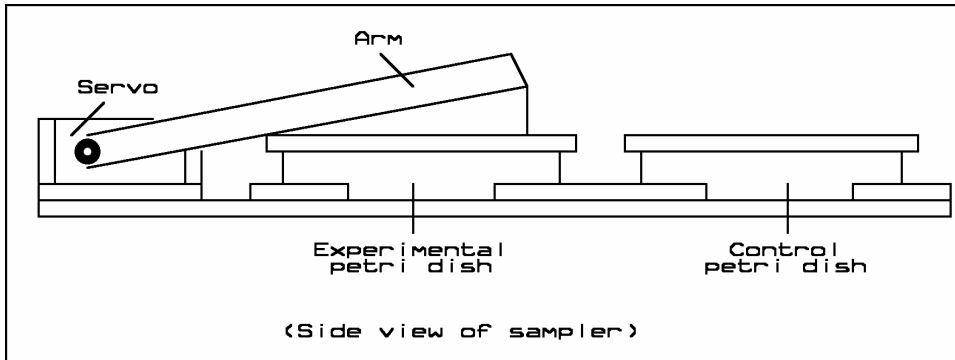
**Sampler Arm**

- ✓ Cut all but one arm off the servo horn
- ✓ Cut the thick walled square plastic tube to a length of 4-1/2"
- ✓ Carefully cut a 1/2" long slot into one end of the plastic tube  
Note: This slot is only wide enough for the servo horn to slide into
- ✓ Slide the servo horn arm into the slot and drill two small holes through the plastic tube and servo horn arm (make the holes only large enough for the #12 AWG wire)
- ✓ Strip the insulation from the #12 AWG wire
- ✓ Cut the wire into two 1" long pieces
- ✓ Bend the wires into “C” shaped staples
- ✓ Epoxy the servo horn into the plastic tube and pin in place with the staples



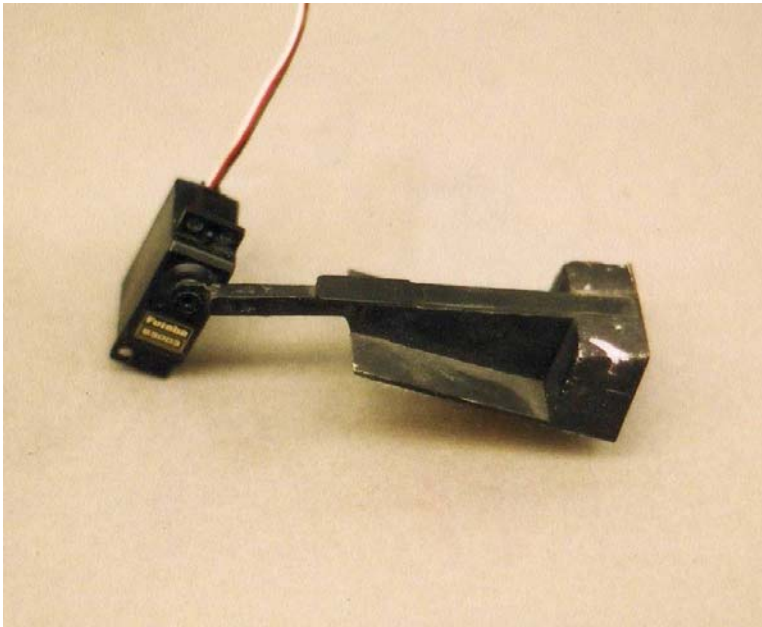
*Sampler Arm Diagram*

- √ Place servo horn and arm on servo, do not bolt at this time
- √ Cut a 2" by 3" rectangle from the 1/8" plywood
- √ Place #1 petri dish into its clamps
- √ Lay 2" by 3" plywood on top of #1 petri dish
- √ Cut a sheet of 1/8" balsa as large as the servo to raise it 1/8" higher  
Note: Raise the servo 1/8" to be sure petri lid clears dish when raised (you may find the raised servo is not necessary after trying to raise the dish lid)
- √ Place servo on sampler base, such that its arm rests on top of petri dish #1



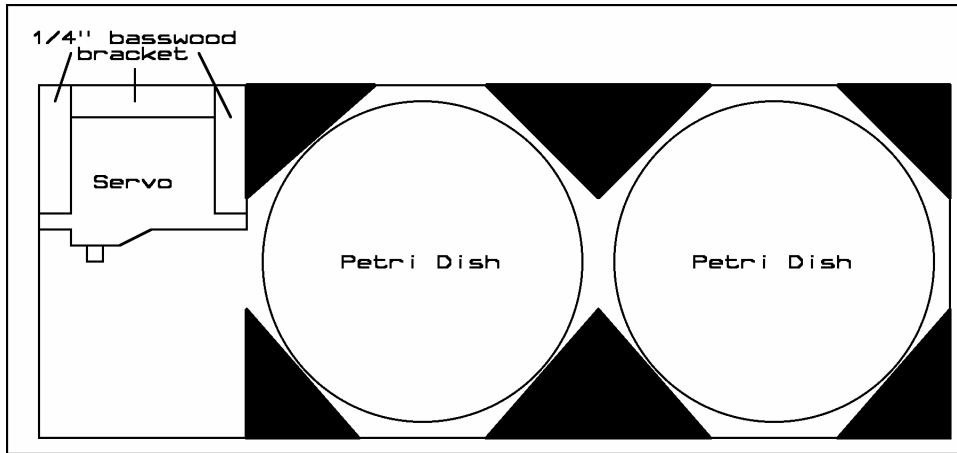
***Sampler Arm on Petri Dish – Side view of the sampler when it's complete***

- √ Cut Styrofoam to fill the gap between the sampler arm and the 2" by 3" rectangle
- √ Epoxy the Styrofoam into place so that 2" by 3" base is now a part of the arm



***Servo Arm with Servo - Note: I did some additional beefing up of my arm, but I do not think this is necessary***

- √ Leave Servo in place and cut the 1/2" by 1/4" wood to form a bracket for the servo

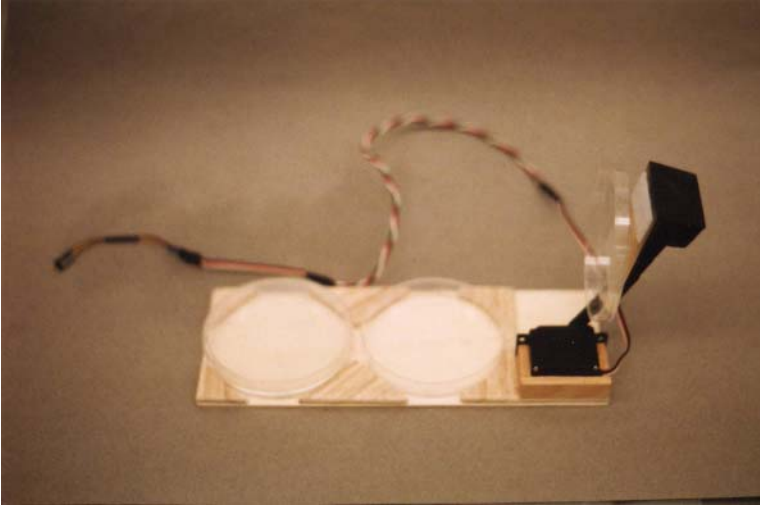


*Bracket  
Diagram - The  
wood forms a  
bracket for the  
servo*

- ✓ Trim the bracket to fit the servo cable
- ✓ Epoxy the bracket into place
- ✓ Drill one hole in each side of the bracket as pilot holes for the servo screws
- ✓ Bolt the servo into the bracket

### **Finishing Sampler**

- ✓ Remove the servo and petri dishes
- ✓ Remove the servo horn from the servo
- ✓ Cut two pieces of masking tape and tape them to the plywood base and inside the petri dish clamps
- ✓ Place a masking tape mask on the bottom surface of the 2" by 3" plywood rectangle  
Note: The tape prevents paint from getting on plywood base where the Velcro will later be placed
- ✓ Paint the top of the sampler black
- ✓ Paint the servo arm black
- ✓ Remove the tape and stick the Velcro into place, beneath the petri dishes  
Note: The petri dishes will get a strip of Velcro taped to their bottoms so they stick inside the sampler base
- ✓ Cut lengths of sticky back Velcro to position to the underside of the sampler base, making sure their positions line up with Velcro strips on the face of the near spacecraft hatch
- ✓ Cut sticky back Velcro and apply to the bottom of the 2" by 3" plywood rectangle  
Note: The lid of petri dish #1 gets a strip of sticky back Velcro to adhere it to the servo arm
- ✓ Attach the servo horn to the servo, but do not bolt it down at this time
- ✓ Rotate the servo to its mid position
- ✓ Remove the servo arm
- ✓ Bolt the servo back into the servo bracket
- ✓ Put the servo horn back onto the servo so that the mid position of servo leaves the petri dish #1 closed
- ✓ Bolt the arm into the servo



*Completed Arm, Lifting Petri Dish – The other petri dish is the control*

### Servo Cable Extension

Chances are the servo cable is far too short to reach from the top of the airframe to the CC/PS inside. So instead of purchasing a \$10 servo extension cable, modify the servo cable yourself with these directions.

- √ Cut the servo cable in half
- √ Strip ½” of insulation from the ends of both wires
- √ Cut three #24 AWG stranded wires to a length of 24 inches
- √ Strip ½” of insulation from both ends of all three wires
- √ Watching the colors of the wires, solder a wire extension to one end of the servo cable
- √ Slide heat shrink over the soldered joint and shrink
- √ Slide on a second set of heat shrink tubing on to the extension wires
- √ Solder the remaining ends of the extension wires to the remaining ends of the original servo cable (again, watch your colors and make the original cable match up)
- √ Slide heat shrink tubing over the soldered connection and shrink

## 8.4 Using The Sampler

### Controls/Calibration

- √ Test the flight code to ensure the Experimental petri dish is kept closed at the start of the flight
- √ Write the flight code to so that the Experimental petri dish is closed before the predicted burst

### Prep The Petri Dishes

Perform the following procedure a day or two before the launch

- √ Sterilize two petri dishes and filled them with agar (Section 7.2)
- √ Tape one lid to its petri dish (the control)
- √ Apply sticky Velcro to the top and bottom of the experimental petri dish to match the Sampler Base and Sampler Arm Velcro
- √ Apply masking tape to the Experimental petri dish (masking tape is easier to remove)
- √ Mark each petri dish with Experimental or Control (as appropriate)
- √ Store the petri dishes where they can't be contaminated

### **Flying The Experiment**

Perform the following procedure the morning of launch

- √ The morning of launch, mount the Control and Experimental petri dishes
- √ Press the Velcro of the Sampler Arm to the top of the Experimental petri dish
- √ Shortly before launch carefully remove the masking tape from the Experimental petri dish (don't accidentally open the petri dish on the ground)

### **Experiment Results**

- √ After recovery, tape both petri dishes shut before attempting to remove them from the near spacecraft
- √ Remove the petri dishes and store them so that they are not exposed to high temperatures  
Note: An ice cooler is a good location to store the petri dishes
- √ Once home, incubate the petri dishes for several days and observe for growths
- √ Compare colonies in the Control Petri dish (which wasn't opened) to colonies in the Experimental petri dish

Unless you have a way to identify bacteria, you'll have to be content with collecting bacterial spores. Perhaps a microbiologist would be willing to help you out. Be sure to record the colonies with a camera and a microscope (Intel QX3+).

## **9.0 Temperature Sensors**

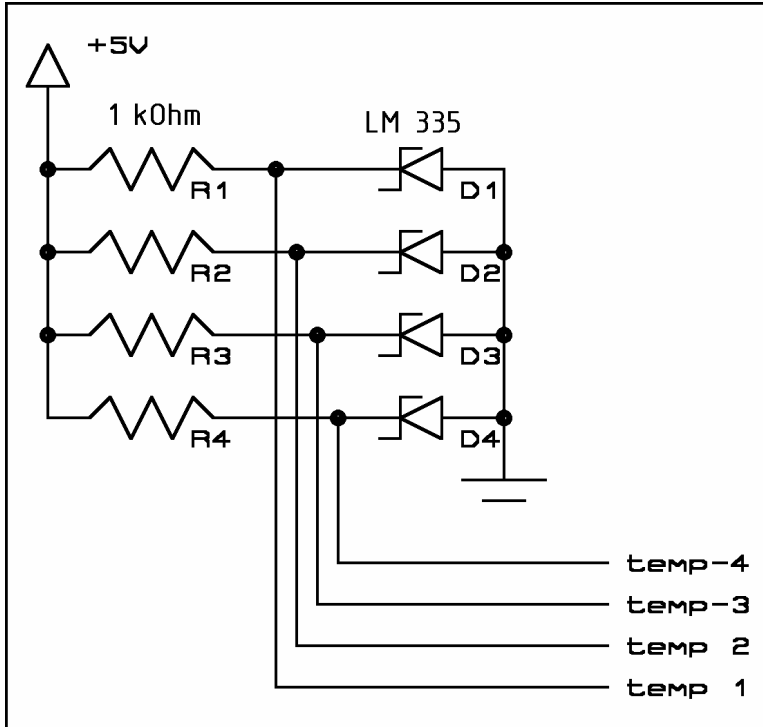
The two types of temperature sensors described in this section are the Temperature Sensor Array and Thermochrons. Along with describing the construction and use of temperature sensors, there is also a bit of discussion about the effects of the near vacuum of near space on measuring temperatures.

### **9.1 The Temperature Sensor Array**

There may be times when you want to measure multiple temperatures during a mission. In this case it's handy to have an array of sensors for this experiment. The temperature sensor array in this section uses four LM335 sensors attached to long cables. The LM335 cables allow you to position them anywhere as needed on the N/C. The array interfaces to any flight computer with ADC ports.

#### **9.1.1 Theory Of Operation**





**Temperature Sensor Array Schematic** – D1 through D4 are LM335 temperature-controlled zener diodes, R1 through R4 are 1k $\Omega$  resistors.

The LM335 is a temperature-controlled zener diode in a TO92 form factor. It has three leads, one for voltage, one for ground, and a one for adjustment. Zeners are wired in reverse polarity (as compared to a traditional diode like the 1N4001) and operate at voltages above their breakdown voltage. The voltage drop across a zener is fixed, even as the applied voltage is changed (for as long as the voltage is above the zener's breakdown voltage). In the case of the LM335, the breakdown voltage is dependent on its temperature. When the LM335's temperature changes by 1 K (kelvin), its breakdown voltage changes by 0.01 volts. So a voltage of 3.00 volts corresponds to a temperature of 300 k, or 27 degrees C, or 81 degrees F.

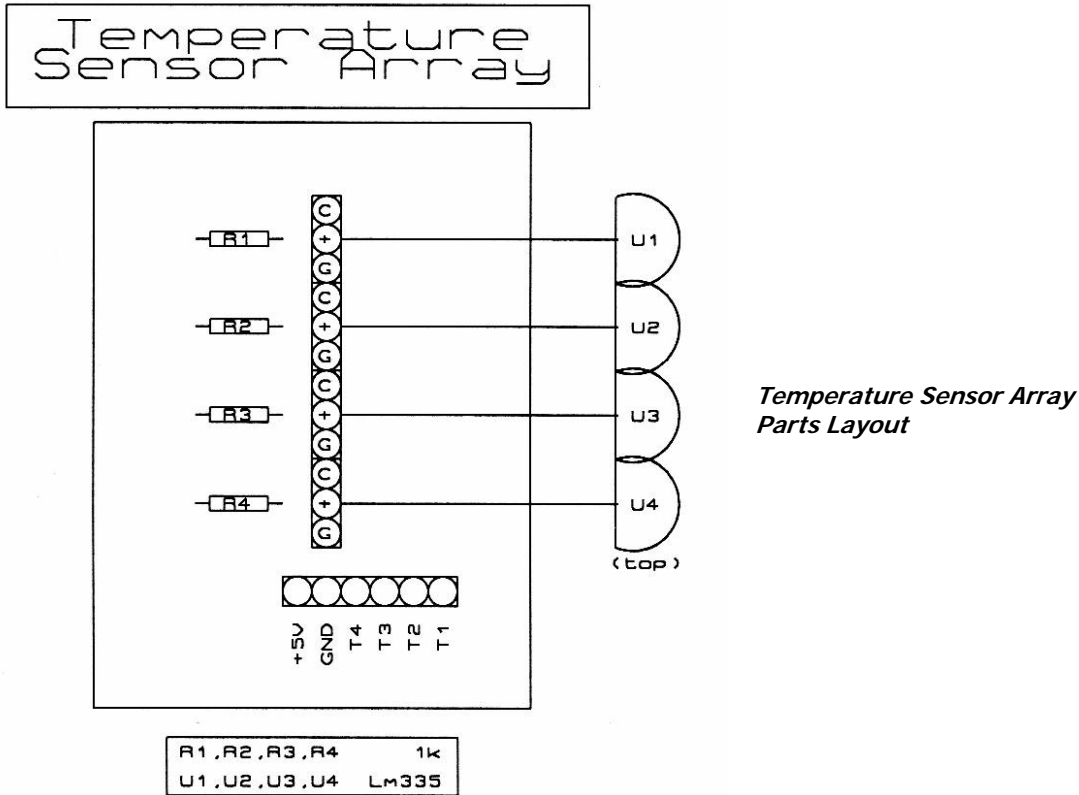
In the temperature sensor array, all three wires are connected to the LM335, but only two are used. The third lead is used to calibrate each LM335, but it's easier to do this calibration in software after the mission.

### 9.1.2 Materials

The temperature array requires the following components

- Four 1k resistors
- Four LM335 temperature controlled zener diodes
- Stranded, #24 AWG wire, three colors preferred (make one red and one black)
- Headers (and heat shrink) for connecting sensor to the flight computer
- ½" heat shrink tubing
- 3/32" heat shrink tubing
- Correplast
- Nylon wire zip ties

### 9.1.3 Procedure



Construction occurs in three phases: soldering the components to the PCB, making the interface cable, and making the sensor cables

### Discrete Components

- ✓ Bend the resistor leads to a length of 0.4 inches (use a lead bender)
- ✓ Solder the resistors to the PCB and cut the excess leads

### Interface Cable

The interface cable connects the PCB to the flight computer's ADC ports

- ✓ Cut six wires to a length of 12", make one of them black and one of them red
- ✓ Strip ¼" of insulation from the ends of the wires
- ✓ Solder the red wire to the +5V pad  
Note: This wire is connected to +5V on the ADC port
- ✓ Solder the black wire to the GND pad  
Note: This wire is connected to Ground on the ADC port
- ✓ Solder the remaining wires to the Signal pads (T1 to T4)  
Note: These wires are connected to four signals on the ADC port
- ✓ Slide several lengths of heat shrink tubing over all of the wires to form a harness
- ✓ Terminate the wires with the appropriate connectors for the flight computer's ADC port

Here are two examples

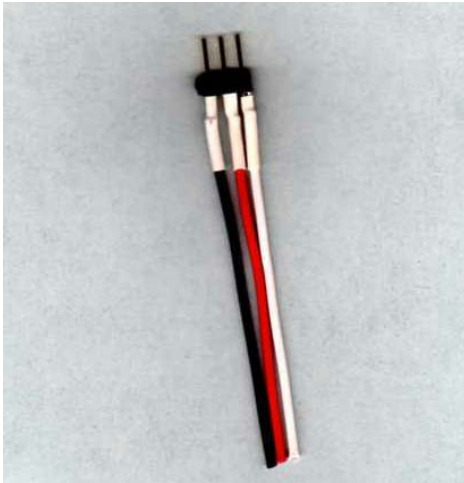
#### 1. Male headers on the interface cable and female receptacles on the ADC ports

- ✓ Slide thin heat shrink on each wire
- ✓ Solder wires to a male header, keeping track of the function of each pin in the header
- ✓ Slide the heat shrink over the soldered pins

## 2. Female receptacles on the interface cable and male headers on the ADC ports

- √ Crimp female crimp pins on each wire
- √ Solder the wires to the pins
- √ Insert pins into a 3 X 4 block, keeping track of the function of each pin in the header

Label the ADC connector so you can keep track of which cable is for which sensor  
Cover the label in clear heat shrink

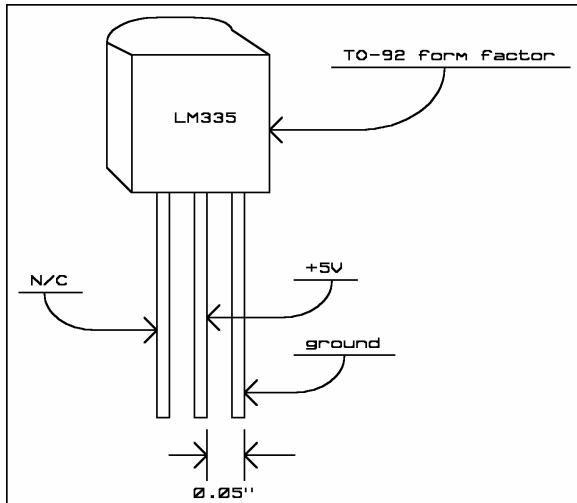


*ADC Connector – A nicely done heatshrink job*

### Sensor Cables

Sensor cables connect the LM335s to the PCB

- √ Cut four sets of three wires, each 24" long, make one of the wires red and one of the wires black
- √ Strip ¼" from one end of each wire
- √ Solder this end to the PCB
  - Note: The black wires are soldered to the G pads
  - The red wires are soldered to the + pads
  - The remaining four wires are connected to the C pads
- √ Cut the leads of the LM335s to a length of ½"
- √ Strip ½" of insulation from the free ends of the wires
- √ Slide several lengths of heat shrink over each bundle of three wires to form three harnesses
- √ Slide 1" lengths of heat shrink over each wire (cover the soldered LM335 leads)
- √ Tin the LM335 leads and the ends of each wire
- √ Solder the wires of each cable to the leads of the LM335s



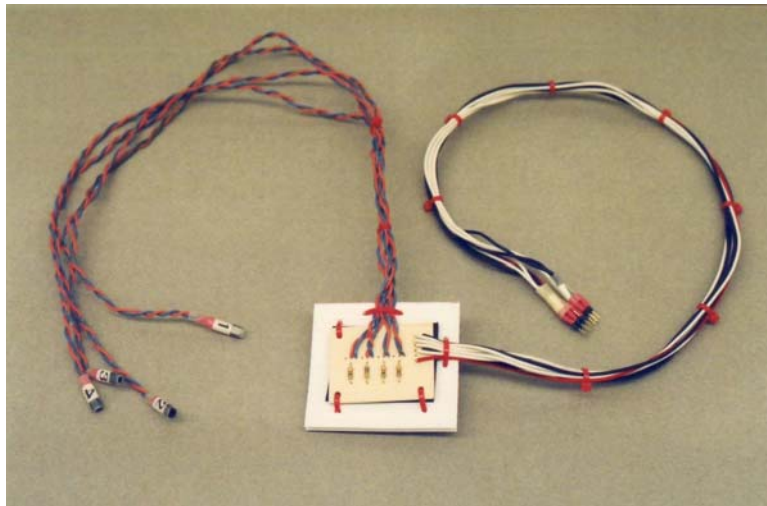
*LM335 Pin-out Diagram*

Note: The LM335s in the PCB diagram are illustrated as being viewed from the top  
Each black wire is soldered to the bottom lead (as illustrated) of the LM335s  
Each red wire is solder to the center lead of the LM335s  
The remaining wires are soldered to the top lead of the LM335s

- ✓ Cover each soldered lead with heat shrink
- ✓ Slide a 1" length of heat shrink over each LM335 and a portion of its harness

### Completing The Board

Cut correplast to size to mount the PCB and strain relief the temperature cables  
Punch holes in the correplast to nylon zip tie the PCB to the correplast  
Zip tie the sensor cables to the correplast



*The Completed Temperature Sensor Array*

### 9.1.4 Using The Temperature Sensor Array

Temperatures are determined by code to operate the ADCs. Before use, the temperature sensors need to be calibrated. Connect the array to the ADC and leave the sensors in an environment where they will be equal temperatures (keep them out of direct sunlight). Observe their final temperature. Either find the actual temperature with a trusted thermometer, or average the values from all the sensors.

Record the difference between the actual temperature and each temperature sensor. Record the difference and use it in spreadsheet to adjust temperatures of each sensor.

In a spreadsheet cell, use one of the following formulas to convert ADC values to temperatures (the formula assumes the ADC reading is in cell A1, adjust this cell address as needed).

**To convert to degrees Celsius**

$$(+A1/10)-273$$

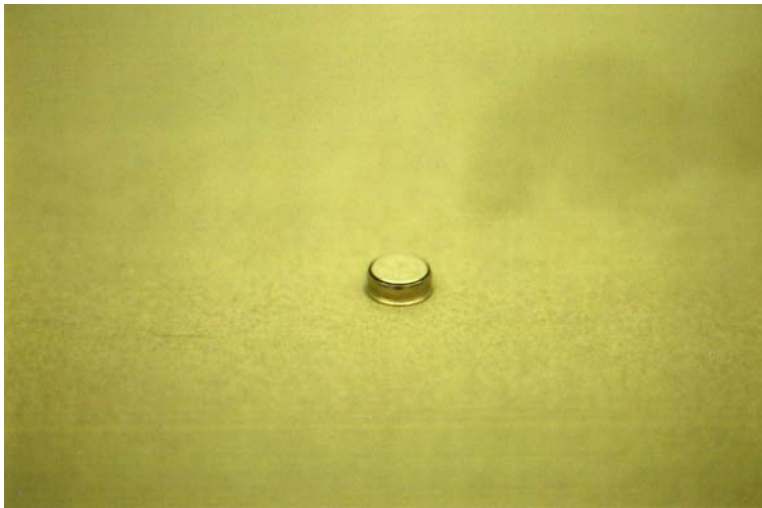
**To convert to degrees Fahrenheit**

$$(((+A1/10)-273)+40)*1.8)-40$$

## 9.2 Thermochrons

One of the neatest toys produced by Dallas Semiconductor is the Thermochron. As the name implies, they record both the time and temperature. The Thermochron is made of stainless steel and sealed from the elements. Each Thermochron is stamped with its own unique ID. To use a Thermochron, you program it before the mission (even days before the mission), place it into an experiment, and forget about it until after it is recovered. What could be simpler?

### 9.2.1 Theory Of Operation



*The Bare Thermochron - About the size of five stacked dimes, inside is a battery, temperature sensor, clock, and memory.*

According to Dallas (now a part of Maxim IC), each Thermochron contains a lithium battery capable of providing power to the device for ten years. Also inside the stainless steel shell is the silicon die for the clock, memory, and temperature sensor. The top face of the Thermochron is one contact for the one-wire network that communicates with iButtons. The sides and bottom of the Thermochron provides the ground contact (the ground connection is not counted as part of the network). The Thermochron communicates through the 1-Wire network connected to the serial port of your PC or laptop. The communications goes through the iButton reader you purchase with your first Thermochron. The Wizard function in the Reader software steps you through the programming process. After defining the mission, it is download to the Thermochron. After recovery, the data (basically time and temperature) from the Thermochron's mission is uploaded to the PC or laptop for displayed in iButton software or to be downloaded into a text file. There's a small amount of memory in the Thermochron for storing data, it's just like storing a file on a small floppy diskette. I have never used this option, but I imagine flight information could be stored there. The Thermochron records temperatures to a minimum of -40 degrees. So they are not appropriate for recording air

temperatures in near space. However they make excellent temperature sensors in other experiments or for locations inside an airframe.

### 9.2.2 Source For Thermochrons And Software

The website <http://www.ibutton.com> has all the information on ordering Thermochrons and other one wire devices. Contact Dallas-Maxim before ordering a Thermochron to be sure they are delivering them. The Reader software is a part of the iButton Reader. To receive a Reader, software, and Thermochron, order the introduction kit.

### 9.2.3 Programming The Thermochron



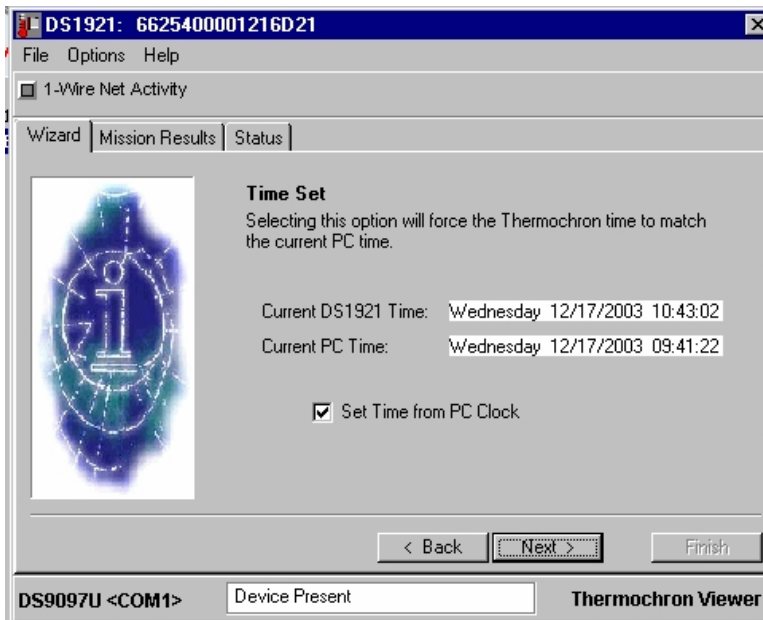
*Thermochron Being Programmed – The thermochron is in its reader, sitting on top of the PC.*

- √ Install the iButton Viewer (TMEX) software on a PC or laptop
- √ The night before a mission plug the Reader into a PC or laptop with the TMEX software (the FRR is an excellent time to do this)
- √ Start the PC or laptop and open the TMEX-iButton group
- √ Start the iButton Viewer
- √ Record the ID (the last four characters are usually is good enough since chances are that any two Thermochrons will not have the same last four digits in their ID) of the Thermochron if more than one flies
- √ Plug the Thermochron into the Reader  
Note: There are two iButton pads on the Reader, use either one. Two Thermochrons can be plugged into the Reader at the same time and you can select which one to program  
Note: If you press the Thermochron hard enough, it will snap into the Reader and you won't have to hold it in place



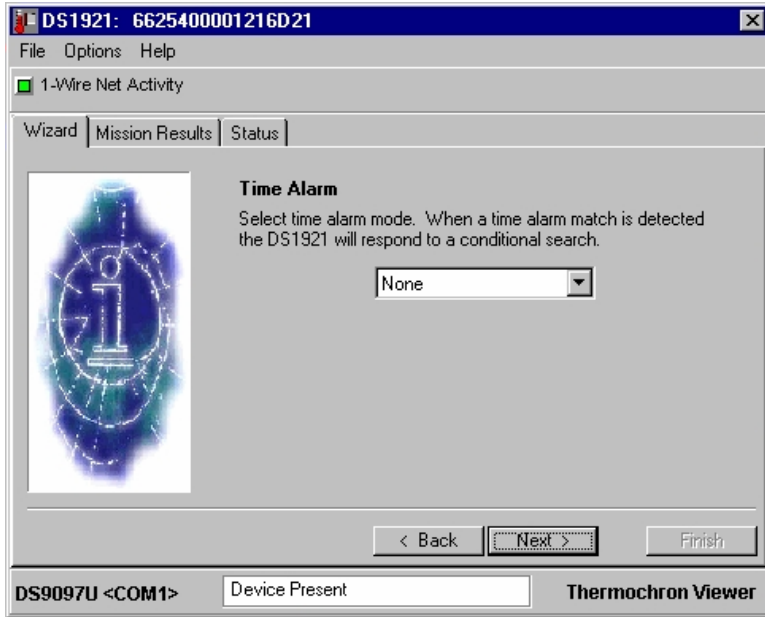
*A ThermoChron Kit - The reader cable plugs into a serial port. The thermoChron is the silver disk inside the plastic fob.*

- ✓ The iButton Viewer reads the iButton detected in the Reader and informs you that it cannot read the directory in the ThermoChron memory
- ✓ Skip the request to format the memory space in the ThermoChron, as you won't need it for a near space mission
- ✓ Close the next window
- ✓ Select the Wizard tab and click on the NEXT button



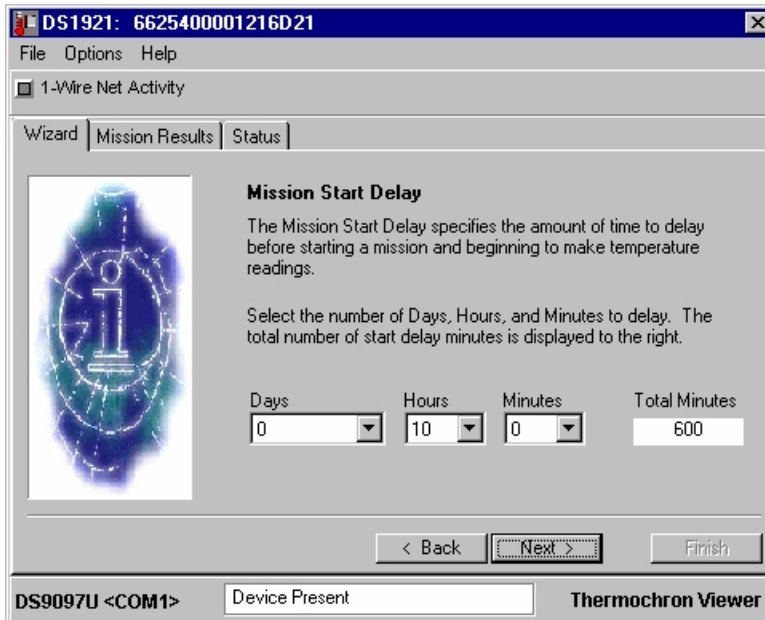
*Time Set*

- ✓ Confirm the time in the iButton, making sure it matches the time according to a GPS receiver as you'll need to compare the temperature to the time to accurately determine the altitude
- ✓ Set no Time Alarm (NONE)



*Time Alarm*

√ Set the Mission Start Delay in Days, Hours, and Minutes

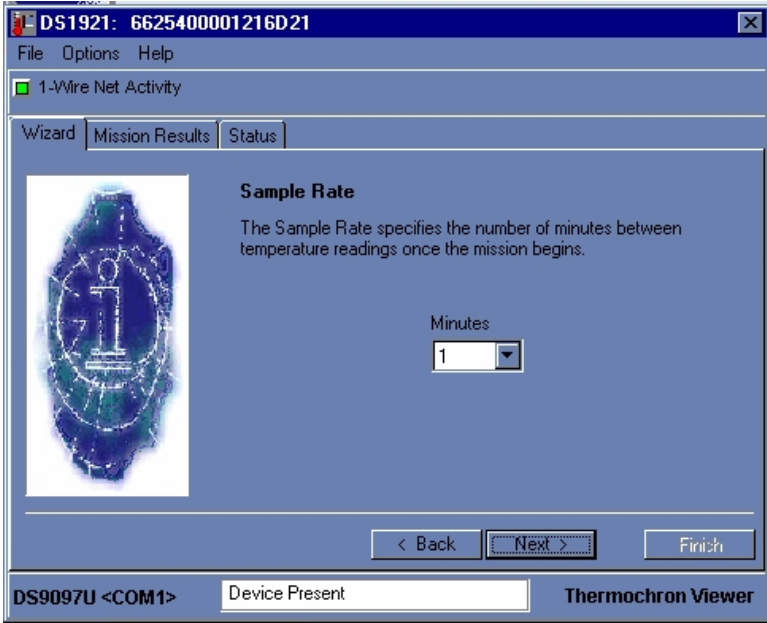


*Mission Start Delay*

Note: The ThermoChron does not start recording time and temperature until after the Mission Start Delay. Be sure to start recording data a little before the expected time of launch.

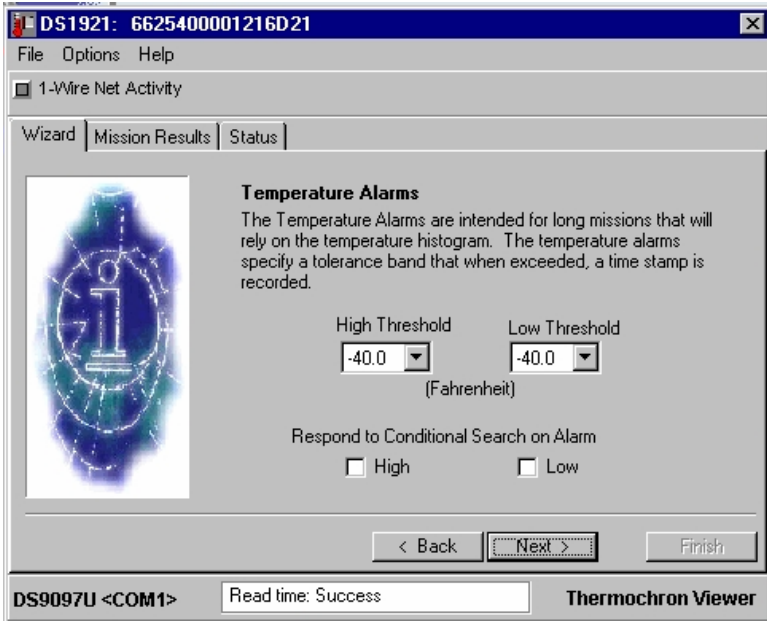
√ Select one minute for the Sample Rate



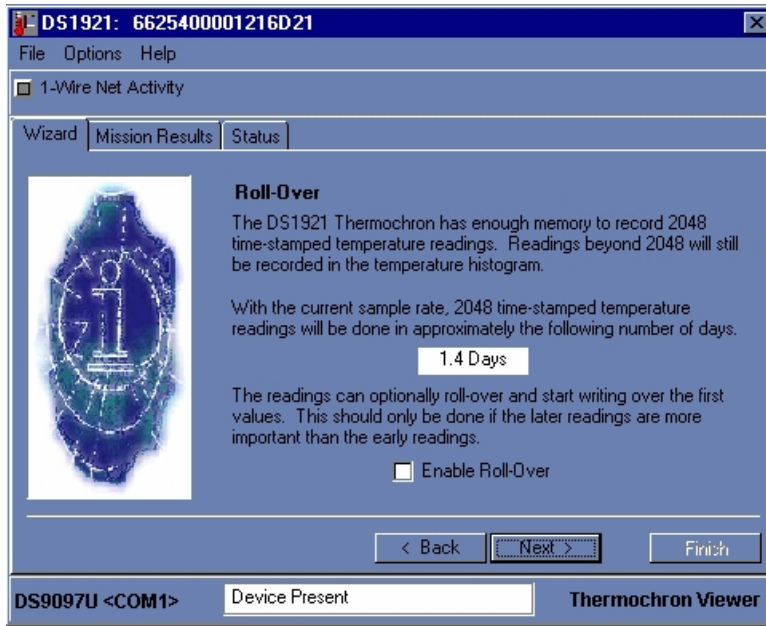


*Sample Rate*

- ✓ Skip setting a Temperature Alarm (if the temperature goes too low, you'll find out after the mission)
- ✓ DO NOT Enable Rollover



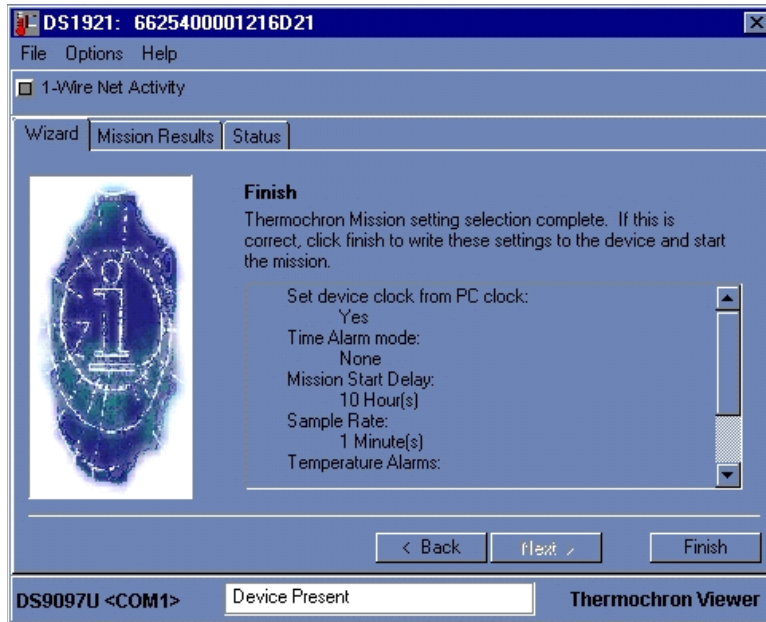
*Temperature Alarm*



*Roll-Over*

Note: By enabling rollover the ThermoChron will overwrite important science data should you be unable to recover the capsule within 1.4 days

✓ Click on the FINISH button to activate the ThermoChron



*Finish*

### 9.2.4 Using The ThermoChron

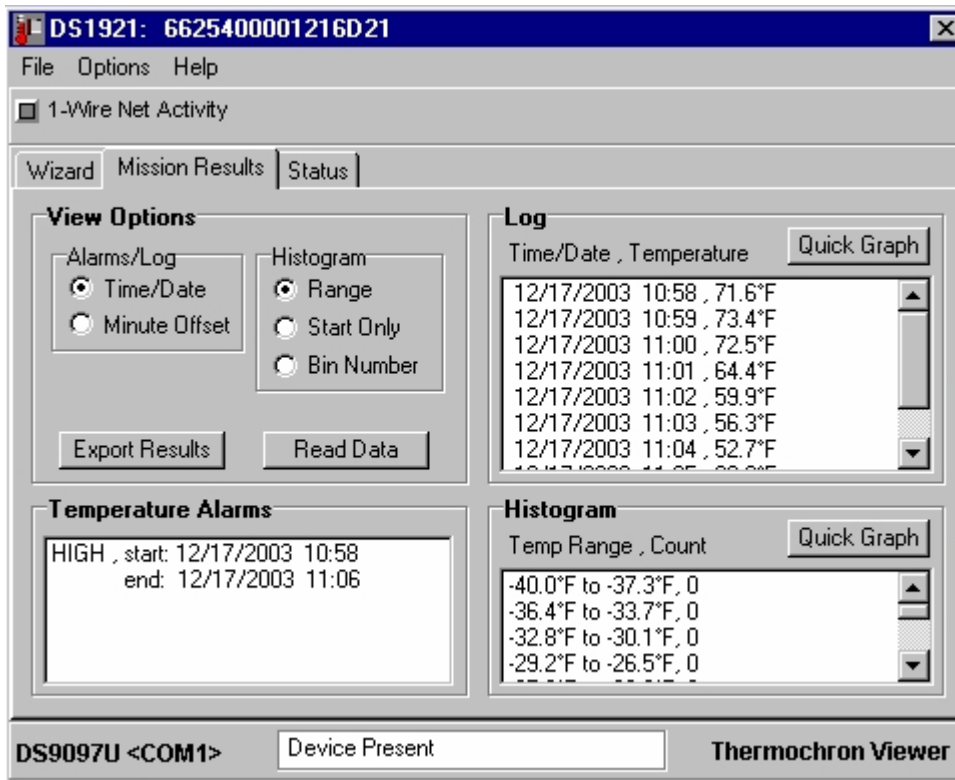
If you order extra ThermoChrons, test them together and compare their recorded temperatures. This indicates the corrections you may have to add to ThermoChron data. You want to compare like temperature sensors during a near space experiment.

Place the ThermoChron into a fob, if it already isn't in one. The fob makes it more difficult to lose the ThermoChron. Place the ThermoChron where its temperature will not drop below -40 degrees during the flight. Be sure to record the ThermoChron's ID and location before launch. Looking at

Thermochron data doesn't indicate the location where the temperatures were recorded, but your notes will.

### Processing Thermochron Data

- ✓ Start the PC or laptop and open the TMEX-iButton group
- ✓ Start the iButton Viewer
- ✓ Record the ID (the last four characters are usually is good enough) of the Thermochron if the mission flew more than one
- ✓ Plug the Thermochron into the Reader
  - Note: There are two iButton pads on the Reader, use either one. Two Thermochrons can be plugged into the Reader at the same time and you can select which one to program
  - Note: If you press the Thermochron hard enough, it will snap into the Reader and you won't have to hold it in place
- ✓ The iButton Viewer reads the iButton detected in the Reader
- ✓ Select the Mission Results tab



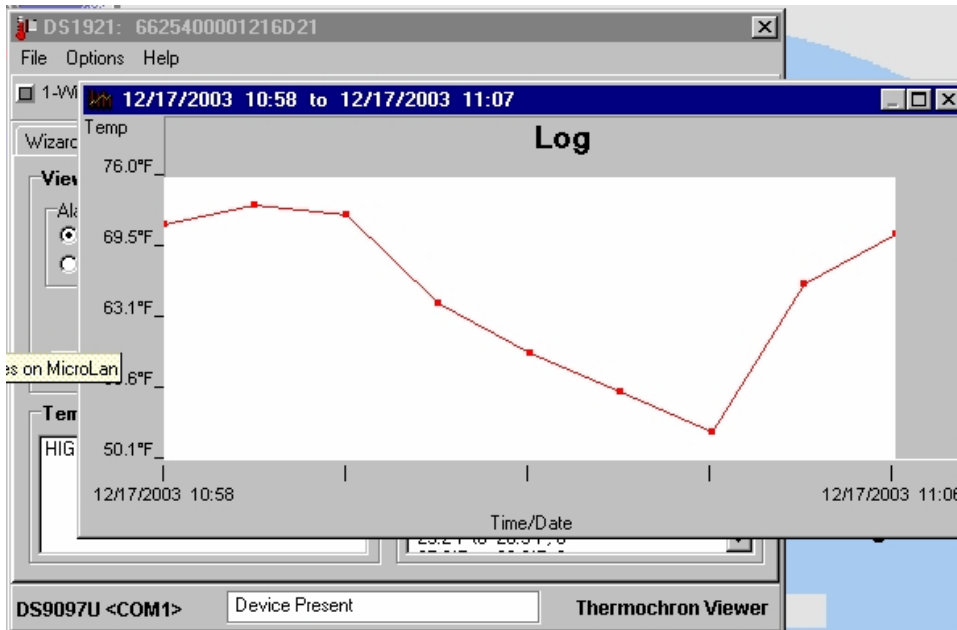
*Mission Results*

- ✓ The iButton Viewer begins downloading the current data from the Thermochron
- ✓ Select either the Export Results or Read Data button

### Read Data

The Log and Histogram is updated

Select the Log Quick Graph button to see the results of the mission



*Log Quick Graph*

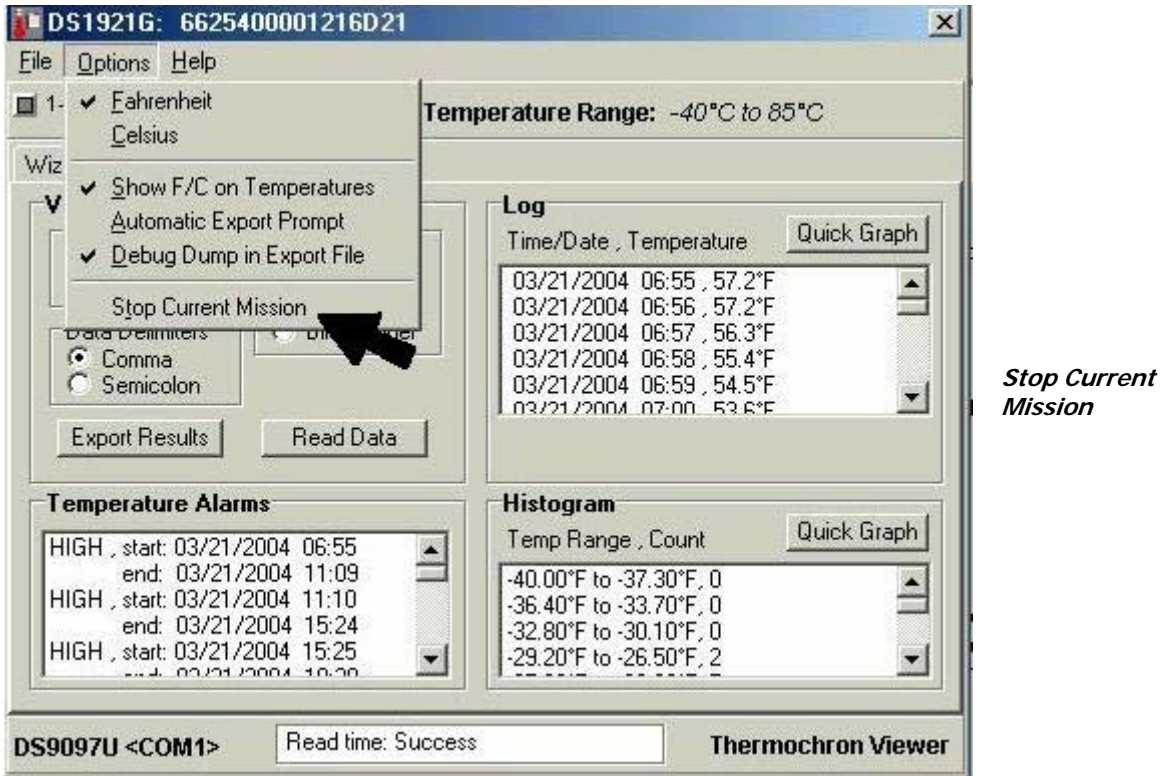
### Export Results

This is the most important step, as you can't share the data without first getting it into a spreadsheet.

- √ Enter a name and location for the file  
Note: Enter a meaningful name for the file, one based on the flight designation and/or ThermoChron location
- √ The resulting file is saved as a text file and ends with TXT

### Ending A ThermoChron Mission

- √ To save the ThermoChron's battery, end the ThermoChron's mission after recovery
- √ Click the Options Menu Item
- √ Select Stop Current Mission  
Note: I believe stopping the current mission preserves the battery inside the ThermoChron.



- √ Close out of the iButton Reader

### Graphs Or Charts

The resulting file from the Thermochron contains a Histogram, Log, Alarms, Checksums, etc. Of that information, only the log is needed. An excerpt of a log is shown below.

```

08/03/2002 10:23 , 83.3°F
08/03/2002 10:24 , 85.1°F
08/03/2002 10:25 , 86.0°F
08/03/2002 10:26 , 86.0°F
08/03/2002 10:27 , 86.9°F
08/03/2002 10:28 , 86.9°F
08/03/2002 10:29 , 87.8°F
08/03/2002 10:30 , 88.7°F
08/03/2002 10:31 , 89.6°F
08/03/2002 10:32 , 90.5°F
08/03/2002 10:33 , 92.3°F
08/03/2002 10:34 , 93.2°F
08/03/2002 10:35 , 95.0°F
08/03/2002 10:36 , 95.9°F
    
```

Open the Thermochron file in WordPad

#### Step 1

- √ Use the mouse and highlight and delete all information except for the Log Data

#### Step 2

Note: The Log Data contains the date, time, and temperature

- √ Click on Edit in the menu
- √ Click on Replace in the drop down menu

- √ Enter the date in the Find What window  
Note: Add one blank to the front of the date and two blanks after the date
- √ Leave the Replace With window blank
- √ Click the Replace All button

**Step 3**

- √ Click on Edit in the menu
- √ Click on Replace in the drop down menu
- √ Enter a colon (:) in the Find What window
- √ Enter a comma (,) in the Replace With window blank
- √ Click the Replace All button

**Step 4**

- √ Click on Edit in the menu
- √ Click on Replace in the drop down menu
- √ Enter a comma with a blank before and after it ( , ) in the Find What window
- √ Enter a comma (,) in the Replace With window blank
- √ Click the Replace All button

**Step 5**

- √ Click on Edit in the menu
- √ Click on Replace in the drop down menu
- √ Enter a letter F in the Find What window  
Note: If you don't click the Match Case option, then the case of the F is not important
- √ Leave the Replace With window blank
- √ Click the Replace All button

**Step 6**

- √ Run down the end of each line and delete the degree symbol and save the file

**Spreadsheet Processing**

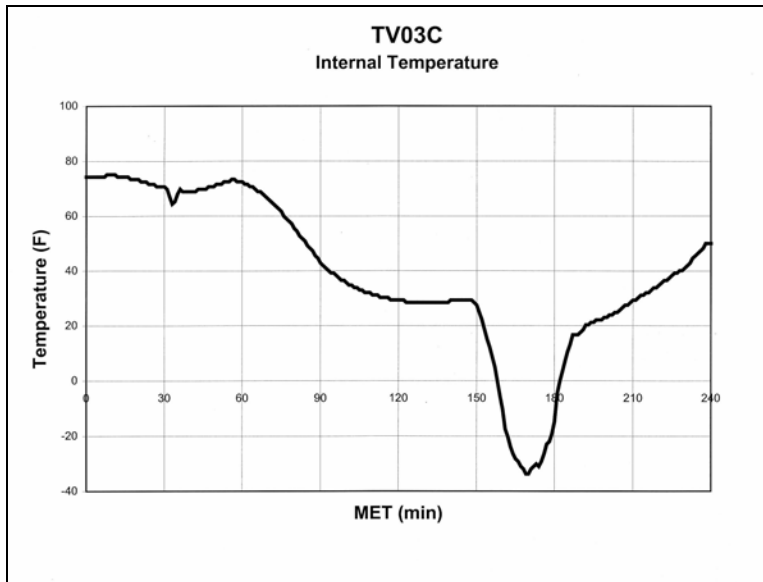
- √ Import the cleaned up text file into a spreadsheet as a comma-delimited file
- √ Import any other Thermochron files on separate pages
- √ Copy and paste the temperatures of separate files into separate columns
- √ Note: Do not copy the time column from each imported temperature file and be sure to line up the times the temperatures were taken
- √ Add a row to the top of the spreadsheet
- √ Enter a meaningful name to each column indicating where the temperatures were recorded
- √ Insert a column after the minutes of time column
- √ Create a Mission Elapse Time (MET) column from the data in the hours and minutes columns with the following spreadsheet command  
 $(+A3*60)+B3-nnn$

These spreadsheet command assumes the following.

1. The Hours column is column A
2. The Minutes column is column B
3. nnn is the time of launch in minutes

Note: The time of launch is calculated on the spreadsheet. Enter the spreadsheet command  $(+A3*60)+B3$  into the first few cells. Observe the calculated time at the actual time of launch. Then go back to the first command and update it with the actual time of launch. Copy the corrected commands to all cells in the MET column.

Create a graph with the Thermochron data. Some flights may compare the results from multiple Thermochrons whereas others may not. Be sure to label which lines represent which Thermochrons if more than one is shown on the graph.



*Internal Temperature Graph*

## 10.0 Technology Tests

### 10.1 Materials Exposure

How do everyday items hold up to the effects of near space? A material exposure test is another simple and “entertaining” near space experiment.

#### 10.1.1 Theory Of Operation

Just like the seeds in near space experiments, near space is a way to test materials in an environment for which they were not originally designed. Near space tests materials for exposure to the following conditions: near vacuum, extreme cold, and increased ultraviolet radiation. One way to experiment with making space exploration less expensive is to carry off-the-shelf materials into near space. Perhaps tests like these will identify readily available substitutes for more expensive, space-qualified materials. And just like the seeds in near space experiment, a material exposure test is another great activity for elementary students.

#### 10.1.2 Suggested Exposure Tests

Here’s a short list of material exposure tests suitable for elementary through high school students.

##### **Water**

Test what happens to the water during the flight. Fill a test tube with water and videotape the results. Seal the test tube with a stopper that has a small hole drilled in it. Consider inserting a valve into the stopper to control when the air pressure leaves the test tube. Servo controlled valves are available from hobby stores specializing in RC aircraft. You may also want to dye the water for increased visibility.

##### **Rubber Bands**

Test the ability of rubber bands to function in the cold, ozone, and UV radiation of near space. Wrap various rubber bands on different types of materials (black plastic and aluminized Mylar are two examples). The rubber bands should be placed under stress during the test by stretching them.

### **Glues And Adhesives**

Test how well different types of glue and adhesive tape stand up to near space conditions. Test their ability to adhere to different surfaces while securing a small load. The load on the adhesives can come from a spring pulling the surfaces a part. Be sure there is no way parts of the test can fall free of the near spacecraft if the adhesive fails.

### **Ultraviolet Sensitive Materials**

Send fluorescent papers and plastics into near space and photograph them during the flight. If the materials and camera are sealed inside of a UV passing filter, then visible light cannot contribute to the observed brightness of the materials.

### **Ultraviolet Protection**

If the previous test returns useful results, then try protecting some surfaces with sunscreen to determine the effectiveness of sunscreen,

### **Gases In Near Space**

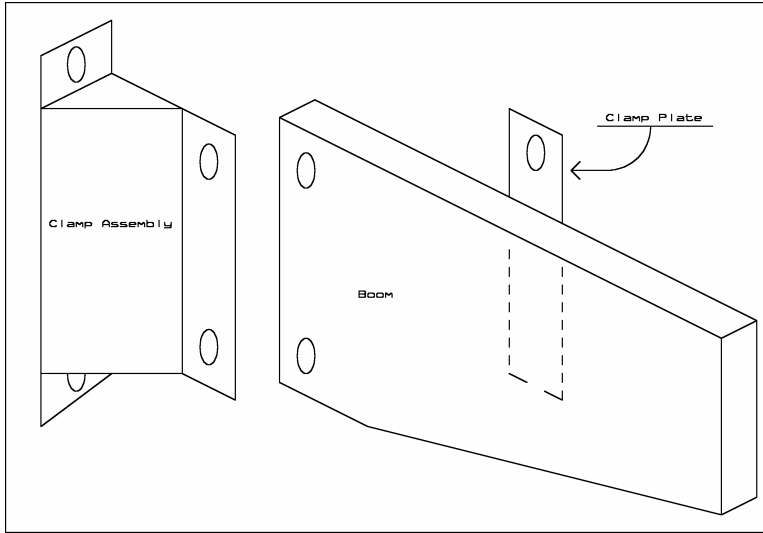
Fill balloons with different types of gases (CO<sub>2</sub> and He for example) and determine if the balloons behave identically. If you like the results from the gas balloon test, then try sending a marshmallow into near space. But don't send up an ordinary marshmallow; send a Marshmallow Peep, or other animal-shaped marshmallow, into near space instead.

## **10.1.3 Suggested Tools**

### **Mounting Lightweight Experiments For Photography**

Some experiments must be positioned in front of a camera or camcorder if results from the experiment are to be recorded. The ideal boom is lightweight, long enough to position the experiment where the camcorder can focus on it, and mountable to the camera quad panel. For times when longer booms are needed and the weight of the experiment is light, use plain ¾" thick Styrofoam as a boom. The following boom design has been used successfully for a gas balloon experiment. It consists of a Clamp Assembly for attaching the long Styrofoam boom to a camera quad panel. For this to work, the boom uses two of the camera quad panel's mounting holes. The mounting holes perform a double function, bolting the camera quad port to the airframe and bolting the Clamp Assembly to the camera quad port. Upon landing the boom will probably break, but the experiment stays close to the recovered capsules and the Clamp Assembly can be reused. By mounting the boom to a camera quad port, photographs of the experiment with the Earth's horizon in near space are returned to the students performing the experiment. Awesome!





*The Styrofoam Boom - The boom is designed to break before damaging an airframe.*

### Materials

- 1/8" thick plywood
- 1/32" thick plywood
- 3/4" thick Styrofoam
- Epoxy
- #6-32 mounting hardware (nuts, bolts, and washers)

### Procedure

#### Clamp Assembly

The Clamp Assembly consists of a mounting washer and a right angle plate made up of a mounting plate and a panel plate. See the diagram above for an illustration on the Clamp Assembly and long Styrofoam boom.

- ✓ Cut the 1/8" plywood into three rectangles, one (the panel plate) measuring 6" by 1", the last two (the mounting plate and the mounting washer) measuring 1-1/2" by 4"
- ✓ Align the panel plate with the edge of a camera quad panel and mark the location of the two mounting holes on one side of the camera quad panel
- ✓ Center and epoxy the mounting plate to the panel plate so that the mounting plate is perpendicular to the mounting plate and on the edge of the mounting plate
- ✓ Cut a four inch length of Styrofoam to 3/4" thick (you're creating a square cylinder four inches tall and 3/4" on a side)
- ✓ Slice the Styrofoam in half diagonally, making a wedge
- ✓ Epoxy the wedge into the intersection of the panel and mounting plates
- ✓ Cut 1/32" plywood to size to form a jacket over the exposed Styrofoam and epoxy it on the Styrofoam
- ✓ Clamp the mounting plate and mounting washer together
- ✓ Mark the location for two holes, 1/2" from the far edge of the plate and washer and 3/4" from the top and bottom
- ✓ Drill the two holes large enough for #6-32 mounting hardware
- ✓ Paint to taste

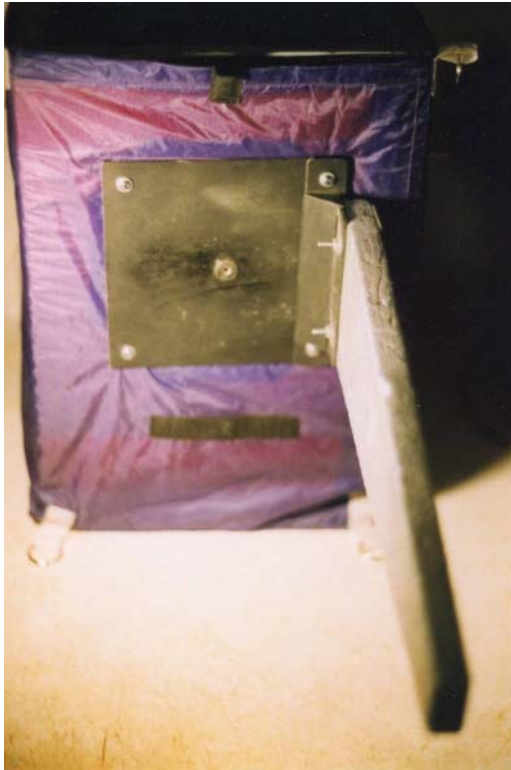
#### Long Styrofoam Boom

The maximum length of the boom depends on the weight of the experiment mounted to the end of it. The long Styrofoam boom can be strengthened with a jacket of 1/32" plywood laminated to its

surfaces. On the other hand, the boom can be considered expendable and left to break upon recovery. Remember that as long as the boom only breaks when the near spacecraft lands, the experiment attached to it remains close by.

- √ Cut a length of ¾" Styrofoam as long as needed and four inches wide
- √ Carefully drill two holes in one end, one-inch from the end and ¾" from the top and bottom faces (the holes line up with the holes in the Clamp Assembly)
- √ Hot glue any necessary end fixtures to the end of the long Styrofoam boom
- √ Paint to taste

Note: Many younger kids like to decorate items with stickers. If the boom is designed for an experiment performed by younger students, consider letting them decorate the boom to their taste.



*Boom mounted to an airframe.*

### **LEGO®Technics**

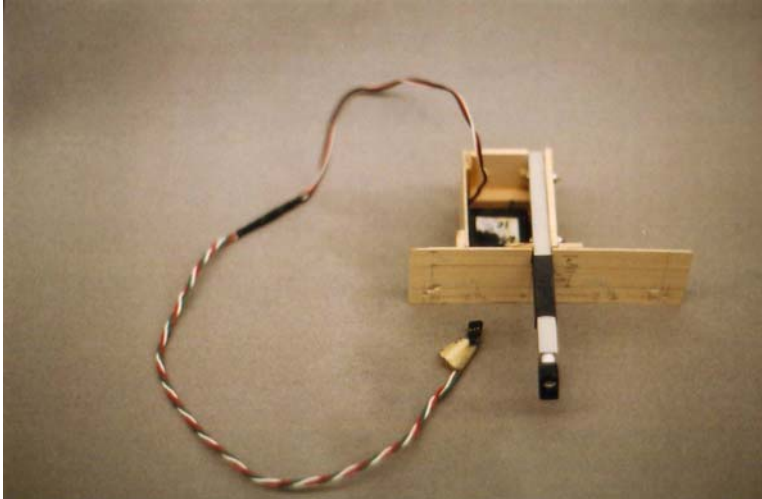
Students may want to design their experiment into a LEGO® Technics structure. Consult a LEGO book for information on building strong structures. If you deem the structure is safe enough to launch (safe enough that parts won't fall off during the flight), then use nylon wire ties to secure the LEGO Technics structure to a boom. Remember, LEGO Technics can be heavy, so mount them to a stronger experimental boom.

### **UV Beads**

A line of plastic beads is manufactured that are sensitive to UV radiation. Indoors, away from a UV source, the beads are pale white in color. The beads turn different colors when exposed to UV. The beads have a hole drilled through them, making them easy to mount. I purchased my bag of UV beads from the Teacher Source.

## 10.2 Droppers

During some missions, you may want to release mini-payloads from near spacecraft. Safe mini-payloads make fun projects that can perform their own experiments or be used in amateur radio competitions, like fox hunting. In this section, the construction of a dropper release mechanism is explained.

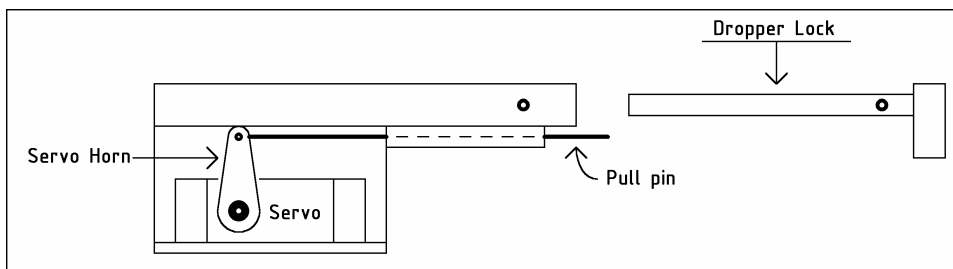


*A Dropper - Mounted behind a quad panel.*

### 10.2.1 Materials

- Parallax Standard Servo (P/N 900-00005) (Equivalent to Futaba S-148)
- 1/8" diameter plastic tubing
- 1/4" diameter plastic tubing
- 1/4" diameter plastic tubing
- Piano wire
- 3/8" by 3/8" square plastic tube
- Heat shrink large enough to slide over 3/8" by 3/8" square tube
- 1/8 inch thick plywood
- 1/2" by 1/2" basswood
- Epoxy
- Plastic glue
- Four servo-mounting screws
- Two #2-72 mounting hardware, 3/4" long
- #24 AWG stranded wire (three colors)
- 1/8" thick heat shrink tubing

### 10.2.2 Procedure



***The Dropper -** The thin plastic tube confines the pull pin. The lock slides into the larger tube and is locked into place with a twist tie.*

Building the Dropper entails building a Servo Box and epoxying it to a front panel. The servo box has an opening on its left side where the Dropper Arm is attached. To add the Dropper to an airframe, the Dropper is mounted to the inside face of a quad panel with the Dropper Arm protruding through the quad panel. Before launch, the item to be released is placed on the extended pin and secured with the locking pin.

### Assembling The Servo Box

- √ Cut a rectangle from 1/8" plywood measuring 1-3/4 inches by 3-1/2 inches (bottom piece)
- √ Cut two pieces of 1/2" by 1/2" basswood to a length of 1-3/4 inches (front and back bottom braces)
- √ Epoxy front and back bottom braces flush to edges of 1-3/4 inch long side of bottom piece
- √ Position servo on its side, with bottom of servo aligned with a 3-1/2 inch side of the plywood and between the two bottom braces
- √ Mark location of servo
- √ Cut two 3/4" long pieces of 1/2" by 1/2" basswood (servo mounts)
- √ Position and epoxy basswood to bottom piece so servo can be bolted to them  
Note: Only bottom bolt hole of servo ears are used to bolt servo into place
- √ Trim one of the basswood pieces so servo cable fits
- √ Attach servo horn to servo and position servo at mid-position
- √ Remove servo horn without rotating servo
- √ Drill small pilot hole and screw servo to basswood servo mounts
- √ Cut three of the four arms off of a servo horn
- √ Bolt modified servo horn to servo, with arm pointing vertically  
Note: Be sure servo horn is free to rotate
- √ Cut 1/8" plywood to rectangle measuring 1-3/4 inches by 3-1/2 inches (right side)
- √ Epoxy right side to bottom piece with their bottom and right edges flush to one another
- √ Cut 1/8" plywood to square measuring 1-3/4 inches by 1-3/4 inches (back piece)
- √ Epoxy back piece to bottom piece with their back and bottom edges flush to one another

### Assembling And Attaching The Front Panel

- √ Cut 1/8" plywood to rectangle measuring 1-3/4 inches by 6 inches (front panel)
- √ Find center of front panel (3 inches from either end) and draw a vertical line down the middle (mid-line)
- √ Epoxy front panel to bottom piece with their front and bottom edges flush to one another and left edge of bottom piece (the remaining opened side) aligned with front piece mid-line  
Note: The left edge of the Servo Box is flush to the mid-line of the front panel
- √ If desired, cut and epoxy additional 1/2" by 1/2" basswood to length to reinforce Servo Box to back piece and front panel

### Assembling Dropper Arm

- √ Cut 1/8" plywood to rectangle measuring 1-3/4 inches by 3-1/2 inches (left side)
- √ Cut 3/8" by 3/8" square plastic tube to a length of six inches
- √ Cut 1/8" plastic tube to a length of four inches
- √ Glue the plastic tube to the bottom of square tube so it is flush with left edge and one end
- √ Lay glued square and round tube on top and flush to open side of Servo Box  
Note: Adjust position of tubing so that the servo horn is lined up beneath smaller round tube (the servo horn piano wire enters the round tube)
- √ Mark location of square tube on front panel and back piece
- √ Cut 3/8" deep notches into front panel and back piece so the top of the square tube is flush with the top of Servo Box

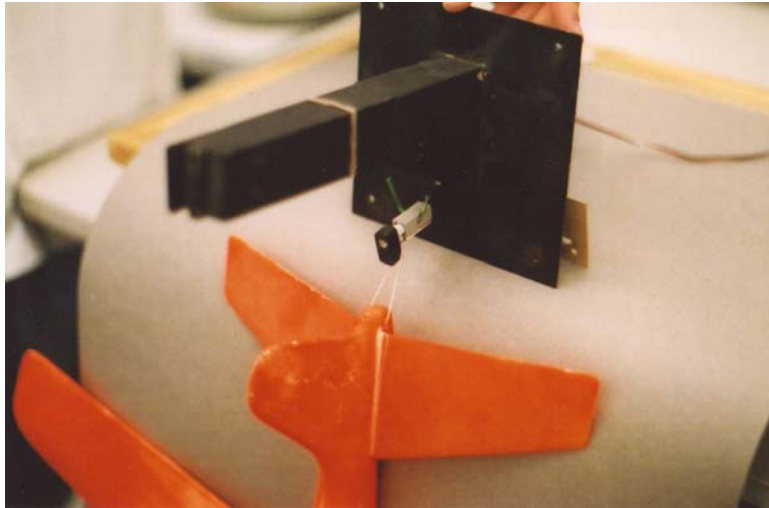
- √ Leave square and round tube in place and line up left side flush to Servo Box and Dropper Arm
  - √ Clamp Servo Arm to left side
  - √ Remove left side and Dropper Arm (keeping them clamped together)
  - √ Drill two small holes for #2-72 bolts so that the square tube can be bolted to left side
  - √ Use two bolts, four washers and two nuts to bolt Dropper Arm to left side
  - √ Place side and Dropper Arm onto the Servo Box
  - √ Ensure the Dropper Arm fits the properly to open side of Servo Box and to the notches cut in back piece and front panel
  - √ Once the Dropper Arm fits properly, mark location of center of front and back braces in the left side
  - √ Drill small holes into left side and front and back brace so that servo-mounting screws attach the Dropper Arm to Servo Box
  - √ Cut 1/8" plywood to rectangle measuring 3-1/2 inches by 2 inches (top panel)
  - √ Rubber band top panel over Servo Box to keep items from falling into Servo Box
  - √ Slide heat shrink tubing over 3/8" square tube where it extends beyond Servo Box and shrink down
- Note: The heat shrink tubing strengthens glued joint between 1/8" round tube and 3/8" square tube

#### **Assembling Locking Pin**

- √ Cut the 1/4" plastic tubing to a length of five inches
- Note: This tubing will be shortened later
- √ Cut 1/2" square basswood to a length of 3/4"
- √ Drill a 1/4" diameter hole near the end of the basswood block
- √ Epoxy the basswood block top end of 1/4" tubing (Locking Pin)
- √ Slide Locking Pin into 3/8" square tube until 1/4" tube is stopped by a Dropper Arm mounting bolt
- √ Measure gap between end of 3/8" tube (Dropper Arm) and back face of basswood block (Locking Pin)
- √ Subtract 1/4" from size of gap (this is the amount of the Locking Pin to remove)
- √ Cut the above amount from clear end of Locking Pin
- √ Slide Locking Pin into Dropper Arm
- √ Ensure there is approximately a 1/4" gap between Dropper Arm and Locking Pin
- √ Drill a 1/8" diameter hole in side of Dropper Arm and Locking Pin
- √ Remove Locking Pin and Dropper Arm from Servo Box
- √ Cut piano wire to a length of six inches
- √ Fold end of piano wire over and hook it through top hole of modified servo horn
- √ Position servo to its mid-position
- √ Slide free end of piano wire into opening of 1/8" tube of Dropper Arm
- √ Reattach Dropper Arm to Servo Box
- √ Cut piano wire to a length that extends from end of Dropper Arm by 1/2"
- √ Slide Locking Pin into Dropper Arm and mark where piano wire touches basswood block
- √ Remove Locking Pin
- √ Drill a very small hole into basswood block of Locking Pin where the piano wire would enter
- √ Reinsert Locking Pin into Dropper Arm aligning piano wire
- √ Cut a one-inch length of twist tie and insert it into Locking Pin and Dropper Arm hole

### 10.2.3 Using The Dropper

- ✓ Tie a loop of thin woven Dacron to the item to be dropped
- ✓ Ensure the servo is set (or pushed) to its mid-position  
Note: This leaves the piano wire release extending from the Dropper Arm
- ✓ Pull the Locking Pin out of the Dropper Arm
- ✓ Hang the Dacron loop over the piano wire
- ✓ Replace the Locking Pin, aligning the piano wire into the hole in the Locking Pin
- ✓ Insert a short length of twister seal into the Dropper Arm and Locking Pin



*Glider Attached to Dropper -  
When the servo pulls the pin back,  
the glider will drop free.*

#### Flight Code

Write test software for the Dropper for determining the position command required to release an item in the Dropper. The flight code routine to release Dropper payloads should set a status bit for the Dropper. The status bit is checked after balloon burst to ensure the payload has been released. If the bit is not set, the Burst Section needs to immediately release the Dropper payload.

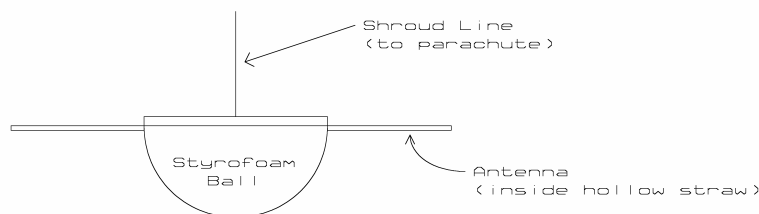
Below are two suggested payloads for the dropper.

#### Dropzonds

A dropzond is an instrumented capsule released from the near spacecraft during a flight. I like the word *zond*, the Russian word for *sonde*. There's a lot of possibilities with the dropzond concept, of which, I have just barely scratched the surface.

#### Construction Notes

The possible shapes for a dropzond are many, but the shape of TVNSP's first dropzond was hemispherical. Here's how TVNSP made it's first dropzond.



*Diagram of Dropzond*

## Materials

- Six-inch Styrofoam ball \*
- One-quarter ounce fiberglass \*\*
- Epoxy
- 1/8" dowel
- Paint or Tapes
- Correplast
- Materials for a parachute \*\*\*

\* These are available at arts and crafts stores, where they are used in flower arrangements or as the basis of Christmas ornaments

\*\* This is available in hobby stores specializing in RC aircraft

\*\*\* It's best to use cloth for parachutes instead of plastic. The tapes used to secure shroud lines to plastic canopies may pull loose in the cold of near space, or the descent may rip the plastic canopy.

## Dropzond Body

- √ Cut a six-inch diameter Styrofoam ball in half
- √ Cut wedge-shaped pieces out of the fiberglass, where the length of the wedge is one-quarter the circumference of the dropzond body and the width of the wedge is slightly larger than 1/8th the wedges length \*
- √ Apply epoxy to Styrofoam surface and layer in lightweight fiberglass
- √ Sand fiberglass shell smooth
- √ Repeat applying fiberglass wedges to the dropzond body to cover the open gaps
- √ Finish sanding the shell
- √ Paint or apply colored tape to shell
- √ Find a diameter across the dropzond body
- √ Punch two 1/8" diameter holes on opposite sides of the dropzond body, about 1/2" below the top (make the holes about one inch deep)
- √ Cut two lengths of 1/8" dowel to a length of 1-1/2"
- √ Epoxy the dowels into the dropzond body (these are used to secure the hatch and recovery system to the dropzond)

\* There's no need to be worry about the accuracy of the fiberglass wedges, as they wrinkle and stretch when epoxied to the Styrofoam hemisphere

A square hollow was cut into the dropzond body to fit a milliwatt beacon and battery into the TVNSP dropzond. The antenna of the beacon was mounted flush with the top of the dropzond body and extended beyond the dropzond.

## Recovery System

- √ Cut a six-inch diameter disk from Correplast
  - √ Cut a large disk from the canopy fabric (18" diameter circles will work for lightweight dropzonds)
  - √ Cut four lengths of thin cord to 36" long (shroud lines)
  - √ Sew the shroud lines to the canopy to form a parachute
  - √ Apply tape to parachute/shroud line knots
  - √ Cut six inches of thin cord or strap
  - √ Find apex of parachute and sew the cord or strap into a loop at the apex
- Note: The loop is about two inches in diameter



*Dropzonde  
Shortly After  
Release - Its  
parachute is  
opened as it falls  
away.*

The second dropzond carried by TVNSP was a Mr. Potatohead figure with his own camo parachute (Idaho air assault). Mr. Potatohead was released at 50,000 feet over Herrington, KS, as a part of the GPSL 2002 launches. Mr. Potatohead was recovered by a rancher who turned him over to the local sheriff.



*Mr. Potatohead - This character  
(the one on the left!) took a ride  
into near space during GPSL 2002.  
His airborne assault of Kansas  
occurred at 50,000 feet.*

## Gliders



Another payload for the dropper is a Styrofoam glider. Inexpensive gliders are available at hobby and toy stores. In one test, an eighteen inch wingspan glider released at 5.5 miles altitude glided for 6.5 miles before landing in a soybean field. Not bad for a \$3 toy.



***Glider** - An inexpensive glider flies for miles when released in near space. Be sure to add your phone number if you want to know when and where it landed, and paint it a bright color to make it easier to spot.*

### Materials

- Styrofoam glider, either 18" or four-foot wingspan
- Fluorescent orange modeling spray paint
- White glue
- Label
- Kite string (30# test is more than strong enough)

### Construction Notes

- √ Glue the wings and tail surfaces to the fuselage with white glue.  
Note: Do not depend on friction to hold the glider together, use glue
- √ Paint the glider fluorescent orange for higher visibility  
Note: Use model paints that are safe for Styrofoam
- √ Make two paper labels for the glider and print on laser printer  
Note: The label informs any finder that the glider is part of an experiment and that there is a reward for finding the glider
- √ Paint the label in clear paint to protect the lettering from the weather
- √ Glue the label to the sides of the glider's fuselage, and not the wings
- √ Tie a short loop of woven Dacron to the tail end of the fuselage

### Tracking Dropper Payloads

Another option for a Dropper payload is to incorporate a radio into the payload that can be fox hunted. A simple dropzond with a larger parachute or a glider large enough to carry an HT and the beacon circuit (Chapter Two, Section Two) are two possible fox hunting targets. Imagine fox hunting a transmitter at 50,000 feet!

### Dropper Payload Antennas

The dipole antenna for TVNSP's dropzond stuck out from the sides of its hemispherical body. The elements were rigid and therefore didn't require any support at their ends. The antenna for a four-foot (wingspan) glider should be lighter and, like an RC airplane, can take advantage of the airframe for support. Three places to tie the antenna elements to include:

- Along the trailing edge of the wing
- Along the bottom of the fuselage
- Between the nose of the fuselage and the top of the vertical stabilizer

## 11.0 Preparing Tiny Trak TNC Logs

This section describes how to edit a TNC log from a Tiny Trak II or III, import it into a spreadsheet, edit the spreadsheet, and create charts or graphs of the results.

### 11.1 Editing the TNC Log

The directions given here explain how to prepare a raw TNC log from a Tiny Trak II or III for importing into a spreadsheet. The next section explains the process of importing the data and generating charts.

Begin by starting Wordpad. Wordpad is used in place of Notepad because of Wordpad's greater editing capability.

- √ Click File
- √ Click Open
- √ In the Types of File window, click the down arrow and select Text Documents (\*.txt)
- √ Browse to find the file, then open it.

A line of data in the file from a Tiny Trak II or Tiny Trak III without the time stamp looks similar to this (except, it will occupy a single line of text):

```
KD4STH-9>APT202,WIDE3-3,qAR,KOYG-7: !3934.12N/10355.75W-110/017/A=045495/Near  
Space Tracker #1
```

A line of data in the file from a Tiny Trak III with the time stamp looks similar to this (except, it will occupy a single line of text):

```
KD4STH-11>APT310,WIDE3-3,qAS,KOUT-  
1:/132529h3935.53N/10400.99W>159/033/A=020569/TVNSP Flight Computer 3
```

- √ In either type of file, highlight the digi-peating information of a line of data, for example, KD4STH-9>APT202,WIDE3-3,qAR,KOYG-7: !
- √ Then right click and select Copy  
Note, we'll also remove the preceding exclamation point with the digi-peating information to save us from future editing.
- √ Click Edit, then Replace
- √ In the Find What window, right click and select Paste  
(This puts the copied text into the Find function or Replace)
- √ Leave the Replace with window blank
- √ Click the Replace All button
- √ After a moment, you will receive a message that the offending text has been removed. Click the OK button.

Note: Sometimes I have noticed that the text I copied will appear in the Find what window, when I open up the Replace option.

This will remove the digi-peating and destination information from the TNC log. A TNC log can contain information routed through different sources, so there will probably be other lines of text with different digi-peating and destination information. Delete the current text in the Find what window. Highlight the next remaining digi-peating and destination information, copy it, then paste it into the Find what window. Be sure no text from the previous search was left inside the window or else a hideous combination of text will exist in the Find what window. Still leave the Replace with window blank. Again click on Replace All and remove the addressing information. Repeat this until all the digi-peating and destination information is removed from the TNC log. Save the file under a new name so that you can keep the original TNC log.

- √ In the Tiny Trak III log with time stamps, delete the following example of text.

```
KD4STH-11>APT310,WIDE3-3,qAR,KC0CAT-1:/
```

Note, we'll also remove the preceding right slash with the digi-peating information to save us from future editing.

When the digi-peating and destination information has been removed, the text should look like this.

Tiny Trak without time stamps

```
3935.97N/10357.68W-315/014/A=085739/Near Space Tracker #1
```

Tiny Trak III with time stamps

```
131529h3936.47N/10402.09W>075/013/A=008332/TVNSP Flight Computer 3
```

- √ Next, copy the beacon text and delete that with the Find and Replace function of Wordpad. Be sure to remove the preceding right slash (/) with the beacon text

The results will look like this.

Tiny Trak without time stamps

```
3935.97N/10357.68W-315/014/A=085739
```

Tiny Trak III with time stamps

```
131529h3936.47N/10402.09W>075/013/A=008332
```

- √ Quickly scan through the remaining text, looking for malformed data that wasn't deleted and clean up the file of them.
- √ Again, save the file.

Now we'll begin to replace the APRS Data Type Identifiers (DTI) with commas.

- √ Begin with the latitude information. Click File, then Replace. In the Find what window type N/. In the Replace with window, type a comma (.). Click the Replace All button.
- √ Save the file
- √ Now replace the longitude ident. Click File, then Replace. In the Find what window type either W- or W>. In the Replace with window, type a comma (.). Click the Replace All button.
- √ Save the file
- √ Now replace the altitude ident. Click File, then Replace. In the Find what window type /A=. In the Replace with window, type a comma (.). Click the Replace All button.
- √ Save the file
- √ Now replace the remaining right slashes. Click File, then Replace. In the Find what window type /. In the Replace with window, type a comma (.). Click the Replace All button.

- √ Save the file

The results will look like the following.

Tiny Trak without a time stamp

```
3935.68,10356.02,288,018,081330
```

Tiny Trak with a time stamp

```
132029h3936.20,10401.61,164,008,014379
```

- √ Replace the hour ident with a comma
- √ Click File, then Replace. In the Find what window type h. In the Replace with window, type a comma (.). Click the Replace All button.
- √ Save the file

Tiny Trak with a time stamp now looks like this.

```
132029,3936.20,10401.61,164,008,014379
```

Now it gets a little more difficult. A comma between the latitude in degrees and minutes and the longitude in degrees and minutes is added next. The second field in each line of data is the latitude. The first two characters are the latitude in degrees and the next five characters (two digits, a period, and two more characters) are the latitude in minutes. Scan through the file and note if the latitude in degrees changes. If so, the next step will be repeated a second time.

Click File, then Replace. In the Find what window type a comma and the latitude in degrees (including the preceding comma will reduce the number of false replacements). In the Replace with window, type a comma (.). Click the Replace All button.

Since the fields are of uniform size, false replacements show up as lines of text that are longer than their neighbors. Scan the text file looking for lines of text that are one or more characters longer than the rest. This is so obvious that it can be done quickly with the Page Down button. When a line of text with a false replacement is found, look for the out of place pattern of commas to locate the false replacement. Delete the comma.

- √ Repeat this step again if the near spacecraft crossed over a whole degree of latitude.
- √ Save the file

Now repeat this process with the longitude. The longitude is now the fourth field (it was the third before adding the last comma). The first three digits are the longitude in degrees. It's followed by five characters of the longitude in minutes and is formatted just like the latitude. Follow the previous step and add the comma into the longitude field.

Save the file

The results will look like the following.

Tiny Trak without a time stamp

```
39,35.68,103,56.02,288,018,081330
```

Tiny Trak with a time stamp

```
132029,39,36.20,104,01.61,164,008,014379
```

If the file does not contain a time stamp, then you are finished editing it. Save the file once again and begin importing the text file into a spreadsheet. If the text file is from a Tiny Trak III with the time stamp, then commas must be inserted between the hours, minutes, and seconds. I know of no easy

way to do this. You will just have to add the commas manually. Your fingers will get tired doing this. After adding the commas into the time field, the text file will look like this.

```
13,20,29,39,36.20,104,01.61,164,008,014379
```

Save the file once more and proceed with importing it into a spreadsheet.

## 11.2 Importing The Tiny Trak TNC Log

If you're fortunate, you were able to edit a clean TNC log with just your flight data. If instead you were handed a complete TNC log containing the position of every APRS station between here and Timbuktu, then the author feels your pain as you manually clean up an APRS log to extract just the important data, i.e. near spacecraft data. If you are forced to this route, then remember to use WordPad in place of NotePad, as WordPad has a larger buffer for files and more editing features. When you have the file, save it as a text file (which is why the author does not recommend using MS Word for editing TNC logs).

Start MS Excel and click on Open File. In the Files of Type window, select Text Files. Look for the saved Tiny Trak text log and click on it. This starts the Text Import Wizard. Select the following options on the three windows.

- √ In Step 1 of 3, Original Data Type, be sure the Delimited button is clicked.
- √ In Step 2 of 3, Delimiters, click the Comma button
- √ In Step 3 of 3, click the Finish button

## 11.3 Editing The Spreadsheet

Add the titles to each existing column (you will add additional column later and name them at the time you insert them)

- a. Right click the top left corner of the spreadsheet to highlight the top row
  - b. In the pop-up menu, click Insert
  - c. Repeat a second time
  - d. In the top row enter into each cell the following titles  
Time, Time, Time, Latitude, Latitude, Longitude, Longitude, Heading, Speed, and Altitude
  - e. In the second row enter the following units for each column
    1. hours, minutes, seconds, degrees, minutes, degrees, minutes, true north, knots, and feet
2. Add an entry for the launch site
- a. Right click the top left corner of the spreadsheet to highlight the top row
  - b. In the pop-up menu, click Insert
  - c. Fill the following cells  
time of launch, latitude, longitude, and altitude

Note: Many GPS receivers do not save the altitude when a position is marked, or recorded in memory. The altitude of the launch site must be determined from a topo map, or better yet, written down at the time of launch.

### 3. Create the MET column

There are two options here, depending on whether the near spacecraft uses a Tiny Trak II or Tiny Trak III.

### Tiny Trak II Option

- a. Right click the Latitude, degrees column and click on Insert
- b. Label the column as MET and its units as minutes  
 Note: These directions assume the Tiny Trak II is transmitting a posit every 60 seconds. If this is not the case, then the amount to add to each cell (as set up in step 3d, must be changed to reflect the posit rate)
- c. Enter a 0 (zero) in the first cell of the MET column
- d. In the second cell, enter the equation,  

$$=+a3+1$$
- e. Right click the top cell and select, Format Cells
- f. In the Category window, select Number
- g. In the decimal window, select 1
- h. Click the OK button
- i. Right click the top cell with the equation and click COPY from the pop-up menu
- j. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- k. Right click the highlighted column and select to PASTE
- l. Save the spreadsheet

### Tiny Trak III Option

- a. Right click the Latitude, degrees column and click on Insert
- b. Label the column as MET and its units as minutes
- c. In the first cell, enter the equation,  

$$=(+a3*60)+b3+(c3/60)$$
- d. Look at the resulting time and subtract the number from the above equation to make the MET time reflect the number of minutes since launch. Alternatively, you can take the launch time in hours, minutes, and seconds and enter it into the above equation. Subtract the result from the above equation. As an example, if the launch occurred at 13:12:00 UTC, the equation will look like,  

$$=(+a3*60)+b3+(c3/60)-792$$
- e. Right click the top cell and select, Format Cells
- f. In the Category window, select Number
- g. In the decimal window, select 1
- h. Click the OK button
- i. Right click the top cell with the equation and click COPY from the pop-up menu
- j. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- k. Right click the highlighted column and select to PASTE
- l. Save the spreadsheet

### 4. Convert Latitudes and Longitudes from units of degrees into units of radians.

- a. Right click the Latitude, minutes column and click on Insert
- b. Label the new column as Latitude and its units as radians
- c. Right click the Longitude, minutes column and click on Insert
- d. Label the column as Longitude and its units as radians

### Tiny Trak II Equation

- e. In the first cell of Latitude (radians), enter the equation,  

$$=(+B3+(C3/60))/57.296$$
- f. In the first cell of Longitude (radians), enter the equation,  

$$=(+F3+(G3/60))/57.296$$

## Tiny Trak III Equation

- e. In the first cell of Latitude (radians), enter the equation,  

$$= (+E3+(F3/60))/57.296$$
- f. In the first cell of Longitude (radians), enter the equation,  

$$= (+I3+(J3/60))/57.296$$
- g. In each new column, right click the top cell with the equation and click COPY from the pop-up menu
- h. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the Latitude (radians) and Longitude (radians) column
- i. Right click the highlighted column and select to PASTE
- j. Right click the top cell in the Latitude (radians) and Longitude (radians) column and select, Format Cells
- k. In the Category window, select Number
- l. In the decimal window, select 4
- m. Click the OK button
- n. Save the spreadsheet

5. Create the change in latitude and change in longitude columns (delta latitude and delta longitude). These columns calculate how far the near spacecraft has traveled from the launch site.

- a. Right click the Latitude, radians column and click on Insert
- b. Label the new column as Delta Latitude and its units as radians
- c. Right click the Longitude, radians column and click on Insert
- d. Label the column as Delta Longitude and its units as radians

## Tiny Trak II Equation

- e. In the first cell of Delta Latitude, enter the equation,  

$$= \$D\$3-D3$$
- f. In the first cell of Delta Longitude, enter the equation,  

$$= \$H\$3-H3$$

## Tiny Trak II Equation

- e. In the first cell of Delta Latitude, enter the equation,  

$$= +G3- \$G\$3$$
- f. In the first cell of Delta Longitude, enter the equation,  

$$= +K3- \$K\$3$$
- g. In each new column, right click the top cell with the equation and click COPY from the pop-up menu
- h. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the Delta Latitude and Delta Longitude column
- i. Right click the highlighted column and select to PASTE
- j. Right click the top cell in the Delta Latitude and Delta Longitude column and select, Format Cells
- k. In the Category window, select Number
- l. In the decimal window, select 4
- m. Click the OK button
- n. Save the spreadsheet

4. Create the Range in miles column

- g. Right click the Delta Longitude, radians column and click on Insert

- h. Label the column as Range and its units as miles

Tiny Trak II Equation

- i. In the first cell, enter the equation,  

$$= 7912*ASIN(SQRT((SIN(E3/2))^2+(COS($D$3)*COS(D3))*(SIN(I3/2))^2))$$

Tiny Trak III Equation

- c. In the first cell, enter the equation,  

$$= 7912*ASIN(SQRT((SIN(H3/2))^2+(COS($G$3)*COS(G3))*(SIN(L3/2))^2))$$
- d. Right click the top cell and select, Format Cells
- e. In the Category window, select Number
- f. In the decimal window, select 2
- g. Click the OK button
- h. Right click the top cell with the equation and click COPY from the pop-up menu
- i. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the Range column
- j. Right click the highlighted column and select to PASTE
- k. Save the spreadsheet

5. Create the Azimuth in degrees column

- a. Right click the Range, miles column and click on Insert
- b. Label the column as Azimuth and its units as degrees

Tiny Trak II Equation

- c. In the second cell of the column, enter the equation,  

$$= 57.296*(ACOS((SIN(D4)-SIN($D$3)*COS(J4/3956))/(SIN(J4/3956)*COS($D$3))))$$

Tiny Trak III Equation

- c. In the second cell of the column, enter the equation,  

$$=57.296*(ACOS((SIN(K4)-SIN($K$3)*COS(M4/3956))/(SIN(M4/3956)*COS($G$3))))$$
- d. Enter the value of the second cell into the first cell of the column
- e. Right click the top cell and select, Format Cells
- f. In the Category window, select Number
- g. In the decimal window, select 1
- h. Click the OK button
- i. Right click the top cell with the equation and click COPY from the pop-up menu
- j. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- k. Right click the highlighted column and select to PASTE
- l. Delete cells that are obvious in error, but do not add data to the spreadsheet to create ascent rates, use only what was saved in the log.
- m. Save the spreadsheet

6. Create the Speed in mph column

- a. Right click the Heading, true north column and click on Insert
- b. Label the column as Speed and its units as mph
- c. In the first cell, enter the equation,  

$$=+j3*1.15$$
- d. Right click the top cell and select, Format Cells
- e. In the Category window, select Number



- f. In the decimal window, select 1
- g. Click the OK button
- h. Right click the top cell with the equation and click COPY from the pop-up menu
- i. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- j. Right click the highlighted column and select to PASTE
- k. Save the spreadsheet

#### 7. Create the Elevation in degrees column

- a. Right click the Azimuth, degrees column and click on Insert
- b. Label the column as Elevation and its units as degrees
- c. In the first cell of the column, enter a 0 (zero)

#### Tiny Trak II Equation

- d. In the second cell, enter the equation,  

$$= 57.296*ATAN((((+O4-\$O\$3)/5280)/J4)-(J4/ 7912))$$

#### Tiny Trak III Equation

- d. In the second cell, enter the equation,  

$$= 57.296*ATAN((((+R4-\$R\$3)/5280)/M4)-(M4/ 7912))$$
- e. Right click the top cell and select, Format Cells
- f. In the Category window, select Number
- g. In the decimal window, select 1
- h. click the OK button
- i. Right click the top cell with the equation and click COPY from the pop-up menu
- j. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- k. Right click the highlighted column and select to PASTE
- l. Delete cells that are obvious in error, but do not add data to the spreadsheet to create ascent rates, use only what was saved in the log.
- m. Save the spreadsheet

#### 8. Create the Ascent Rate in feet/minute column

- a. Label the first blank column (just after the Altitude in feet column) as Ascent Rate and its units as feet/minute

#### Tiny Trak II Equation

- b. In the second cell, enter the equation,  

$$=(+M4-M3)/(A4-A3)$$

Since all packets are seldom ever received, there are gaps in the TNC log. With the Tiny Trak III this is not an issue because the time is transmitted with each packet. However, on the Tiny Trak II, there is no time stamp with each record. Therefore, it is necessary to make adjustments to the spreadsheet at this time. The ascent rate contains clues to missing records. Typical ascent rates are on the order of 1000 feet per minute. Any ascent rates with significantly higher ascent rates (on the order of 2000 feet per minute or higher) indicate missing records.

When a missing record is indicated, follow these steps to correct the TNC log

- √ Determine how many records appear to be missing

- √ For example: Is the ascent rate twice as high as its neighboring cells? Then one record is missing)
- √ Or: Is the ascent rate four times as high as its neighboring cells? Then three records are missing)

In column A for that row, add the required number of minutes to the MET for that column. So in the above examples, an MET of 10 minutes in the first example would be changed to 11 and in the second example, a MET of 78 minutes would become 81.

- √ After entering the change to the MET, the remaining cells in the MET column will update themselves, as will the values in the Ascent Rate column.
- √ Look at the changed value in the Ascent Column cell. Does it make sense now?
- √ Continue working down the Ascent Rate column, looking for missing records and fix the TNC log.

It gets more difficult at the time of burst. The first ascent rates after burst will be high, but depending on the time of posit in relationship to the time of burst, the second posit after burst may have the higher negative descent rate. Descent rates after burst are on the order of 10,000 feet per minute at altitudes near 100,000 feet.

#### Tiny Trak III Equation

- c. In the second cell, enter the equation,  
$$= (+P4-P3) / (D4-D3)$$
- d. Right click the top cell and select, Format Cells
- e. In the Category window, select Number
- f. In the decimal window, select 1
- g. Click the OK button
- h. Right click the top cell with the equation and click COPY from the pop-up menu
- i. Click the second cell down, scroll to the bottom of the page, press the SHIFT key while you click the bottom cell of the MET column
- j. Right click the highlighted column and select to PASTE
- k. Delete cells that are obvious in error, but do not add data to the spreadsheet to create ascent rates, use only what was saved in the log.
- l. Save the spreadsheet

#### 11.4 Creating Charts and Graphs

The charts and graphs to create are: Ascent Rate, Altitude over Time, Range over Time, Elevation over Time, Azimuth and Elevation, Wind Speed, and Wind Direction. The charts are created in the same fashion, only the X and Y values are different. Complete directions for the Ascent Rate are given below. Notes on the X and Y values to use are given for the remaining charts.

#### Ascent Rate Chart (graph)

- √ Click Chart Wizard button
- √ Under Chart Type window, click XY (Scatter)
- √ Under Chart sub-type, click bottom right example (Scatter with data points connected with lines without markers)
- √ NEXT button
- √ Series Tab
- √ Under SERIES window, click the REMOVE button to delete all the series

- √ Now click the ADD button (to add the series we want)
- √ Each series needs a name, X values, and Y values  
(remember, X is horizontal, Y is vertical axis)
- √ Click the button in the NAME: window
- √ Click the name of the column (which you wrote at the top of the column)  
Note: Name should be Ascent Rate
- √ Click the button in the X VALUES: window
- √ Select the first cell in the MET column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the MET column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
- √ Click the button in the Y VALUES: window
- √ Select the first cell in the Ascent Rate column  
Note: cell is selected when you see ants crawling around perimeter of cell
- √ Drag the slider button down
- √ Press and hold the SHIFT key
- √ Click the last cell in the Ascent Rate column  
Note: column is selected when you see ants crawling around perimeter of column
- √ Press ENTER
- √ Click the NEXT button

#### Under Titles Tab

- √ Enter name of chart in Chart Title window  
e.g. Type name of mission and what was measured.  
Note: At this time, do not add a space between the name of the mission and what characteristic was measured, that will be added later when the name and characteristic measured will be separated into two separate lines  
(e.g. TV03Eclimb Rate)
- √ In the Value (X) Axis: window, type MET (minutes)
- √ In the Value (Y) Axis: window, type Ascent Rate (feet/minute)
- √ Under Axes tab
- √ Value (X) axis and Value (Y) axis should already be clicked
- √ Under Gridlines Tab
- √ Click the Major Gridlines square under Value (X) axis:
- √ Click the Major Gridlines square under Value (Y) axis: if it is not already clicked

#### Legend Tab

- √ Unclick the Show Legend button (it's not needed when a single characteristic is graphed)

#### Data Labels Tab

- √ The NONE option should be selected

- √ NEXT button
- √ Click option to Save As New Sheet
- √ Type ascent rate (or other meaningful name) into name window
- √ Click FINISHED button

#### Additional modifications to Chart

- √ Right click center of Plot Area, away from data line or axis
- √ Click Format Plot Area.....

#### Under Border Options

- √ You can leave this alone, but I prefer to click under the Color window (a button with a pull down menu), the Black square

#### Under Area Options

- √ Click the NONE option (this gets rid of the gray background)
- √ OK button
  
- √ Left Click Chart Title
- √ Right Click
- √ Click Format Chart Title.....
- √ Font tab
- √ Under Size window, select a larger font, like 20
- √ OK button
- √ Left click between name of mission and characteristic
- √ Press the ENTER button to break the title into two rows of text
  
- √ Left click on of the Axis Titles
- √ Right Click
- √ Click Format Axis Title.....
- √ Font tab
- √ Under Size window, select a larger font, like 14
- √ OK button
- √ Repeat for other axis title
  
- √ Left click the series on the chart
- √ Right click
- √ Click Format Data Series.....
- √ Under Patterns tab
- √ Click option button in Color: window
- √ Click black square
- √ Click option button in Weight: window
- √ Click next heavier weight (if desired)
- √ OK button

#### The remaining charts

The X and Y values are different for each of the remaining charts. In addition, the wind speed and wind direction charts only plot data collected during ascent. There is no need to plot data after the balloon burst.

For the **MET Altitude** chart, use the following X and Y values

- X Values: MET (minutes) column
- Y Values: Altitude (feet) column

For the **MET Range** chart, use the following X and Y values

- X Values: MET (minutes) column
- Y Values: Range (miles) column

For the **MET Elevation** chart, use the following X and Y values

- X Values: MET (minutes) column
- Y Values: Elevation (degrees) column

For the **Azimuth and Elevation** chart, use the following X and Y values

- X Values: Azimuth (degrees) column
- Y Values: Elevation (degree) column

For the **Wind Speed** chart, use the following X and Y values

Note: Only use data from launch to the highest recorded altitude

- X Values: Speed (mph) column
- Y Values: Altitude (feet) column

For the **Wind Direction** chart, use the following X and Y values

Note: Only use data from launch to the highest recorded altitude

- X Values: Heading (degrees true north) column
- Y Values: Altitude (feet) column

## Good To Know - Cosmic Rays

The scientist Viktor Hess discovered cosmic rays during a balloon flight on 7 August 1912. Several decades earlier, physicists studying electrostatics discovered that electroscopes slowly bled off their charge, no matter how dry or clean the air was. The source of this discharge was not known for certain until Viktor Hess' balloon flight. Hess rode hydrogen filled balloons to altitudes in excess of 15,000 feet in an opened gondola and without an oxygen supply. Carrying durable electroscopes, he discovered that charged electroscopes discharged faster with increasing altitude once his experiment was above 6000 feet. Below 6000 feet, the radiation flux of the Earth was great enough to affect his experiment. What Hess discovered is that the level of atmospheric ionization increased with increasing altitude, indicating an extraterrestrial source for this ionizing radiation.

Briefly stated, cosmic rays for the most part are energetic nuclei. About 86% of cosmic rays consist of protons, or hydrogen nuclei. Of those remaining, 12% are helium nuclei (alpha rays), 1% are energetic electrons, and another 1% are atomic nuclei heavier than helium (elements that astronomers call metals). There are some high-energy gamma rays and neutrinos thrown into the mix as well. To create cosmic rays, a nucleus of an atom must be stripped of some or all of its electrons and then accelerated by solar, galactic or extragalactic-based energy sources. Supernovae explosions are believed to be the energy source that initially accelerates most extra-solar nuclei. Although it's not

entirely clear how at this time, it is believed by physicists that the shockwaves generated in a supernovae blast are responsible for accelerating ionized atoms to cosmic ray energies. Once accelerated, cosmic rays travel the galaxy in curved paths by our galaxy's magnetic field. Some cosmic rays are known to originate from the Sun. Solar-based cosmic rays typically carry less than 1 GeV of energy and their presence in our atmosphere fluctuates with the eleven-year sunspot cycle. Major solar flares can significantly increase the amount of cosmic rays in our atmosphere.

One of the most amazing aspects of cosmic rays is their level of energy. In some cases individual cosmic rays have energies greater than one billion electron volts (1 GeV) or as much energy as contained in the mass of a proton. Amazingly enough, some cosmic rays carry over 1020 eV of energy. That's enough energy to boil a thimbleful of water if all the energy could be transferred to it (in reality, such a cosmic ray would travel right through the water, leaving only a tiny bit of its energy in the water). Put another way, this level of energy is equivalent to a baseball thrown at about 100 mph! Imagine the energy of a fast baseball packed into a single proton. The high energy levels of cosmic rays allow some of them to make the trip to Earth at speeds close to the speed of light. Some cosmic rays have low energy levels and are kept away from the inner solar system, and therefore Earth, by the Sun's magnetosphere. The solar magnetosphere is a bubble surrounding the solar system where the Sun's magnetic field is still strong enough to overwhelm outside influences. As the solar cycle changes over the years (sometimes weaker, other times stronger), some of these cosmic rays are able to travel to the Earth, increasing our exposure to cosmic radiation.

The flux of cosmic rays is at least as great as one cosmic ray per square centimeter per second, or about the same flux as raindrops during a rain shower. When these energetic nuclei slam into Earth's atmosphere they collide with air molecules (mostly nitrogen and oxygen) high in the atmosphere. Upon impact they shatter the air molecule creating a shower of lower energy particles from the subatomic zoo. Subatomic particles like neutral and charged pions (pi mesons), neutrons and more protons. Neutral pions decay into gamma rays, which later create electron-positron (positrons are anti-electrons) pairs. Charged pions decay into muons, a heavier relative of the electrons. Muons have very short half-lives. So short is their half-lives that if it wasn't for the time dilation caused by their relativistic speeds, muons wouldn't live long enough to make the trip down to the Earth's surface where we could detect them. The shower of particles created by the collision of a cosmic ray is called a secondary shower. Particles in the secondary shower continue traveling towards the surface, sometimes colliding with molecules of gas lower in the atmosphere and creating more secondary showers. Eventually secondary showers are attenuated by the Earth's lower atmosphere, protecting us from harm. Pilots and passengers, when flying in airplanes, have less protection from cosmic rays by the Earth's atmosphere. Therefore they are exposed to higher radiation levels during a flight. Not only is the flux of cosmic rays greater with increasing altitude, the flux of cosmic rays detected on the Earth's surface is also dependent on the geomagnetic latitude. The flux is greater near the magnetic poles of the Earth where the Earth's magnetic field funnels cosmic rays to the surface.

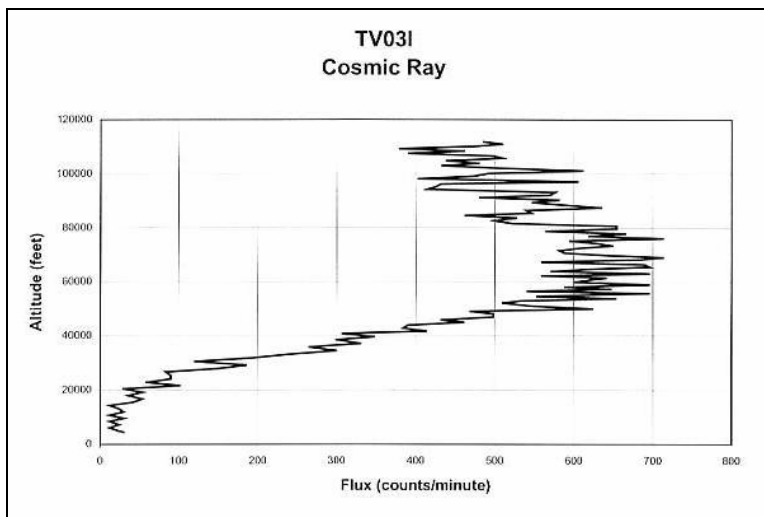
Cosmic ray showers may modify the Earth's ionosphere, ozone layer, and possibly have an effect on our weather. Cosmic rays convert nitrogen 14 atoms into the carbon 14 isotope, giving archeologists a great method of dating organic artifacts that are less than 50,000 years old.

The easiest way to detect the presence of ionizing radiation is with the Geiger counter. The electronics in the Geiger counter create a charge on the walls and central wire of the Geiger-Muller (GM) tube. The gas inside the GM tube cannot conduct electricity between the wire and the metal wall unless the air is ionized. The passage of cosmic ray is just what the air inside the GM tube needs to create an ionized channel. Once the gas inside the GM tube becomes ionized, electrons begin traveling across the tube, increasing the level of ionization inside the GM tube and creating a small

current that is amplified to become the familiar click of 1950s B-grade science fiction movies (Ah, the classics!).

Carrying a Geiger counter up in a near spacecraft lets you measure the increasing cosmic ray flux as the capsule ascends, just like Viktor Hess' 1912 experiment (but in the safety of modern technology). Keep in mind that most of those cosmic rays detected during a near space mission are atoms from outside our solar system and possibly even from outside our galaxy. Some of those detections are from particles that have been traveling through the galaxy or local universe for millions of years. Both are awesome ideas.

The one fault with Geiger counters however, is that they can't measure the energy of each detection. So Geiger counter experiments detect the increased cosmic ray flux as a function of altitude, not the energy of each detection. The energy of each cosmic ray is an important measurement when the cosmic ray flux is found to drop above altitudes of 62,000 feet. It appears the drop in cosmic ray flux occurs because the near spacecraft enters the region of primary cosmic rays. So there really are fewer cosmic rays to detect, but that each detection contains more energy.



*Cosmic Ray Flux vs Altitude*

Encyclopedia of Physics, Second edition, 1991, VCH Publishers, Inc.  
Cosmic Bullets, Clay and Dawson, 1997, Helix Books

## Near Space Humor

### Five Experiments *Not* To Perform In Near Space

1. Will a cat land on its feet if dropped from 50,000 feet?
2. If a bowling ball were dropped from 100,000 feet, how big would the resulting crater be?
3. How many phone calls would the police get if I launch a near space capsule at night if the capsule was covered in flashing strobes, spinning lasers, and playing the tune from the movie, Close Encounters Of The Third Kind?
4. How far will a spud gun shoot in near space? Can this be a test of a near space Star Wars weapon?
5. How high will a Super Ball bounce if it is released at 100,000 feet?<sup>1</sup>

<sup>A</sup> The resistors form a voltage divider for the 140PC. The ratio of the proper values of the resistors depends on the input voltage and the maximum voltage the ADC can digitize. Use at least 1k resistors to keep the current low (don't drain the batteries just to measure the pressure).

<sup>B</sup> This reminds me of a joke:

If you speak three languages, you're trilingual

If you speak two languages, you're bilingual.

If you speak one language, you're an American.

<sup>C</sup> White LEDs contain a blue LED chip that is surrounded by phosphors. The blue light causes the phosphor to emit a wide range of frequencies that combine and appear white to our eyes. Since a phosphor is involved, white LEDs are not suitable for photometers.

<sup>D</sup> If using the LED, observe the polarity. In the photometer, the LED is wired backwards, with the cathode connected to power and the anode connected to ground. If the LED emits light when the photometer is powered, then the LED is soldered backwards in the PCB.

<sup>E</sup> Scientific Wizardry carries petri dishes and agar. Contact Scientific Wizardry at: 2404 S Orchard St # 500, Boise, ID, 83705, ph. (208) 336-4958

<sup>F</sup> If you have a doctor or veterinarian to help you, bacteria cultures can be given antibiotic tests. Be sure to send a control along with the flight sample. During the test, an array of antibiotics is applied to the petri dishes. Each antibiotic affecting the bacteria is recorded and sent back as part of a report. Look for antibiotic response variation between the control and the experimental group. Ask to have the samples autoclaved after the test (this may be automatically done, but check to see).

<sup>G</sup> Non-sterile petri dishes are used in testing

<sup>H</sup> The wires must be cut long enough to reach from the top of the airframe through a hole in one of the E-Quad panels and to the servo controller of the flight computer.

<sup>I</sup> suggested by Justin Formolo, KD7PIT



# Seeds In Near Space

## 1. Goal

Seeds In Near Space exposes students to the process used in science.

## 2. Objective

Students will accomplish the following science related activities.

- A. Perform a literature search
- B. Form a hypothesis
- C. Design the experiment
- D. Prepare equipment used in science
- E. Perform a scientific process
- F. Record data
- G. Analyze results

## 3. Directions

### 3.1 Literature Search

Before a scientist performs a new experiment, he or she must research what has been accomplished to date. Since the goal is to advanced science, either a new experiment is performed, or in some cases, an older result is confirmed. The process of discovering what has been done in the past is called a literature search. The goal is to read journal abstracts to find out what has been done before. An abstract is a short description of an article. Every time a new journal article is written, the author(s) also includes a one-paragraph description of what is in the article and its findings. Once an interesting abstract is found, the entire article is read. As you can see, reading abstracts saves the scientist time.

There is no profession journal dedicated to amateur near space exploration. Therefore you will search for information over the web or be given information by your teacher. You must find the following information in your literature search.

- What are conditions like in near space?
  - What are the layers of the atmosphere and their temperature and pressure
  - Look up the name, Captain Gray, US Army, and find out his story
- What is the ozone layer?
  - What is the function of ozone?
  - What is UV?
  - What is the effect of UV radiation on organisms?
- Have seeds been sent into near space before?
  - If so, what procedure was used
  - If so, what seeds were sent into near space
  - If so, what were the results of the experiment

By the way, while it's not official, we will treat near space as those altitudes above 75,000 feet. During your literature, find a photograph taken of the horizon in near space.

Record what you have uncovered in writing. The findings of your literature search are only worth the paper it is written on!

### 3.2 Hypothesis

A hypothesis is an educated guess. One cannot form a hypothesis until they understand the background material and your literature search has given you some of that background knowledge. Now that you know what the conditions are like in near space and what has happened to some people exploring high altitudes, form a hypothesis about what will happen to seeds exposed to the same high altitudes.

By the way, a theory is a hypothesis with some experimental proof. A theory is not a guess! Calling an idea “just a theory” is actually a compliment, since it means there’s good proof for the idea. In layman’s terms, a theory in science is as good as proven.

### 3.3 Design The Experiment

To determine the effects of each of the conditions of near space on seeds, you need to control what conditions the seeds are exposed to. For example, how do you control exposure to UV radiation or the extreme cold? You must design your experiment in such a way that different factors can be isolated from one another. Keep in mind that the seeds you are sending into near space will be stored inside of test tubes. Now brainstorm ways to control what environmental conditions the seeds are exposed to during their flight. For example, what materials might you wrap a test tube in to control the exposure of the seeds inside? One hint is that the seeds do not have to be positioned outside the near spacecraft they may be placed inside (where it is warmer). After coming up with some ideas, determine which of them you can realistically perform. Write down on paper your plan of action.

- Do you know if all your seeds are viable, that is, will they germinate and grow after you plant them?
- If 50% of your seeds fail to germinate, is that normal?
- If your seeds fail to germinate, was it the low pressure or the low temperature that affected the seeds?

To determine the answer to these questions, you must create a control for each experiment you perform. In this case, a control is a sample that is not exposed to near space. Instead, they are left on the ground. To be scientific, you must compare seeds exposed to near space to seeds that are not exposed to near space. You can’t plant near space exposed seeds and identify what happened to them without having a comparison.

Therefore, you must create a set of controls. The controls must be identical to the experimental samples that will take the ride into near space. They must be treated and packaged the same as the experiments. They must also be labeled as the control so they are not accidentally launched into near space or confused with the experimental samples after recovery.

Are controls only left on the ground? Can controls launched into near space? How can you determine if UV radiation only effects plant seeds but not the cold?

Controls can test for many effects. For instance, a test tube of seeds can be sheltered from UV radiation, but still sent into near space. If the seeds are protected from UV, what near space conditions are they being exposed to?

Use several types of seeds, as some are harder than others. Small seeds chill faster than large seeds. Some seeds may have thinner outer coatings than others and may be more effected by UV radiation.

Now begin preparing the equipment for the experiment. Gather any materials you will need. Also clean a set of test tubes and stoppers (with holes in them) the day before preparing the experiment. This way the test tubes will be dry when the experiment is put together. Finally prepare the recording form. The recording form should list the following information.

Page Number \*

Test Tube Number

Preflight Notes

Seed Type

Date On The Seed Package

Photograph Number Of The Seeds Before Flight

Weight Of The Filled Test Tube Before Flight

Experiment Preparation Of The Test Tube \*\*

Postflight Notes

Observed Problems

Weight Of The Filled Test Tube After Flight

Photograph Number Of The Seeds After Flight

Germination Notes

Container Number The Seeds Are Planted In

Watering And Lighting Directions \*\*\*

Plant Growth \*\*\*\*

\* Write the page number as in the following format, page 2 of 6. This way your team can ensure there are no missing records

\*\* Indicate where the test tubes are placed during the flight and any treatment to the test tubes

\*\*\* Document what kind of lighting the planted seeds get (indoor lights, sunlight, etc) and how often they are watered. This information can be used to design future experiments.

\*\*\*\* Record how many plants are germinating and their heights. Do this daily. You will average the results, so you do not have to identify the individuals plants in the container.

### 3.4 Materials Preparations

- Several test tubes \*
- Test tube stoppers with holes \*\*
- Cotton balls
- Labels (masking tape and a pen)
- Shielding materials, like Aluminum foil or cardboard of various colors, or sunscreen
- Various seeds \*\*\*
- Rubber bands
- Temperature Sensor Array \*\*\*\*
- Digital Camera
- Chemistry Scale
- Record Form

\* Wild Goose is an excellent source of test tubes. Many hobby stores sell Wild Goose products.

\*\* Wild Goose also sells stoppers. If you can't find stoppers with holes, you'll have to cut out the holes or use corks from a hardware store.

\*\*\* Seeds are not usually available at your local gardening store during the autumn and certainly not during the winter. So plan ahead and get seeds before you needed them. Use a variety of seeds, since some are evolved to be tougher than others.

\*\*\*\* See Chapter 8, Section 9.1 for directions on building and using a temperature sensor array capable of functioning at temperatures experienced in near space.

### **Handling Packages Of Seeds**

Be careful not to lose the seeds as you work with them. Also wash your hands to ensure nothing on your hands affects the experiment. Work with one package of seeds at a time. Keep the seed packages sealed until your team is ready to work with them. Shake the first package of seeds to settle the seeds to the bottom of the package. Now carefully open the first package of seeds by cutting the very top of the package open. Be careful not to cut through writing on the package. Do not throw away the seed package after you empty the seeds; keep the package for future reference. So this means store the empty package some place safe and not in someone's locker or backpack!

### **Photographic Record**

Getting a photographic record of the seeds before the launch allows the team to identify morphological changes (changes in appearance) resulting from the flight into near space. Carefully pour (do not dump) and spread the seeds out on a sheet of construction paper with a color that contrasts with the seeds (perhaps black is a good choice). Spread the seeds just enough that they are not stacked on top of each other. Make sure the lighting is good. This means the light must be bright enough for the camera and placed so that shadows do not affect the appearance of the seeds. If possible, photograph the seeds from above and light the seeds from two opposing sides. Keep a log of the photographs taken. In the log indicate the photograph number and what seeds were photographed.

### **Filling Test Tubes**

Because the atmospheric pressure continually lowers during the ascent of a near space mission, you cannot seal a test tube with a solid stopper and expect the stopper to stay on. When the pressure drops low enough, the air pressure inside the test tube may pop the stopper off and spill the seed samples. The following procedure exposes the seeds inside the test tube without the risk of spilling them.

Fill a dry test tube about half way full with the first seed type (use one type of seed per test tube). After filling the test tube place a small ball of cotton on top of the seeds in the test tube. Now cap the test tube with a stopper containing a hole in it. Note that the hole in the stopper allows the air to escape the test tube without popping the top off. The cotton keeps the seeds inside the test tube from falling out the hole in the stopper. Label the test tubes of seeds and make sure the label remains on the test tube until after the seeds are planted. The label allows the team to refer to test tubes without ambiguity. This means that if a team member refers to test tube 1, it's the same test tube 1 now as test tube 1 at the end of the flight.

Now weigh the sealed test tube of seeds. Weighing now allows you to identify changes in mass after the flight and may indicate a factor in seed germination rates after the flight (if there are any). Be sure to record all the information on the test tube in your recording form. Clean up your work surfaces and prepare the next test tube.

Store the test tubes where they are not exposed to lots of light or heat. Because some seeds can't handle freezing temperatures, do not refrigerate the seeds until launch. However you decide to store the seeds, store all of them the same way. Now contact your local near space program and let them know your experiment is ready for flight.

### **3.5 Perform The Experiment**

Test tubes of seeds to be fully exposed to near space require a mounting fixture. This may simply be a set of rubber bands that secures the test tubes to an experiment boom. Test tubes to be left inside the near spacecraft should be rubber banded together to keep them from moving around the interior of the near spacecraft. Discuss securing options with your representative to the near space program.

Afterwards, test the method. Give the mounted test tubes and near spacecraft a good shaking to ensure the test tubes cannot become loose during the flight. Due to the nature of near space flight, the riskiest time is early in the descent, after the balloon bursts. If the test tubes can withstand a good shaking, then the mounting method is sufficient.

Every space mission requires a checklist; there are far too many things for one person to remember. Without a checklist, something will be left undone or not properly configured for the mission. The same applies to amateur near space. Each mission can cost upwards of \$150 each and take several months to plan and launch. Without a proper checklist, valuable time and money can be wasted when an experiment fails because mission requirements are not properly documented. Therefore, you must generate a checklist for your experiment. A checklist must document where each test tube of seeds is to be located. Some may be located inside the near spacecraft, some outside the near spacecraft, and others left on the ground. A checklist must also list any special preparations required for the experiment.

After testing a means to secure the test tubes and a checklist, try them out. Run through the procedures and make sure nothing was left out. Plan a time and location to mount the test tubes. This may be at the Flight Readiness Review or at the launch site on the morning of the near space launch. If the seeds need to be loaded into the near spacecraft a day or more before launch, determine where the near spacecraft will be stored and what effect that may have on the seeds. For instance, will the seeds be left in the sun for an extended time before launch?

In addition to indicating treatment of the seeds before launch, the checklist must also document the treatment of the experiment after recovery. If the control seeds are not going to be left sitting in the car, baking under the afternoon sun, be sure to document that the seeds are to be removed from the near spacecraft after recovery and kept indoors. A checklist should also tell the Chase and Recovery Team to photograph the test tubes before handling the recovered near spacecraft. Are there any other special handling requirements? Then document them.

Make sure everyone associated with the mission, the Launch Crew and the Chase and Recovery Team can understand the checklist. Be sure your checklist is incorporated with the mission checklist. Be sure the Chase and Recovery Crew has a copy of the checklist, also.

### **3.6 Record Data**

Some data will be recorded for your team by the near space program (data like the mission profile and environmental conditions). The rest of the data is recorded by your team's observation of the seeds after their flight into near space.

#### **3.6.1 Near Space Program Data**

After the launch, a Chase and Recovery Team will be responsible for recovery of the near spacecraft. They should follow your checklist and document any information regarding the recovered experiment. In addition to recording the state of the experiment after recovery, those associated with the near space program will also give you a copy of the flight log. While the flight log from each mission is different, the flight log records data like time, altitude, air temperature, and air pressure. If the air temperature and pressure are not recorded in the flight log, then they can be estimated from the altitude and the model of the standard atmosphere.

Begin by entering the flight data into a spreadsheet. You will require the following columns.

#### **Time**

Time is actually three columns, one for hours, one for minutes, and the last for seconds. Each GPS receiver displays the time of day, along with other information. Because of the atomic clocks on each Navstar satellite, the time displayed is incredibly accurate (companies like cell phone companies use GPS receivers not to locate items, but to synchronize the clocks in their telephone networks). The time is given in Coordinated Universal Time (UTC). You can think of UTC as the time in the time zone passing through Greenwich, England. Time from the GPS receiver is displayed right after the NMEA sentence (typically you will only see these two sentences, \$GPGGA or \$GPRMC) and in the following format,

```
$GPGGA,153456,.....
```

The time displayed in this \$GPGGA sentence is 15 hours, 34 minutes, 56 seconds. The first two digits are always the hours, the middle two digits the minutes, and the last two digits the seconds.

Now two questions should immediately pop into your head.

First, how can it be 15 hours when clocks only go to 12 o'clock noon? Second, how can the GPS time be so amazingly accurate when the sentence doesn't tell me the time in fractions of a second?

GPS receivers tell time in the 24-hour clock. Rather than restarting the time at 1:00 PM, they continue counting the hours after 12 as if you were counting numbers on your fingers. This means any hour greater than 12 is time after noon, or PM. Any hour before 12 is read the same way you read AM time. To convert the time after 12 hours to time PM, subtract twelve from the hours. So for example, 20 hours becomes 20-12, or 8 PM.

GPS receivers give the time in second intervals. GPS receivers will not give you the time in between the seconds. So when a GPS receiver says its 24-seconds after the minute, it really is 24-seconds after the minute to an accuracy of less than a millisecond. So there is no need to indicate fractions of a second.

Most likely the near space program will not give you the entire GPS sentence, so you will not have to edit a long sentence just to get the six characters you need for the time. However, the time will still appear in the same format as illustrated above. You will need to break up the time into hours, minutes, and seconds and put each one into its proper column.

### **Altitude**

The only standard GPS sentence to display altitude is the \$GPGGA sentence. The altitude is displayed in units of meters. After the sentence indicates number of satellites being used is the field for the altitude. You can locate this field by looking for the first occurrence of the letter m (for meters). The set of digits just before the first "m" is the altitude of the GPS antenna (and therefore the near spacecraft) in meters. There is a second field with an elevation and letter "m" displayed in \$GPGGA sentence that you can ignore (this field is called the Geoidal separation). So for instance, you may find something like this,

```
...,123456.7,m,...
```

This indicates the near spacecraft is located at an altitude of 123456.7 meters. The altitude field always gives the altitude with a precision of 1/10<sup>th</sup> of a meter. You can confirm you are looking at the altitude field and not the geoidal separation field by the fact that the altitude is always changing and the geoidal separation seldom ever changes.

Again, like the altitude, the near space program will probably give you just the altitude in meters, you will not have edit entire GPS sentences to get the altitude.

### Temperature

The temperature is usually stored on board the near spacecraft and retrieved after recovery. The data may be returned as part of a Thermochron log or as digitized values (ADC log) from a LM335 temperature sensor. If the data is part of a Thermochron log, then the data will be given in units of degrees Fahrenheit and with a precision of 1/10<sup>th</sup> degree. If the temperature data is part of an ADC log, then it will look like the following,

2346

This number indicates the voltage from a LM335 temperature sensor. To convert it back to a temperature, divide it by ten, which is the same thing as adding a decimal point after three numbers from the right. So the above number becomes 234.6. Does it make sense that the temperature of the seeds should be as hot as an oven when the air temperature will be as cold as Antarctica? The problem is one of units. The LM335 returns temperatures in units of Kelvins, and not degrees Fahrenheit. So the seed temperature is 234.6 Kelvins and not 234.6 degrees Fahrenheit. A temperature of 234.6 K is indeed very cold. The Kelvin temperature scale is named after a famous Physicist and is the temperature scale used in science. However, most people are unfamiliar with it. To convert the temperature in Kelvins to the temperature in degrees Celsius, subtract 273.15 from the temperature in Kelvins. Once the temperature is in degrees Celsius, you can easily convert it into degrees Fahrenheit.

### Air Pressure

Since pressure sensors are more expensive than temperature sensors, you may not be given a log of air pressure. If you do not have the air pressure, then consult the following website to calculate the air pressure based on the altitude.

Website URL

Notice there are several fields on the webpage. You will enter the altitude of interest and the webpage will return the air pressure.

If you are given the pressure log, then the near space program will show you how to convert it into atmospheric pressure.

### 3.6.2 Classroom Experimental Data

Work with the test tubes, one at a time. Be sure to clean your hands before working with the test tubes of seeds. First record if there were any problems experienced with the test tube. For instance, did the test tube crack or did shielding material fall off during the flight. Now weigh the test tube and record the result. Carefully empty the seeds inside the test tube onto the same sheet of construction paper used to photograph them the first time. Spread the seeds out like last time and take another photograph. Record the photograph number.

Now plant the seeds. Use the same type of container and soil for all the seeds. Label the container and record it in the record form. Repeat the above process for all the remaining test tubes.

Let the seeds germinate and begin recording the results. On a daily basis, record how many seeds have germinated and their heights. The heights should be the average height of the plants in each experimental or control group. This involves summing the height of each plant and dividing by the

number of plants (a good math exercise). The average number of leaves on the plants is another good variable to record. Consider photographing the plants as they grow. Be sure to record the date and container number of each photograph.

### **3.7 Data Analysis**

You have two sets of data to work with on this experiment, that recorded during the flight (altitude and temperature, for example) and that recorded after recovery (seed germination and plant height, for example). The data recorded during flight can be put into chart format the first class day after recovery. The seed germination and plant data must wait several days to weeks before being put into chart format. Directions for processing Excel spreadsheets and creating charts are located in sections two and three of this chapter.

#### **Making Charts**

Create the following charts from the mission.

##### **Altitude**

Make the X-axis (horizontal axis) the Mission Elapsed Time (MET). The Y-axis (vertical axis) is the altitude, preferably in meters since that's the standard for modern science (but you may want to include the altitude in feet also).

##### **Air Temperature**

Make the X-axis (horizontal axis) the Mission Elapsed Time (MET). The Y-axis (vertical axis) is the temperature, preferably in degrees Celsius since that's the standard for modern science (but you may want to include the temperature in degrees Fahrenheit also).

##### **Air Pressure**

Make the X-axis (horizontal axis) the Mission Elapsed Time (MET). The Y-axis (vertical axis) is the air pressure, preferably in kilopascals since that's the standard for modern science (but you may want to include the air pressure in either pounds per square foot – PSI, millibars (mB), or relative to sea pressure).

##### **Germination Rate**

Make the X-axis (horizontal axis) the days after the seeds were planted. The Y-axis (vertical axis) is the number of seeds that have germinated. Create a single graph for each type of seed to keep the chart from getting too complex. However, to make comparisons easier, chart the germination rate of all the conditions the seeds were tested in. Since several conditions are graphed, be sure to label the plot lines. You may find it useful to paste the digital images of the plants you took into the chart. If you choose to do so, position the images in the chart where they match the date they were taken. That is, if an image was recorded on the third day after planting, then paste the image on the chart over the third day.

##### **Plant Height**

Make the X-axis (horizontal axis) the number of days after the seeds were planted. The Y-axis (vertical axis) is the average height of the plants. Create a single graph for each type of seed to keep the chart from getting too complex. However, to make comparisons easier, chart the average heights of all the conditions the seeds were tested in. Since several conditions are graphed, be sure to label the plot lines. You may find it useful to paste the digital images of the plants you took into the chart.

#### **Looking At Charts**

Now that the team has their charts, look them over searching for differences between the control and the experimental seeds. Characteristics to look for include, differences in germination rates and



difference in average height over time (growth rate). Look at changes in the plant averages, as you will always find differences in individual plants, even among those remaining on the ground. Other changes to look for are in number of leaves and in color.

Did you find differences? If not, then perhaps the seeds are too tough for such a short exposure to near space. Don't be discouraged if there are no differences. If there are no differences, then you have either confirmed or refuted your original hypothesis.

Now decide what you want to do next. Here are two ideas. First, you can let the plants form new seeds and send those seeds up on a flight. This way multiply generations can be exposed to near space. Second, you can fly the same seeds on multiply flights. If a single flight is too short to create a noticeable effect, perhaps three flights are enough.

Finally, there is one other near space condition this section didn't cover. That's cosmic rays. Perform a literature search on cosmic rays and determine what these seeds should have experienced on their flight. Would all the seeds carried up on the flight be exposed to the same amount of cosmic rays?