by L. Paul Verhage

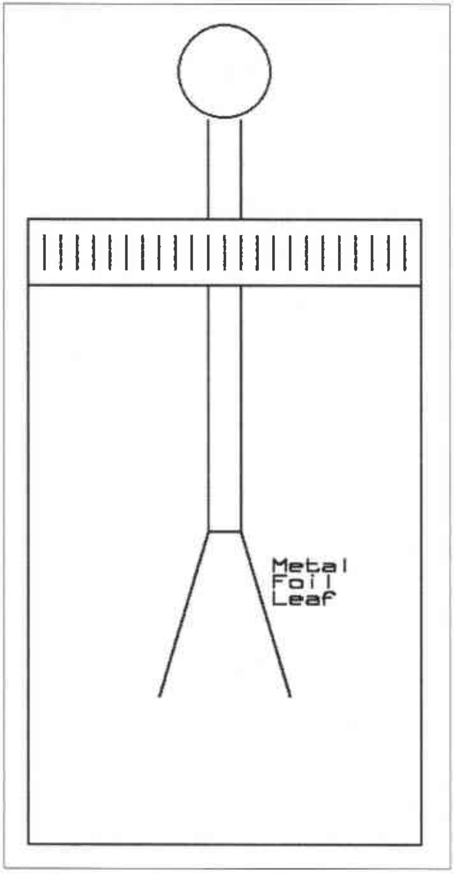
Approaching the Final Frontier

Near Space

The History of Cosmic Rays

The study of electrostatics was our first step in the field of electronics. In electrostatics, electric charges are relatively stationary. So, the natural philosophers (early scientists) who studied the phenomenon of electrostatics concentrated primarily on the creation, storage, and interaction between the two types of electric charges. One of their tools was the electroscope, a device consisting of two metal foil leaves draped over a metal rod and protected within a glass jar.

Figure 1. The electroscope.



The electroscope indicates the presence of electric charges by the spreading of its two metal foil leaves. The presence of charges of the opposite polarity is indicated by the collapse of the previously charged leaves. If no opposing electric charges are present, the leaves should remain spread apart after their initial charge.

Instead, it was discovered that, once charged, the leaves of the electroscope did not remain charged. The electroscope slowly loses its charge — no matter how dry or clean the air. The source of this discharge was unknown.

Viktor Hess' Experiment

On August 7, 1912, physicist Viktor Hess began making balloon flights with electroscopes onboard. In his flights, he rode in an open gondola under a hydrogen filled balloon to altitudes in excess of 15,000 feet. The experiments were not without risk. The hydrogen in his balloons was flammable and, at high altitudes, he found that there was less oxygen to breathe and that the air would begin to get cold.

On these flights, Hess discovered that his charged electroscopes would discharge more quickly at higher altitudes. The effect became apparent once his balloon climbed above 6,000 feet and the interference caused by natural radiation emitted by the ground.

Hess' electroscopes discharged more quickly because the air was a source of ions that neutralized the charge on his electroscope. Since the electroscope discharged more rapidly at higher altitudes, he concluded the ionization of the atmosphere increased as he rode higher in his balloon.

The increase in ionization with increasing altitude indicates that the ionization is caused by an extraterrestrial source. In other words, there was a source of radiation in space that was ionizing molecules in the atmosphere and causing his electroscopes to discharge. This same source of radiation was also discharging electroscopes on the ground, but more slowly than in his balloon experiments.

In 1936, Hess was awarded the Nobel Prize for his discovery of cosmic rays, the extraterrestrial source of radiation. Cosmic radiation was a fascinating topic for people in the last century. As I recall, there is even an old black and white Frankenstein movie that mentions cosmic rays as being responsible for the origin of life on Earth.

Initially, it was believed that cosmic rays were a form of electromagnetic radiation, like microwaves or gamma rays. Electromagnetic radiation is carried by photons, which are particles without rest mass or electric charge. Photons are not affected by magnetic or electric fields.

However, since cosmic rays *are* affected by magnetic and electric fields, they must consist of charged particles, like electrons and protons.

It took several decades to straighten out this error in books written for the general public. I can recall seeing cosmic rays listed at the high end of the electromagnetic spectrum in high school science materials. Because of this cosmic error, I got burned when correctly answering a question about the electromagnetic spectrum during tryouts for the College Bowl in 1981.

Cosmic Rays as a Tool of Science

The first particle accelerators were built less than 100 years ago. These first generation devices couldn't reach very high energies.

So, to study subatomic physics, physicists launched their experiments in high altitude balloons, where they could use cosmic rays as their source of high energy subatomic particles. The results of these experiments led to the discovery of several important subatomic particles.

One subatomic particle discovered in cosmic ray experiments was the meson. The meson was predicted to exist and be responsible for holding the nucleus of the atom together. There are actually several types of mesons — like the mu and pi mesons (called the muon and pion) — and only one is responsible for keeping the protons inside the nucleus together. As it turns out, the first meson discovered was not the one found inside the nucleus. Another particle discovered from cosmic ray experiments was the first anti-matter particle — the anti-electron or positron — which was predicted by physicist Paul Dirac.

Today, particle accelerators can reach such high energies that it's no longer convenient to do subatomic research with cosmic rays. However, that doesn't mean cosmic rays are no longer an item of research. Now, cosmic rays are researched in an effort to understand astronomical and nuclear processes occurring in the Sun and beyond the solar system.

The Nature of Cosmic Rays

Their Composition

The vast majority of cosmic rays are energetic nuclei — high speed atoms stripped of their electrons. About 86% of cosmic rays are protons or hydrogen nuclei (remember, the hydrogen nucleus doesn't have a neutron). Twelve percent are helium nuclei (alpha rays), 1% are energetic electrons, and the remaining 1% are atomic nuclei heavier than helium; these are elements that astronomers call metals. There are some high energy gamma rays and neutrinos thrown into the mix, as well.

Their Energies

One of the most amazing aspects of cosmic rays is their level of kinetic energy. Some cosmic rays carry over 100 quintillion electron volts of energy. That's enough energy to boil a thimbleful of water if all that energy could be transferred to it. (In reality, such a cosmic ray would travel right through the water, scarcely noticing it, and leave only a tiny bit of its energy in the water.)

Put another way, this amount of energy is the same as the kinetic energy of a baseball thrown at about 100 mph! Imagine the energy of a fast baseball packed into a single, invisible proton. The high energy levels found in cosmic rays allow them to make the trip to Earth at speeds very close to that of light.

The Source of Cosmic Rays

In optical astronomy, astronomers can point their telescopes in the direction of the light they are observing and see the light's source. However, galactic, solar, and terrestrial magnetic fields so thoroughly mix up the paths of cosmic rays that other methods must be used to determine their source. The possible sources of cosmic rays are determined by how they respond to the solar cycle, their composition, and their kinetic energy. So far, it's believed that there are three sources of cosmic rays.

Solar Cosmic Rays

These cosmic rays originate with the solar chromosphere (the solar layer above the photosphere — the visible surface of the Sun) during high energy events like solar flares. Solar cosmic rays tell us the types of elements and their proportion residing in the outer atmosphere of our Sun.

These tend to be the lowest energy cosmic rays. Their presence goes up shortly after a flare and can increase by a factor of hundreds to even hundreds of thousands. Such events can last for only a few hours or several days. Solar cosmic rays represent a hazard for astronauts traveling outside of the Earth's protective magnetosphere. Fortunately, our Apollo astronauts made their lunar expeditions during a time of solar quiet.

Anomalous Cosmic Rays

These are the nuclei of difficult to ionize atoms. They originate as neutral atoms drifting into the solar system from interstellar space. When exposed to solar ultraviolet radiation, these atoms become ionized. Once ionized, the solar wind can capture them and carry them away from the solar system. When traveling with the solar wind, these ions are called "pickup ions."

Pickup ions are carried to a point where the solar wind is forced to slow down from supersonic to subsonic speeds by the resistance of the local interstellar medium. This region — where solar wind flow goes from supersonic to subsonic — is called the terminal shock. Smaller versions of terminal shocks are seen within the solar system when the solar wind plows into the magnetosphere of planets.

The passage through a terminal shock can accelerate pickup ions and change their direction of travel. After multiple passes through the terminal shock, these cosmic rays can break free and travel back into the solar system, where they can be detected. The remaining, anomalous cosmic rays escape the solar system and travel between the stars.

Anomalous cosmic rays have intermediate energy levels and are representative of the atoms found in nearby interstellar space. They are influenced by the 11 year solar cycle, which changes the location of the Sun's terminal shock.

Galactic Cosmic Rays

These cosmic rays are the highest energy cosmic rays we find. They are fully stripped of their electrons. Galactic cosmic rays probably originate in supernova remnants, which are the expanding clouds of gas and dust that were once the outer layer of a massive star. The explosion itself didn't create the cosmic rays. Instead, the powerful and expanding magnetic fields and shock waves associated with supernova remnants accelerate ionized atoms.

After the ions pick up enough energy, they can escape from the supernova remnant as galactic cosmic rays and travel interstellar space. We know supernova remnants can accelerate charged subatomic particles because the radio signals the remnants emit indicate the presence of powerful magnetic fields that are accelerating electrons.

When the charged electron accelerates, it emits a radio wave called synchrotron radiation. The study of the isotopes found in galactic cosmic rays and their half lives indicates that these cosmic rays can travel for several million years before being detected on Earth.

Most galactic cosmic rays have low enough energies that the Milky Way's magnetic field bends their paths around a radius smaller than the galaxy. This effectively traps these lower energy galactic cosmic rays within the Milky Way galaxy. However, a small percentage of the galactic cosmic rays contain more energy than is available in supernova remnants.

Their energies are too great for them to be held within the galaxy's magnetic field. So, these ultra-high energy cosmic rays must originate outside the galaxy. However, these high speed cosmic rays cannot travel for long through intergalactic space before their collisions with photons left over from the Big Bang (the cosmic microwave background) significantly lower their energies.

It's believed these ultra-high energy cosmic rays originate in nearby, active nuclei galaxies, which appear to be powered by massive black holes. Perhaps, instead, these cosmic rays are trying to tell us about exotic physics occurring deep within intergalactic space.

One of the benefits of galactic cosmic rays is that their collisions with atoms in interstellar gas create some of the rare elements needed for life, but that are not synthesized by the fusion reactions within the stars.

Detecting Cosmic Rays

Geiger Counters

The easiest way to detect the

The Near Space Email Group

In an effort to share current information with this column's readers, I have created an Email distribution list under Yahoo! Groups. My Email list is not designed to replace the many lists for amateur near space groups that already exist. I plan to make announcements, update column information, and answer reader questions in this list. I will also keep subscribers up-to-date on the status of my book on amateur near space exploration.

To join the Near Space Email group, go to **http://groups.yahoo.com/**

Sign in if you're already a member of Yahoo! — if not, click under New Users, then Click Here To Register.

Under the Join a Group field, type NearSpace and then press Enter.

Under the list of groups displayed, click NearSpace (it will be the only group listed).

In the upper right of the screen, click to join the group.

I hope you find the Email list useful in your efforts to begin your own program of amateur near space exploration.

presence of ionizing radiation is with the Geiger counter. The electronics in the Geiger counter create a difference in charge between the walls and the central wire of the Geiger-Muller (GM) tube. The gas inside the GM tube cannot discharge this potential difference unless the air becomes ionized. The passage of cosmic rays 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, further 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!) Gases inside the GM tube eventually quench the ionization inside it. If it wasn't for the quenching gas, the ionization would continue, preventing the detection of another cosmic ray.

The time it takes to quench a GM tube is called its dead time. The dead time for the GM tubes I use in my cosmic ray experiments is 90 microseconds. As long as there is at least a gap of 90 microseconds between cosmic rays, my GM tube will detect them all. This means that, on an average, I can detect a flux greater than 11,000 cosmic rays per second with my Geiger counter.

There are several limitations with Geiger counters. The first is that Geiger counters cannot measure the energy of each detection, so my Geiger counter experiments only detect the increased cosmic ray flux as a function of altitude and not the changing energy of each detection.

Another limitation is that Geiger counters cannot indicate the direction of travel of a cosmic ray. In my experiments, I have no way of determining if the cosmic ray flux is truly uniform in nature. One last limitation to mention is that Geiger counters cannot indicate which type of subatomic particle was detected. My cosmic ray experiments cannot tell me if the composition of cosmic rays changes during the experiment.

That said, there are some tricks to get around these limitations and I'll discuss them in a future column. (I've been experimenting with one of them.)

Photographic Film

Some early cosmic ray experiments carried stacks of photographic film with thick emulsion between sheets of lead. When a cosmic ray collided with a lead atom, it created a shower of secondary cosmic rays that left dark streaks in the developed film. The photographic film stack was placed between the poles of a magnet.

From the dimension and direction of curvature of the streaks found in the emulsion, the type of particles created in the collision was determined. I get the impression that grad students were the ones searching through the photographic stacks with a microscope and determining the composition and energy of their cosmic ray prey.

I didn't understand how photographic stacks were made up when, in 1998, I sent a sheet of dental X-ray film up on a flight in an effort to detect cosmic rays. Of course, there were no signs of cosmic rays on the developed film.

Plastic Sheets

The collision between cosmic rays and some types of plastics damages the molecules of the plastic. An etchant will preferentially etch away the damaged plastic, creating a cone-shaped pit where the cosmic ray impacted the plastic. The type of etchant used depends on the type of plastic, but most etchants are either strong acids or bases.

The depth of the pit etched in the plastic reveals the energy of the cosmic ray responsible for the collision. The plastic visors of some of the Apollo astronauts were treated with an etchant in order to detect some of the cosmic rays that the astronauts were exposed to on their way to the Moon. An excellent source of information on this process can be found in the book *Nuclear Tracks in Solids*, by Fleischer.

A Cosmic Trip Through Earth's Atmosphere

Slamming Into Air

To a cosmic ray, our atmosphere

acts like a 13-foot-thick slab of concrete. This is a good thing for us, since we don't handle extreme exposures to radiation very well. A cosmic ray diving into the Earth's atmosphere is called a primary cosmic ray. The flux of primary cosmic rays at the top of the atmosphere is about one cosmic ray per square centimeter per second — or about the same flux of raindrops during a rain shower.

Secondary Cosmic Ray Production

When cosmic rays slam into Earth's atmosphere, they are primarily colliding with nitrogen and oxygen molecules. Upon impact, the primary cosmic ray shatters the molecule, creating a shower of lower energy particles from the subatomic zoo — subatomic particles, like neutral and charged pions, neutrons, and more protons. Neutral pions decay into gamma rays, which later create electron-positron pairs. Charged pions decay into muons, a heavier relative of the electron. This shower of particles created by the

Solution to the Voltage Divider Question

As you will recall, in the July column, I asked the question, "How can we prove that using a fixed resistor of a value equal to the geometric mean of the range of a variable resistor yields the greatest range in values in the voltage divider circuit?" Well, the readers of this column replied with the answer.

I will send Treasure Valley Near Space Program patches to the first two responses because, together, they showed me the way to mathematically prove my observation. By the time this column goes out, Erick McAfee of Texas and Colorado College Physics Professor Val Veir should have their patches. The patches were carried to an altitude of 104,571 feet onboard my near spacecraft launches at the Great Plains Super Launch on July 3, 2004.

From Erick and Val's suggestions, plus A. A. Klaf's book *Calculus Refresher* (great book, by the way) and some fooling around on my part, I have put together the following proof.

The Plan of Attack

The voltage range generated by a voltage divider is equal to the maximum voltage generated by the divider, minus the minimum voltage generated by the voltage divider. If the output voltage of the voltage divider is graphed with respect to the possible values of the fixed resistor, we get a curve that is low on its two extreme ends and has a peak value somewhere near the middle. That peak value of the voltage range will occur at a point over the fixed resistor value that is equal to the geometric mean of the maximum and minimum resistance values of the variable resistor.

By using calculus, we can make this into a max-min problem and find the point at which the slope of the output voltage curve goes to zero (this is at its peak value). At this point, we will find that the value of the fixed resistor is equal to the square root of the product of the minimum and maximum resistances of the variable resistor or, in other words, the geometric mean of the maximum and minimum values of the variable resistor.

The Proof

We begin with:
$V = V_{max} - V_{min}$

Note that:
$V_{max} = V_A \cdot [R_{fixed} / (R_{fixed} + R_{min})]$
and
$V_{min} = V_A \cdot [R_{fixed} / (R_{fixed} + R_{max})]$

I'm going to drop V_A (the voltage applied to the voltage divider circuit) from the math, since it's just a constant and doesn't affect the best value of the fixed resistor.

Making my substitution, I get the following:
$V = [R_{fixed} / (R_{fixed} + R_{min})] - [R_{fixed} / (R_{fixed} + R_{max})]$

Now, take the derivative with respect to the fixed resistor value and set everything equal to zero:
$V / d R_{fixed} = d[R_{fixed} / (R_{fixed} + R_{min})] / d R_{fixed} - d[R_{fixed} / (R_{fixed} + R_{max})] / d R_{fixed} = 0$

According to A. A. Klaf, the derivative of the equation $S = R / (R + A)$ with respect to R is equal to $A / (R + A)^2$

Making this substitution, I get the following:
$R_{min} / (R_{fixed} + R_{min})^2 - R_{max} / (R_{fixed} + R_{max})^2 = 0$

Flip the ratios (by moving them to the opposite side of the equality), multiply out the squared numerator, and we get:
$(R_{fixed}^2 + 2R_{fixed}R_{max} + R_{max}^2) / R_{max} - (R_{fixed}^2 + 2R_{fixed} R_{min} + R_{min}^2) / R_{min} = 0$

Divide the terms by either R_{min} or R_{max} (the value in the denominator) and we'll have:
$R_{fixed}^2 / R_{max} + 2R_{fixed} + R_{max} - (R_{fixed}^2 / R_{min} + 2R_{fixed} + R_{min}) = 0$

Note that we can move the minus sign into the second half of the equation and subtract the 2Rfixed to end up with:
$R_{fixed}^2 / R_{max} + R_{max} - R_{fixed}^2 / R_{min} - R_{min} = 0$

Combining like terms and moving them to opposites of the equation gives us:
$R_{fixed}^2 / R_{max} - R_{fixed}^2 / R_{min} = R_{max} - R_{min}$

Factor out the R_{fixed}^2 and move the remainder to the other side of the equation and we get:
$R_{fixed}^2 = (R_{max} - R_{min}) / (1 / R_{max} - 1 / R_{min})$

Now, at this point, I ran into a brick wall, but, knowing what I had and what I wanted, I discovered the following equation by playing around with some algebra:
$R_{min} R_{max} (1 / R_{min} - 1 / R_{max}) = R_{max} - R_{min}$

I substitute in the left side of the equation for the $R_{max} - R_{min}$ in the previous equation to get the following:
$R_{fixed}^2 = R_{min} R_{max} (1 / R_{min} - 1 / R_{max}) / (1 / R_{max} - 1 / R_{min})$

Divide out the like terms and we get:
$R_{fixed}^2 = R_{min} R_{max}$

So, the condition of having the maximum voltage range occurs when:

$R_{fixed}^2 = R_{min} R_{max}$

or when the value of the fixed resistance is equal to the geometric mean of the maximum and minimum resistances of the variable resistor.

collision of a cosmic ray is called a secondary shower.

Particles in the secondary shower continue traveling toward the surface, sometimes colliding with other molecules lower in the atmosphere and creating more secondary showers. Eventually, secondary showers are attenuated by the Earth's atmosphere, protecting us from harm. There can be millions of subatomic particles in a secondary shower and they can cover several acres of land once they reach the ground.

The secondary cosmic rays detected on the Earth's surface are mostly muons. On average, there are close to 100 of these muons impacting every square yard of land per second. Some of the surviving primary cosmic rays are so energetic that they can be detected in deep mines.

Effects

Aircraft pilots and their passengers receive less protection from cosmic rays by the Earth's atmosphere than we do at sea level. Even residents of Denver, CO (sorry EOSS) receive more radiation cosmic rays than do residents of San Diego, CA. Not only is the flux of cosmic rays greater at higher altitudes, but the flux of cosmic rays also increases the closer the aircraft flies to the geomagnetic poles. The flux is greater near the magnetic poles of the Earth because the Earth's magnetic field dips earthward and funnels cosmic rays to the surface.

The muons found in cosmic ray showers have very short half lives. Their half lives are so short that, if it wasn't for the time dilation caused by their relativistic speeds, muons would never live long enough to make the trip down to the Earth's surface, where we can detect them.

Cosmic rays may modify the Earth's ionosphere, influence cloud production, affect the ozone layer, and possibly have an impact on our weather. Cosmic rays convert some of the nitrogen-14 atoms in our atmosphere into the carbon-14 isotope, giving archeologists a great method of dating (radiocarbon dating) organic artifacts that are less than 50,000 years old.

There are several good sources of information on cosmic rays, like the book *A Thin Cosmic Rain* by Friedlander and several Internet sources. (I didn't have a problem with finding nonsense when doing my Internet search — unlike what occurs with some topics.)

Detecting Cosmic Rays with the Aware Electronics RM-60

My tool of choice for measuring cosmic rays in near space is the RM-60 Geiger counter. This Geiger counter is manufactured by Aware Electronics (**www.aw-el.com**) as a PC- or laptop-based radiation detection system. The RM-60 measures 1-1/4" by 2-3/8" by 4-3/8" and weighs a mere 4 oz. It's designed to take its power (5 to 9 volts at about 2 mA) from the serial port of a PC. Software loaded on the PC records and graphs the detections from the RM-60.

The manual that comes with each unit is very thorough and even contains background information and suggested experiments.

The output from the RM-60 is a constant +5 volt signal until an event is recorded. At that point, the voltage drops to 0 volts for the length of the GM tube's dead time. The BASIC Stamp is quite capable of detecting radiation from the RM-60.

You only need to modify a phone cable to interface the RM-60 to the BASIC Stamp. Imagine adding a radiation detector to your BOE-BOT. To interface the RM-60, you will need a telephone cable (the kind with RJ-11 jacks on both ends) and a method to connect one end of the phone cable to your BASIC Stamp.

In a future column, I will discuss the flight computer I use and how I interface sensors to it.

For now, however, you can wire the RM-60 to a Board of Education (BOE) and launch that on your near spacecraft. Let's modify the phone cable. You'll need about 10 minutes to do this.

1. Cut one end off the telephone cable (the other end is left in place so it can plug into the RM-60).

2. Strip about 1" of outer insulation

Figure 2. The RM-60 Geiger counter.

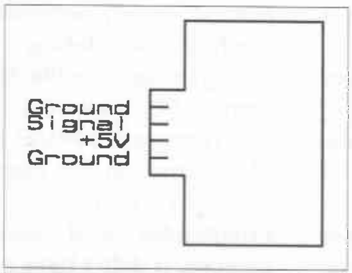


Figure 3. RM-60 pinouts.

from the cut end of the phone cable. (Be careful not to damage the insulation around the wires inside the cable.)

3. Carefully strip about 1/2" of insulation from each of the four wires inside the cable. (This is a very small gauge wire.)

4. Bring the two outer wires together and solder them together. (They are connected to ground.)

5. The second wire is the 5 volt signal from the RM-60. This wire is connected to a BASIC Stamp I/O pin.

6. The third wire is the 5 volt supply to the RM-60. This wire is connected to the 5 volt output from the BASIC Stamp. Even in high radiation environments, its current draw does not exceed 20 mA — well within the capability of the Stamp's built-in voltage regulator.

The diagram in Figure 3 is looking into the open socket of the RM-60. I have accidentally crossed my wires without ill effect to the RM-60.

The OnSet Prize

The OnSet Computer Corporation (**http://onsetcomp.com**) has generously agreed to sponsor a prize for the highest altitude amateur near space flight during the 2004 calendar year. This is the largest sponsorship to amateur near space exploration to date. By achieving the highest altitude flight this year, you will win the following OnSet products:

- A four channel, eight-bit HOBO Data Logger that measures relative humidity, temperature, light intensity, and one external voltage of your choice.

- Boxcar Pro 4 software for programming the HOBO, downloading data collected by the HOBO, graphing and analyzing data, and exporting the results to other file formats.

- An external temperature sensor (on a six foot cable) for the HOBO Data Logger.

This award is a miniature weather station for your near spacecraft and would be a part of an awesome science fair project. With the OnSet Prize, you can measure the internal temperature of your near spacecraft, the outside air temperature, the relative humidity of the air, and the Sun's intensity during flight. With these measurements, you can determine the height of the stratosphere and how it varies over the course of the year. You can also determine the rotation rate of your near spacecraft. It's very difficult to get this kind of data from a near space mission at the extremely low weight of the HOBO Data Logger and its sensors.

To be eligible for the OnSet Prize, you must accomplish the following:

1. Announce your flight at least a week prior to launch (the general launch location, callsign of the near spacecraft, and its frequency).

2. Use a GPS receiver and APRS to transmit position data during the mission.

3. Transmit APRS data such that other amateur radio operators can record the data.

4. Obey FAR 101 requirements.

5. Recover the near spacecraft.

6. Announce the results of the flight (include several packets or posits around the peak altitude).

I monitor several amateur near space group Email lists. I recommend making your announcement either on the EOSS Balloon Launch Announcement list, the KNSP Email list, or the GPSL Email list. All these groups are available to the public from Yahoo Groups.

If at all possible, please transmit your flight related packets or posits to a gateway and to the Findu website. In this way, everyone can monitor the flight.

Be sure to get my attention when you announce your peak altitude. I'll Email a reply to all announcements.

In December or once no other near space groups announce that they will launch a mission before the end of the year, I will announce the winner. Since I'm a high school teacher and take road trips during Christmas break, I will try to present the award personally. If that can't be arranged, I will send the award through the mail.

I'd like to thank OnSet Computer Corporation for sponsoring this prize. You'll find their products in the NASA Space Grant Consortium's BalloonSat Program. Be sure to check out the OnSet website and get a look at the great products they offer. You'll find a lot of justifications for launching near space missions with OnSet Computing Corporation.

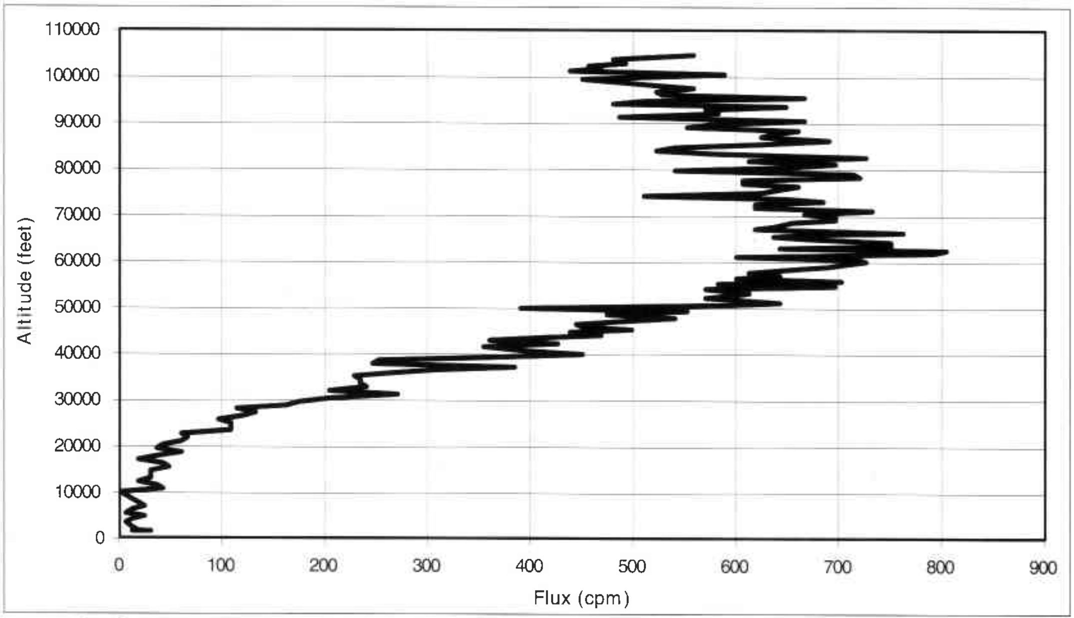


Figure 4. Cosmic ray flux.

However, I do not recommend you do this, as I may have been lucky.

I like to solder the wires of the telephone cable to a straight male header with 0.1" between centers. This type of header is available from Jameco as part number 109575. I tin each wire and then slide thin heat shrink tubing over it.

Next, I tin the short pins in the header and press a tinned wire in contact with a header pin and heat them with a soldering iron.

The solder on the wire and the header pin melts and fuses the wire to the pin. After it cools, I slide the heat shrink over the soldered connection and shrink the tubing. Afterward, I can plug the RM-60 into the BOE's breadboard or my flight computer, like I would a servo.

I use the following code to determine the counts per minute from the RM-60. My code is written for the BS2pe, so you will need to modify the count time if you use a different flavor of BASIC Stamp. On my flight computer, I store the results into a RAM Pack B. If you are sending up an RM-60 with your BOE, then you can store the results in the EEPROM of the Stamp. After recovery, you can download the results of the flight.

```
gm                CON      0
radiation         VAR      WORD

Geiger_Counter:
  COUNT gm,34843,radiation
  DEBUG DEC radiation
```

This code assumes the RM-60 is connected to P0 and counts the number of pulses from the RM-60 for 10 seconds. Since I have so many other experiments onboard my near spacecraft, my flight computer can only afford to count cosmic rays for 10 seconds at a time. After recovery, I download the results from the Geiger counter into a spreadsheet and multiply the results by six to get the cosmic ray flux in units of counts per minute.

In your experiments, you should count cosmic rays at a fixed interval. Use the APRS data from your near spacecraft to determine the altitude at each measurement. When you combine the cosmic ray count with the altitude in a spreadsheet, you generate a chart like the one in Figure 4. It shows data that was recorded and collected at the Great Plains Super Launch on July 3, 2004. My near spacecraft weighed nine pounds and made an altitude of 104,571 feet on a 1,500 gram balloon with 15 pounds of lift.

This chart is typical of what my near spacecraft measure. The flux increases with increasing altitude, as Viktor Hess would be familiar with. The cosmic ray flux increases until an altitude of 62,000 feet is reached. Higher than that, the cosmic ray flux decreases. t appears that the drop in cosmic ray flux occurs because the near spacecraft enters a region where there are primary cosmic rays that have not yet produced cosmic ray showers. There really are fewer cosmic rays to detect, but each detection on average contains more energy.

Had this flight occurred shortly after a solar flare, the cosmic ray flux most likely would have continued increasing above 62,000 feet. If the mission had taken place closer to the geomagnetic poles, the increase in cosmic ray flux would have climbed more rapidly.

So, get out there and start using the RM-60. For $150.00, it's a great little Geiger counter. I do not work for Aware Electronics and I don't receive compensation from them. I'm just a satisfied customer. Let me know how your Geiger counter experiments turn out. Remember that you can contact the amateur near space group closest to you and arrange for them to carry your experiment into near space.

Onwards and Upwards,
Your Near Space Guide

Resources

Parallax — **www.parallax.com**
Aware Electronics — **www.aw-el.com**
Jameco — **www.jameco.com**
OnSet — **http://onsetcomp.com**