CHAPTER ZERO

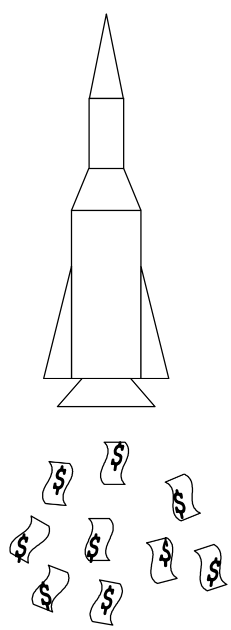
Designing Your Own Program of Near Space Exploration

"It really is a poor man's space program"
-Pete Sias (WB0DRL)

Chapter Objectives

1.0 An Introduction to Amateur Near Space Exploration[A]

Many dream of designing, building, and launching satellites into space. Unfortunately there are problems achieving this dream. But with today's technology and tools, many of us can realize some of this dream.



Launching a rocket is an expensive proposition *– Do you have money to burn?*

1.1. How Reality Hinders the Layperson's Dream of Space Exploration

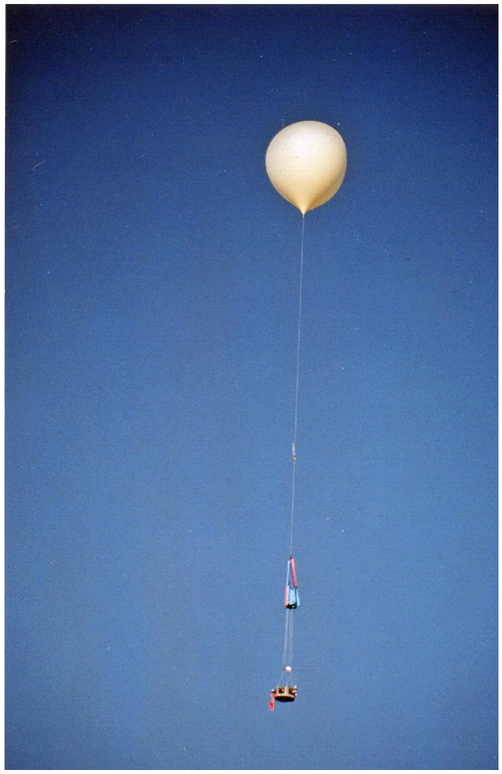
Many people reading this book dream of building and launching a satellite of one's own. However the currently high cost of launch prevents most of us from achieving this dream (this may change in our lifetimes). The cost of launch is just the first layer of cost stopping us. If we are going to spend the money to launch a satellite into orbit, we must guarantee the satellite lasts long enough on orbit to justify the high launch cost. This "insurance through construction" adds a second layer of cost to launching a satellite. How do you know your satellite is constructed properly or well enough to last once in orbit? After constructing a satellite, professionals test the satellite under launch and space-like conditions. These tests involve placing satellites into thermal vacuum and acoustic chambers for hours at a time. Since these specialized facilities aren't used as frequently as the local car wash, test time spent inside of them is very expensive. Testing your satellite after construction adds a third layer of cost to launching a satellite. Next there is the element of time. It can take years for an amateur (and non-amateurs) to construct a satellite. What is your time worth? Time spent constructing a satellite adds a fourth layer of cost to launching a satellite. Finally, there are telemetry costs. Once a satellite is on orbit, you must receive telemetry from it (if you don't then why launch it in the first place?). Do you build a ground station to receive the satellite's telemetry? If you construct your own earth station, don't forget to include salaries and training costs for the engineers operating it. Another option is to rent time on someone else's ground station. This rent is not free. Telemetry is not a one-time cost like the other costs. Telemetry costs grow year after year. One way or another, collecting telemetry from your satellite adds a fifth layer of cost to launching a satellite.

1.1.1. The Final Bill

What is your total cost of launching a satellite into orbit? First, you would pay approximately $10,000 per pound to launch a satellite into Earth orbit on a commercial launcher. Think about it: this is more expensive than a house or car. This is the kind of cost associated with some fine arts and jewelry. Second, you would pay from hundreds of dollars on up for a ready-made CubeSat microsatellite to thousands of dollars, and perhaps more, for the space-rated components needed to construct a larger satellite. Third, add several more thousands of dollars for testing the completed satellite. Fourth, you would spend from months to years of labor in design and construction of your satellite. Finally there is the money spent acquiring the satellite's telemetry. Depending on the situation, this can run into the thousands of dollars. How many readers of this book have this kind of money in their bank accounts? How many readers have enough free time on hand to complete the satellite? Are you still interested in launching a satellite into space?

1.2. The Near Space Solution

Obviously the costs described above are not showstoppers for everyone; after all, many universities and AMSAT, the Radio Amateur Satellite Corporation, launch their own satellites. The costs involved are more of a problem for most individuals and small groups. In this book I present a solution that works in most cases for these people while increasing the exposure to space related activities. The solution involves designing a satellite for missions into near space as opposed to space (or deep space). What is near space? Near space is that region of the earth's atmosphere between the altitudes of 75,000 and 330,000 feet. The Good to Know section at the end of this chapter discusses several properties of near space. Read that section and you'll see just how closely near space matches the real space environment. But first, take a look at how affordable near space can be, in both dollars and time, compared to the cost of launching a satellite into orbit.



Launching a Near Spacecraft – *No roar, no flames, and a lot less money but still awesome results and adventure.*

2.0 Amateur Near Space Exploration as an Affordable Hobby

To fly a mission into near space requires more than purchasing a helium-filled weather balloon. You also need to construct a near spacecraft, recovery parachute, launch equipment, and a telemetry station. In addition to spending money building the elements of your program, you will also spend time building the program and chasing missions. I will show you the costs of the bare bones near space program, but keep in mind that a meatier program is still very affordable.

2.1. Building a Near Spacecraft (Avionics, Airframe, and Recovery System)

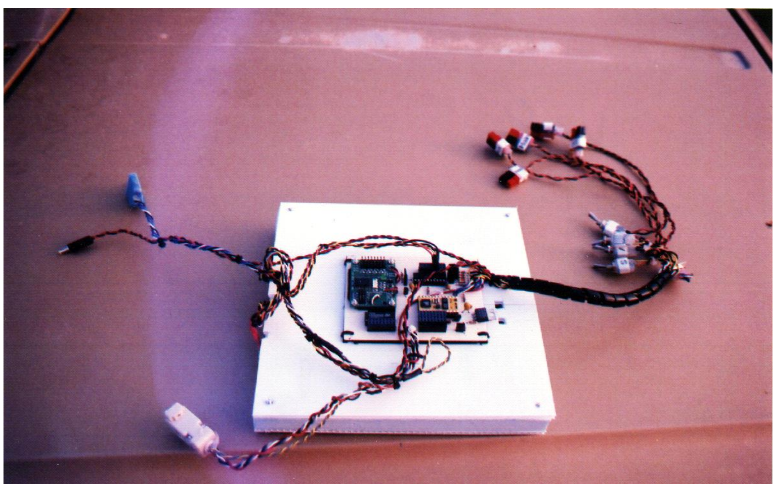
The cost of constructing a near spacecraft is broken into three categories: avionics, airframe, and recovery systems. Note that the design outlined below is for a reconfigurable near spacecraft that is launched on multiple missions without modifications to the airframe or flight computer. Think of building this near spacecraft as building your own reusable Space Shuttle.

2.1.1. Avionics Cost

Avionics is a combination of the words aviation and electronics. Near space avionics is essentially the flight computer of the near spacecraft. The flight computer operates experiments, collects data, determines the status of the near spacecraft, responds to contingencies, and telemeters flight and science data to ground stations.

AVIONICS COST	
Item	**Price**
Etrex GPS Receiver [1]	$110
BS2p microcontroller [2]	80
MIM [3]	83
MAX186 ADC [4]	Free
SSC II [5]	45
ULN2803 [6]	3
DJ-S11 2 Meter Radio [7]	80
Printed Circuit Board [8]	6
Miscellaneous Parts	10
Avionics Cost Total:	**$417**

1-7: See Endnote B for explanations and details.



Flight Computer *– A finished flight computer mounted on a pallet. Something this complex can be built on your kitchen table for less than the cost of a good set of golf clubs.*

2.1.2. Airframe Cost

The airframe is the body of the near spacecraft. The goal is to make airframes light and reusable. Styrofoam sheets meet this requirement while insulating the interior volume of the capsule.

AIRFRAME COST	
Item	**Price**
Styrofoam Sheet	$10
Hot Glue	1
Space Blanket	3
Scrim	1
Ripstop Nylon	12
Link Rings	1
Dacron Ribbon	1
Plastic Handle	3
Airframe Cost Total:	**$32**

Bill All (N3KKM) *– Preparing two modules in a near spacecraft for a <u>very</u> early morning launch. Each airframe costs less than $50. and is totally reusable.*

2.1.3. Recovery System

The simplest recovery system is a parachute. As your program matures, you will probably add recovery aids to the parachute.

RECOVERY SYSTEM COST	
Item	**Price**
Parachute Fabric (ripstop)	$80
Sewing Tape (twill)	5
Link Rings	4
Bearing Swivels	4
Dacron Line	3
Recovery System Total	**$98**

Handling the Parachute Carefully *- Keep the parachute off the ground and from getting tangled while preparing for launch. This photo was taken by a near spacecraft while we were prepping the balloon and parachute – no one realized it was taking photos at the time.*

2.1.4. Total Estimated Cost for a Near Spacecraft

NEAR SPACECRAFT COST	
Item	**Price**
Avionics	$417
Airframe	32
Recovery System	98
Near Spacecraft Total	**$547**

2.2. Operating a Near Space Mission

I have broken down the costs of operating a near space mission into four groups: the cost of ground support equipment, the cost of consumables, the cost of telemetry, and the cost of tracking and recovery.

2.2.1. Cost of Launch Support Equipment

Equipment to launch a balloon is a one-time purchase. Most of the equipment is used to fill the balloon with helium. The kite winders and folding table are used to launch the balloon and to prep the capsule. After some experience, you will probably add additional equipment to this list.

LAUNCH SUPPORT EQUIPMENT COST	
Item	**Price**
Regulator and Hose	$50
Electronic Fish Scale	25
Bed Sheet	5
Duct Tape	5
Kite Winders	10
Folding Table	15
Launch Equipment Total:	**$110**

Launch Support Equipment *– The author preparing to fill a balloon, using readily available equipment. None of the launch equipment is special order.*

2.2.2. Cost of Launch

This is the consumable cost of a mission. If you can discover a way to save and reuse the burst balloon and its helium, you'd make a million.

COST OF LAUNCH	
Item	**Price**
Balloon (1200 gram) [1]	$ 60
Helium (300 cubic feet)	100
String	1
Total Cost per Flight:	**$161**

1: See Endnote C for explanation and description.

A Near Space Stack *– this mission is just a few minutes away from launch.*

2.2.3. Cost of Telemetry

The best way to save on telemetry costs is to make friends with your local amateur radio (ham radio) community. Amateur radio uses packet radio to send digital data over the radio. Many ham radio operators are excited by the prospect of tracking high altitude balloons. So, you may initially be able to add zero dollars to your program to collect telemetry. When you construct your own mobile tracking station, you need a laptop computer, Terminal Node Controller (TNC), Handi-Talkie (HT), and licensed Automatic Position Reporting System (APRS) software. Many of you may already have some of these items.

Mark Conner's (N9XTN) Mobile Tracker *– With this, he can chase a near spacecraft anywhere.*

2.2.4. Cost of Tracking and Recovery

After you launch the near spacecraft on its mission into the stratosphere, you must retrieve it after it lands. This is the fun part of near space missions. It's like a road rally, but no one in the Chase Crew knows quite for sure where they are going to end up! Some flights only go ten miles while others may go over 150 miles, and some people drive gas efficient vehicles while others drive SUVs. Therefore, the cost of tracking and recovery varies for each mission. Fortunately, you can predict the distance traveled by the mission before deciding to launch. After spending money for fuel chasing the near spacecraft, you need to add the cost of a hearty lunch for your Chase Crew.

2.3. Building a Program of Near Space Exploration

Now let's look at the time required to prepare your equipment. Instead of spending over a year building and testing your satellite, you might spend only a few months building and testing a near spacecraft. Instead of waiting another year to get your satellite on a launch manifest, you can launch a near space flight on any day the weather cooperates. Finally, on launch day, the entire mission can be completed in time for lunch.

2.3.1. Beginning Six to Twelve Months Before Launch

- √ Earn an amateur radio (ham radio) license
- √ Or recruit local ham radio operators
- √ Practice tracking with APRS
- √ Become familiar with FAR 101[D]
- √ Build the airframe
- √ Build the avionics
- √ Sew the parachute
- √ Build one or several experiments
- √ Program and test the BS2p flight computer
- √ Assemble the balloon filling equipment
- √ Learn to use the Balloon Track program[E]
- √ Practice launch procedures
- √ Set a launch place and date

2.3.2. The Day Before Launch

- √ Pick up two tanks of helium
- √ Complete the Flight Readiness Review (FRR)
- √ Recharge the capsule's batteries

2.3.3. The Day of the Launch

- √ Arrive early to the selected launch site
- √ Fill the balloon with helium
- √ Prep the capsule
- √ Assemble the stack (capsule, parachute, and balloon)
- √ Raise and release the balloon
- √ Go on a cross-country adventure chasing the balloon
- √ Celebrate your victory with lunch at your favorite restaurant
- √ Make plans for your next launch

2.4. The Total Bill

Near space exploration is affordable; in fact, it's less expensive than many popular hobbies. For less than $1000, plus the cost of your experiments, you can build a program and fly two missions (one practice and one real) into near space. Launching a twelve-pound near spacecraft, 1.5 pound parachute, and 1200-gram balloon costs ten dollars per pound of payload. Compare this to spending $10,000 per pound of payload to launch a satellite into Earth orbit. The tasks required to develop a program of amateur near space exploration and launch your first missions can be accomplished within one year of the start date.

A near space program is one of the ultimate experiences for the technically minded. A near space project requires knowledge in a wide variety of subject fields including high tech radio technology, electrical engineering, mechanical engineering, mission planning, data analysis, recovery system design, and public relations. What ever your interest, there's something for you in a near space program.

3.0 The Near Spacecraft as an Example of an Amateur Built Spacecraft

Once in space, spacecraft are for the most part out of reach. They are on their own and unable to rely on the human hand to correct them. Being so remote, spacecraft must send telemetry if we are to know what they sense. The benefit of this remoteness is that spacecraft can perform remote sensing of the Earth and the space environment around them.

Once launched, near spacecrafts have the same limitations and abilities. Near spacecrafts are also out of our reach and must rely on sound engineering design to remain functional. We depend on reliable telemetry to monitor their progress throughout their missions. And, like spacecrafts, near spacecrafts can also remotely sense large swaths of ground and the near space environment around them.

So what kind of spacecraft does the near spacecraft most closely match? According to Rick Fleeter of Aero Astro, and other individuals, small satellites are classified by their weight. I have listed these weight categories in the table below.

SMALL SATELLITE CLASSIFICATION	
Category	**Mass**
Picosatellites	0 to 2 kg
Nanosatellites	2 to 20 kg
Microsatellites	20 to 200 kg

The Federal Aviation Administration (FAA) regulations limit the weight of near spacecrafts if we desire to launch them with minimal hassle. This weight limit is twelve pounds distributed in two or more packages, each package no more than six pounds in weight. This places the near spacecraft squarely within the nanosatellite category. If you decide to build a near spacecraft, you would be constructing a functioning model of a nanosatellite. Ask your neighbors if they build nanosatellites in their kitchen during their spare time!

Designing and building a near spacecraft is not the end of the story. Launching and recovering a near spacecraft is an involved undertaking. You must assemble ground support equipment, design flight procedures, train personnel, and implement a near space communications infrastructure before launch. As you can see, a near space program closely resembles a real space program, but on a much smaller scale.

4.0 My Philosophy for Managing a Near Space Program

Here are two of the factors influencing today's satellite market: first, companies and space programs cannot get unlimited funds from their sponsors or customers. Second, the customer (a company or the public) wants to see rapid results.

How do today's satellite designers meet these two requirements? Designers start by keeping a spacecraft's mass low. Low mass makes satellites less expensive to build and launch. This makes effective, capable microsatellite and nanosatellite designs one of the hottest goals of today's satellite market. To meet the need for rapid turnaround time, many satellites are designed under some sort of a faster-cheaper-better paradigm. This includes designing nanosatellites with a small design team, where each member of the team is knowledgeable with most aspects of the satellite design. This also means a lean management style with limited numbers of management or responsibility layers (which is a very good thing, as you will never have enough people involved).

What limitations apply to you as a near spacecraft designer? First, you have a weight limitation placed upon you by the FAA (There are also other reasons to keep capsule weights low, and I will cover those in later chapters). Second, you probably do not have enough time, money, or commitment from other individuals. As a result, you design and build near spacecraft in ways similar to today's microsatellite designers. You design and build lightweight near spacecraft. You manage a small team of personnel where each team member is knowledgeable of most, if not all, of the near spacecraft and its launch systems. You build your near spacecraft in a manner similar to the Naval Research Laboratory (NRL) or the first OSCAR (Orbiting Satellite Carrying Amateur Radio) satellites. You do not design and construct large and expensive near spacecrafts requiring years to build and launch. Finally, you do not use committees for the design and construction of near spacecraft. Besides, committees design near spacecrafts slowly (if at all) and often the product is still unacceptable to most people.

If many people want to get involved in your near space program, then I think it is best to divide them into small groups and give each group responsibility for designing their own near spacecraft. However, do have them select a standardized design as outlined in this book, so the modules are compatible. Don't get discouraged if no one volunteers to get involved in your program. Being the only person with the responsibility to build an entire program is possible, but you will probably need to rely on occasional outside expert help. You will also require the help of others when you're ready to launch. But you have time to get that help, and having a completed near spacecraft helps getting that tracking and recovery support.

Here is an example of what is possible when only a few people manage a near space project. Back in 1996 I created the Kansas Near Space Project (KNSP). It required less than two years to build and launch the first near spacecraft, and that was without the help of this book. I was very fortunate to have access to experts when questions did arise. The KNSP launched nineteen missions in just thirty months. KNSP near spacecraft reached altitudes ranging from 51,500 feet to 114,600 feet (an amateur record at the time). KNSP flights returned video, still images, cosmic ray counts, along with other experimental results and tests. The project even launched cockroaches into near space!

So here it is in a nutshell: if you want to explore near space, run your program like today's microsatellite designers. Rely on small teams. Make sure each team member understands as much of the near spacecraft as possible. Do not let members of the team focus on tiny portions of the program or near spacecraft. Construct several near spacecrafts quickly and cheaply. You will have time to expand near spacecrafts in the future; so don't get bogged down with endless design revisions. Do not try to design a near spacecraft that pleases everyone, as chances are it cannot be done. If design modifications are necessary, rely on designing multiple generations of near spacecraft where each new design is based on previous designs. Evolution in design is better than revolution in design as there will be fewer errors. Read this book to select a standard and try to stick with it.

5.0 Is Near Space Right for You?

Can you afford to be somewhat single minded about a hobby for a few months? Do you enjoy reading some of the less popular science books in the Borders bookstore? Do you want to design some really clever experiments? Do you get a thrill risking several hundred dollars of your own equipment? Do you thrive on the excitement of driving into small towns in vehicles loaded with high tech electronic equipment? Do you have a desire to drive dusty gravel roads eating two pounds of road dirt? Do you want to attract the attention of the techie babes (or if you are female, the techie studs)?

If you answer yes to these kinds of questions, then amateur near space exploration is just your kind of hobby. After beginning a near space program, you're going to have some of the most amazing pictures hanging on your living room walls.

6.0 The Organization of This Book

I have written this book in fifteen chapters (zero through fourteen) and five appendices. Each chapter deals with one aspect of building and operating a near space program. After each chapter's primary focus is a short topic covering background information. This information is for those who want to know more than just how to build and launch near spacecrafts. Each chapter concludes with a short humor section. Some of the humor will be top lists while others are humorous, but true stories from my near space files. I believe you will enjoy the content and humor of each chapter.

After completing the contents of each chapter, you will have a functioning program of amateur near space exploration. Following this book will spare you some of the head banging I went through when designing my own near space programs. This book will also introduce you to some of the people in the amateur near space community and I hope you will have the opportunity to meet these people. They are all wonderful to work with and know.

So are you excited about amateur near space exploration? Are you ready to begin building your own program of amateur near space exploration? Then pour yourself a nice cup of tea and start reading!

Onwards & Upwards!
– L. Paul Verhage

Good To Know: The Near Space Environment

Near space? This is probably a new term for you. Let me explain why I call the region of the Earth's atmosphere above 75,000 feet near space.

Most aircraft fly at altitudes below 50,000 feet. Military spy planes, the U-2 (not the rock band) and SR-71 for instance, fly at higher altitudes (higher than 100,000 feet in the case of the SR-71). Flights of the X-15 reached higher altitudes still. However the X-15 was really a rocket with wings rather than an airplane. According to the International Aeronautical Federation (FAI), space begins at an altitude of 62.5 miles or 100 kilometers. This is equal to 330,000 feet. At 63,000 feet the atmospheric pressure is equal to the vapor pressure of water at a temperature of 98.6 degrees F. In other words, your blood would boil. This altitude is called the Armstrong Line, or the boundary of the aerosphere. Above this transition zone the sky changes from dark blue to black and you can begin to detect the Earth's curvature. This transition occurs somewhere around 75,000 feet. I call the region of Earth's atmosphere above 75,000 feet near space because of what it looks like. Besides, 75,000 feet is a good round number.

Blood Boils in Near Space

Let us compare environmental conditions at mean sea level, at 85,000 feet, and on Earth orbit or 300 miles overhead. In the table below is listed the following conditions: average air pressure, distance to the horizon, color of the sky, and cosmic ray flux and type of cosmic ray at these three altitudes.

Some Visible Characteristics of Near Space				
Altitude	**Pressure**	**Horizon**	**Sky Color***	**Cosmic Rays****
Ground	1013 millibars	3 miles	Blue	4 counts/min All secondaries
85,000 feet	20 millibars	350 miles	Black	700 counts/ Min Primaries and Secondaries
300 miles	0 millibars	1500 miles	Black	? All Primaries

*** Chapter Fourteen discusses the topic of sky color ** Chapter Eight discusses the topic of cosmic rays**

You can see from this table that conditions in near space are much closer to what astronauts see in orbit than to what we see on the ground. The atmospheric pressure at 75,000 feet is about 3% of the air pressure at mean sea level. Put another way, near space has at least 97% of the vacuum available in space. The atmosphere of near space is far too thin to scatter or refract sunlight. This makes the sky above the horizon black, rather than blue as seen from the surface. With so little air above 75,000 feet, sunlight is more intense than at the Earth's surface. In near space the Sun's UV flux increases. The increased UV flux occurs because near space is within the Earth's protective ozone layer. Not only does the atmosphere protect us from dangerous UV, the atmosphere also protects us from cosmic radiation. At altitudes above 62,000 feet the cosmic ray flux is some 200 times greater than on the ground. In near space the energy of each cosmic ray is also much greater. During an ascent into near space the air temperature drops to between –60 degrees to –90 degrees F. This combination of low pressure and temperature makes near space lethal to unprotected animal life. Conditions at 100,000 feet are identical to environmental conditions on the surface of the planet Mars.

At 80,000 feet the Earth's horizon is over 300 miles away. This is over one hundred times farther away than the horizon is for an adult on the ground. At 100,000 feet, the Earth's horizon increases to over 400 miles away. Compare this to what Shuttle astronauts see. In low Earth orbit astronauts see a horizon that is about 1500 miles away. Astronauts see a horizon that is only four times more distant than the horizon in near space.

One final observation: earlier it was stated that near space is not a microgravity environment. Because of the $1/R^2$ nature of gravity, at an altitude of 100,000 feet the near spacecraft weighs 1% less than it does at sea level. It's not microgravity, but it is measurable.

In most characteristics the near space environment is closer to what Space Shuttle astronauts experience in orbit than what we experience closer to the surface of the Earth.

Near Space Humor: A Real Near Space Mission [F]

JNSC *– Preparing to launch from the Johnson Near Space Center.*

The early morning of June 6, 1998, was clear and starlit. On mornings like these I begin my day with a trip to the office. There I check out the latest weather reports, winds aloft reports, and any late email messages. According to the morning's winds aloft report, our near spacecraft would recover near Kansas City. After completing these preliminaries, I drove to the KNSP launch site, the Johnson Near Space Center (JNSC). As the program manager I try to arrive first at the center where I turn on the lights and throw open the doors to welcome my volunteer launch crew. However, this trip to the JNSC would be a little bit different. Only a few miles away from the JNSC, a deer decided to run out in front of my Ford Escort. Needless to say, the deer did not win this confrontation. My car did not do so well either. There was no way I could drive this car on the chase. I would have to ride with someone else.

This launch would be our second time to launch two near spacecrafts at once. Usually KNSP only launches one near spacecraft at a time. Launching two at a time permits KNSP to get twice the data and experience with only a little more than one launch's worth of effort. My seasoned crew efficiently filled both balloons (1500 grams each) and certified the near spacecraft ready for launch. I believe the first near spacecraft launched was the Asimov II. It carried a small Styrofoam glider among other experiments. The program for this flight would release the glider at 50,000 feet. But the release mechanism decided to act up on this flight and released the glider at an altitude of 200 feet instead. If nothing else, it verified the mechanism worked and that a glider can be released from a near spacecraft and recovered. Next followed the launch of a near spacecraft named Sagan. Whereas the Asimov II was a general purpose near spacecraft, the Sagan was solely designed to loft a camcorder into near space as part of a KNSP program called VINES (Video In NEar Space). The second launch was flawless. Now it was time to pursue the near spacecraft. Mark Conner (N9XTN), the KNSP Meteorologist, gave four chase crewmembers a ride for this flight. Originally his passengers had planned to take the author's car on this chase, but the deer changed those plans.

The second incident of the launch occurred when the Asimov II passed 14,000 feet. Its onboard GPS hiccupped. This hiccup fooled the onboard electronics, placing the near spacecraft into descent mode. Now that it was in descent mode, the near spacecraft stopped performing experiments. The near spacecraft continued to transmit telemetry, but only engineering data and no science data. The Sagan continued sending telemetry every sixty seconds. It also continued recording video and would attempt to record balloon burst. I had high hopes for some spectacular video footage.

At 90,000 feet the Asimov II balloon burst, terminating its flight. At the same time, Chase Crews noticed the altitude of the Sagan was 98,000 feet, a record altitude for KNSP at the time. However we also noticed that the last telemetry was fifteen minutes old. Apparently the Sagan had failed at 98,000 feet. I surmised the balloon had burst and that the descent damaged its electronics. Fortunately there was a back-up, low-power transmitter on the Sagan. The plan was to use that beacon to track the Sagan after we recovered the Asimov II.

In Bonner Springs, Kansas, we left Bob Davis (K0FPC) to begin tracking the Sagan. Mark, Charles, Nathan, Tater, and I continued to Independence, Missouri to recover the Asimov II. There was so much traffic on the roads that I thought we would never get there. Eventually we did get through Kansas City and approached one of its suburbs, Independence. The wonderful thing about tracking a near spacecraft with APRS is that you know its exact location. You also know exactly what roads get you there. I gave helpful comments to Mark as he drove, but Mark probably thought I was not being very helpful at all. We made a turn into a residential section of town and were approaching the near spacecraft, finally. There were so many cars parked on the side of the road that we could not see the near spacecraft on the ground. However, we did notice some half dozen people gathered in a circle, looking down at the ground. It did not take a rocket scientist to figure out what was going on, although we did have five rocket scientists in the car. As we pulled up to the curb I said to everyone in the car, "X-Files, everyone." We exited the car and approached our audience. "Don't worry about it, we'll take care of everything," we said walking up to them. We explained to the homeowners and their neighbors what they had found. As is usual, we found the homeowners interested in what we were doing. Except this time there was a surprise for us! The homeowner had called a local television station. That's right; he called the news rather than the police when this strange object parachuted into his front yard. In fact, his wife saw the near spacecraft from the living room window as it landed in the yard.

It was fortunate that a television crew was on the way. This gave KNSP the opportunity to ask the local community to help look for the Sagan. Presently the news crew arrived and interviewed the homeowner and the author. That evening, a story about a near spacecraft landing in someone's front yard made the television news in Kansas City! After the interview we packed up the near spacecraft and headed back to Bonner Springs. From there we began our sweep in search of the Sagan. We received extra help when Don Pfister (KA0JLF) and his wife, Cris (N0XZB) met us. Unfortunately, the beacon of the Sagan had the same frequency as some home electronics. I'm sure many homeowners wondered what we were doing driving slowly up and down their streets, occasionally stopping the cars to get out for a walk around someone's yard with radios. I suppose we should count ourselves lucky that we were not arrested.

Since we were not detecting the Sagan's beacon, we decided to take to the air. From the air you can see for miles and also into fenced-in backyards. Outside Leavenworth, Kansas we found a cemetery that owned a private airstrip. The plan was to find a private pilot willing to take one of us up in his or her airplane. We arrived at the airstrip to find a locked gate. Fortunately, an old man on his motorcycle did show up a few minutes later. He turned out to be a private pilot who owned a Cessna 152 parked at the airstrip. Best of all, he said he'd be delighted to take a passenger up at no cost in search for the Sagan. Nathan volunteered for the ride. We outfitted him with some radio gear and saw him off. With any luck he would return with a visual confirmation of the Sagan's landing position.

While we waited, Don was occupied with business of his own. The next thing we knew, he had arranged for a flight with an ultralight instructor. The instructor owned a two-seater ultralight. Don would ride in the back as observer while the pilot flew him over the Leavenworth. We also outfitted Don with radio gear and saw him off. However, on its trip down the runway, the ultralight's engine throttled down and the pilot taxied back. The engine's fuel supply had stopped supplying the engine. After a few seconds of searching, the pilot found the cause of the problem. Don's helmet had bumped the fuel valve above his head. Don had accidentally killed the fuel flow to the engine. Fortunately he discovered this while still on the ground. There was no floor beneath his feet. Don worried about being pulled out of the ultralight when they were taxiing on the runway if he did not keep his feet up. Now not only did Don have to crouch down for the flight, he also had to keep his legs up. Now that Nathan and Don were airborne I felt confident we would find the Sagan.

With in an hour both Nathan and Don returned to the airstrip with no sight of the Sagan. Either they didn't see it, or the near spacecraft landed outside our predicted recovery zone (it turns out the Sagan recovered on the very edge of the predicted recover zone). The only thing to do now was to go home and hope someone would find the Sagan and give KNSP a call. Before we left for home though, we stopped at a pizza parlor for a well-deserved dinner. My volunteers were not helping the situation any with their jokes about my deer collision. Have you ever had a time when you wished everyone would change the subject?

The next morning the television station, Channel Four, gave me a call asking for additional details. After lunch they called a second time: one of their listeners reported seeing the previous night's newscast. The listener had an object similar to the Asimov in his backyard. I immediately called the second homeowner to determine if what they had was a radiosonde from the National Weather Service (NWS). No, it was not, the device had a KNSP label on it! I drove the two-hour trip to Tonganoxie feeling like I was at 98,000 feet. Once there, I finally recovered the Sagan and drove it home. At home the first thing I did was to review the video of the balloon burst. Talk about spectacular! The camcorder was recording as the balloon shredded at 98,000 feet in pitch-black skies. As the Sagan made its screaming descent, fragments of latex and a swirling cloud of talcum power remained behind. This is not the first record of a balloon burst in near space, but it was the clearest record of the event. I could not have asked for more!

Now, this is not a typical near space mission. Normally they go a lot more smoothly. Nothing gets lost, and chase crews are usually close enough to observe the landing. Instead of a 36-hour flight, typical near space missions take only three hours to complete. Chase crews most often share lunch after the recovery and are home in time for dinner. I hope soon you will have stories to tell of your own near space adventures.

A

This article was adapted from the author's 18 March 2002 presentation at the Space and Robotics 2002 Conference, Albuquerque, NM. The Idaho Space Grant Consortium and Dr. Basart of Iowa State University made this presentation possible

B

1. **Garmin makes several models of the 12 channel, Etrex Global Positioning System (GPS) Receivers. The basic Etrex is the least expensive model available. Garmin is online at www.garmin.com**
2. **The BS2p is the BASIC Stamp® 2p microcontroller module by Parallax, Inc. This microcontroller is based on one of the Ubicom SX microcontrollers and is programmed using the PBASIC language. Parallax is online at www.parallax.com.**
3. **The Micro Interface Module (MIM) is a one-way radio modem (a mo rather than modem?) for radios. The MIM is also built around a Microchip PIC microcontroller. A MIM can be ordered from http://web.usna.navy.mil/~bruninga/mim22.html.**
4. **The MAX186 is an analog-to-digital converter (ADC) IC with a resolution of 12 bits and eight separate channels. An ADC converts analog voltages from a sensor to digital values for the BS2p. Maxim IC will send two free sample ICs if requested. The Maxim website is at www.maxim-ic.com.**
5. **The Serial Servo Controller II (SSC II) was developed and is sold by Scott Edwards Electronics (Seetron). The SSC II is also based on a Microchip PIC microcontroller. Sending simple serial commands to the SSC II allows the BS2p to position up to eight servos and reduces the workload of the BS2p. Order SSC II's from the web at www.seetron.com.**
6. **The ULN2803 is an eight darlington pair IC. This IC allows the BS2p to control up to 12 volts at currents of one amp, compared to the 5 volt, 20 mA limit inherent to the BS2p.**
7. **Alinco is a manufacturer of amateur radio gear. The DJ-S11 is a lightweight, handheld radio with an output power of 340 mW. This is sufficient power for line-of-sight communications of over 300 miles.**
8. **This price assumes you make your own printed circuit boards.**

C

One 1200-gram balloon can carry near spacecrafts to altitudes of least 85,000 feet.

D

FAR 101 refers to Federal Aviation Regulation, Section 101. This section governs untethered balloon flight.

E

Balloon Track is a program for predicting the flight of a balloon, including its recovery zone. The program is available at no cost from the Edge of Space Sciences website at, http://www.eoss.org.

F

Excerpted (and embellished) from the author's article in the February 1999 issue of QST.

CHAPTER ONE

Constructing the Near Space Capsule Airframe

"Let us create vessels and sails adjusted to the heavenly ether, for there will be plenty of people unafraid of the empty wastes"
- by Kepler, in a letter to Galileo

Chapter Objectives

1.0 Two Simple Airframes

In the first section of this chapter I'll describe two quick-to-make airframes that near space groups have used very successfully. One of these airframes, along with a simple tracker and parachute, quickly gets your first mission airborne. These simple airframes are ideal for getting a program started while you construct more complex airframes and flight computers.

Lunch Bag Airframe *– Airframes can be built from anything that is lightweight and provides some insulation, including reusable lunch bags.*

1.1. A Fast and Simple Airframe – The Lunch Bag

What is the fastest way to get into near space? Probably by using an airframe that is available from your local department store. A good example of a quickly constructed airframe is Mark Conner's (N9XTN) first near spacecraft. Mark constructed his first airframe from a reusable lunch bag. These lunch bags are insulated and soft-sided. The lunch bag's only closure is a zipper which wraps three quarters of the way around the bag. This airframe design provides both cushioning and insulation for the interior avionics. To maintain the airframe's dimensions, cut a block of foam rubber to fit the interior shape of the lunch bag. Either cut pockets into the foam rubber block to immobilize the avionics inside the airframe, or tie the avionics to a corrugated plastic pallet. The lunch bag's handle strap secures the recovery parachute to the airframe. However, the recovery parachute's single attachment point makes this airframe twist more frequently. This makes the reusable lunch bag a less stable camera platform, which is most noticeable during the early descent of the near spacecraft after balloon burst.

It can be difficult to integrate external experiments into this style of airframe, as the soft-sided bag provides little mounting capability. However, experiments designed to mount either inside the airframe or to dangle freely outside the airframe are easily integrated. To keep from having to cut a foam rubber block for each new mission, cut an extra open pocket into the original foam rubber block. Place the internally mounted experiment into this pocket and fill the remaining open space with Styrofoam[A] peanuts. A cosmic ray experiment consisting of an internally mounted Geiger counter or an environmental sounder consisting of externally mounted temperature, pressure, and relative humidity sensors are examples of interesting experiments you can carry on this style of airframe. Exercise caution when closing the bag's zipper on cables extending from the interior of the bag.

Cameras are a bit more difficult to fly in this style of airframe but can still be flown. In this case it is best to mount the camera inside the airframe and to cut a hole into the wall of the airframe for the camera lens. Sew the raw edges of the cut hole to keep the fabric of the lunch bag from fraying and the bag's insulation from falling out. Keep it simple by using a camera with an automatic timer. Some of these cameras are available with delays of up to ten minutes. How about sending a camcorder into near space? The camcorder takes up more space than a camera, so a change needs to be made. There's no reason a second lunch bag airframe can't be attached to the original lunch bag airframe by strong nylon lines or Spectra[B] kite line (the preferred line). The camcorder is then placed into its own lunch bag. Use a cut foam rubber block to securely mount the camcorder into its airframe. If you send a camera or camcorder into near space, make sure you remember to open the camera lens and start the camcorder before launch.

1.1.1. A Fast and Simple Antenna

The best antenna for this style of airframe is one designed to dangle freely. As an example, Mark's first near space antenna is a J-pole made from ladder line. One end of the ladder line connects to the BNC-type antenna cable connector of the Handi-Talkie (HT) inside the airframe. The ladder line then passes outside the airframe through the slightly unzippered lunch bag and hangs freely below the near spacecraft. Telemetry from Mark’s near spacecraft is very good with this antenna. Ground stations hundreds of miles away regularly receive telemetry from Mark’s near spacecraft. A second type of antenna is a soft dipole, with the top element tied to a parachute shroud line. The bottom element of the dipole antenna is left to dangle below the airframe. See Chapter Three, Section Three for information on making these antennas.

1.1.2. A Fast and Simple Tracker as Avionics

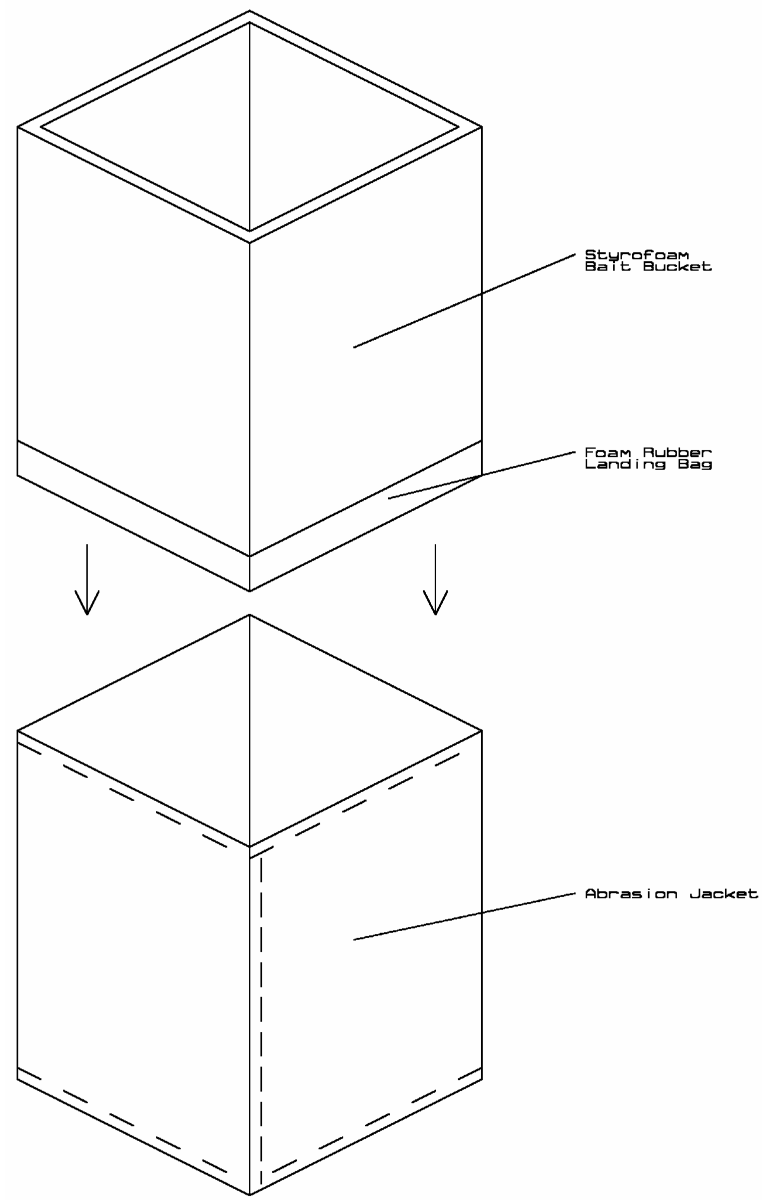
Individuals looking to get into near space in a jiffy can use the above airframe design coupled with a simple automatic position reporting system (APRS) tracker as avionics. Three examples trackers are: 1) the Kenwood D-7A data radio and global positioning system (GPS) receiver; 2) theTiny Trak II with a Garmin GPS receiver and Alinco DJ-S11; and 3) the MIM with a Garmin GPS receiver and an Alinco DJ-S11 HT. In the case of the D-7A and GPS receiver, mount the avionics inside pockets cut into the foam rubber insert. In the case of the Tiny Trak II or MIM, mount the GPS and HT inside a pocket cut into the foam rubber insert and zip tie the Tiny Trak or MIM PCB to a sheet of corrugated plastic placed in the bottom of the airframe. For information on building this simple tracker or flight computer, read Chapter Two, Sections Five or Six. Of course an APRS tracker limits the science your near spacecraft can perform. More can be done if you replace the APRS tracker with a flight computer as described in chapter three.

Interior of Lunch Bag Airframe
-The interior of Jeff Melanson’s (K7INN) lunch bag airframe. Inside, the GPS, TNC, HT, and a thermochron are cushioned with foam rubber.

This design, a reusable lunch bag, dangling J-pole antenna, and simple APRS tracker, may be just the thing to introduce a radio club to near space activities. This may be especially true when the club is hesitant to spend the time and money to create a more advanced program. Some near space programs with more elaborate avionics use this design as a backup tracker on near space flights.

1.2. A Slightly More Complex Airframe – The Bait Bucket

For an airframe with more flexibility, you might try Bill All's (N0KKM) first design. Bill's first near spacecraft was the popular Styrofoam cooler or bait bucket with a homemade abrasion jacket.



Bait Bucket with Abrasion Jacket *– Jacket patterns to follow.*

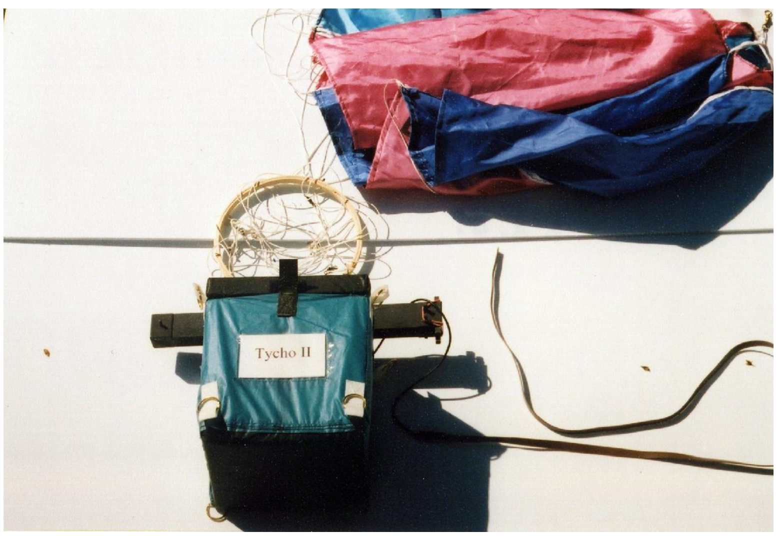
Its foam walls provide both insulation and a solid surface for mounting external experiments. It is difficult to cut experiment ports into a bait bucket. However, small experiments can be mounted to the antenna boom of the bait bucket airframe. After making the abrasion jacket for the bait bucket airframe, mount the antenna on top of the bucket lid. See Chapter Five, Section Three for directions on making the antenna boom. Since the airframe always has an HT inside of it, the coax to the HT's external antenna should be permanently mounted into the airframe. Cut a small hole in the foam wall of the cooler or bucket lid and pass the coax through it. Seal the hole with caulking compound or a chunk of cut foam. As for a recommended coax to use, read Chapter Four, Section Three on making antennas with lengths of pre-crimped coax.

1.2.1. Mounting Avionics and Internal Experiments

One method of mounting avionics is to cut a sheet of corrugated plastic material, such as Coroplast[C], to fit the bottom of the airframe, and simply zip-tie the avionics to this "pallet". If pockets on the pallet are needed to hold components like the HT, they can be built into this avionics pallet by hot gluing Styrofoam blocks to the corrugated plastic.

Internal experiments placed inside the airframe will bounce around during a mission, causing endless mischief. To prevent this from occurring, fill the remaining internal space of the airframe with foam peanuts. However, be sure you DO NOT use biodegradable peanuts! These peanuts dissolve in water. If there is any condensation inside your airframe during a mission, you will end up with a thick starchy muck coating your avionics and experiments. Personally I believe the S-shaped peanuts are better than the shell-shaped peanuts, as the S-shaped peanuts occupy more volume and can't pack as tightly as the shells.

1.2.2. Attaching the Recovery System



Bait box Capsule With Parachute Attached to Jacket *- A bait bucket modified into a near spacecraft module. This one operated as a backup tracker for a mission reaching 98,000 feet.*

In this style of airframe, unlike a reusable lunch bag, there is no handle for attaching the recovery system (the parachute's shroud lines). If you mount the parachute's shroud lines to the airframe through holes drilled into the Styrofoam, the lines will rip up the airframe once the balloon bursts. When this occurs the ground slows the near spacecraft's descent speed, instead of a parachute (this is known as lithobraking, as opposed to aerobraking, and is frowned upon by the FAA). Obviously, this recovery method is very hard on hardware and property. So let me recommend a better method for attaching recovery systems to Styrofoam cooler and bait bucket style airframes.

This method uses a fabric bag (a jacket) to hold the airframe. Attachment points for recovery systems and other modules are sewn securely into the jacket. The airframe is not required to withstand the stress of the recovery system's shroud lines. You need the following materials to make the airframe jacket:

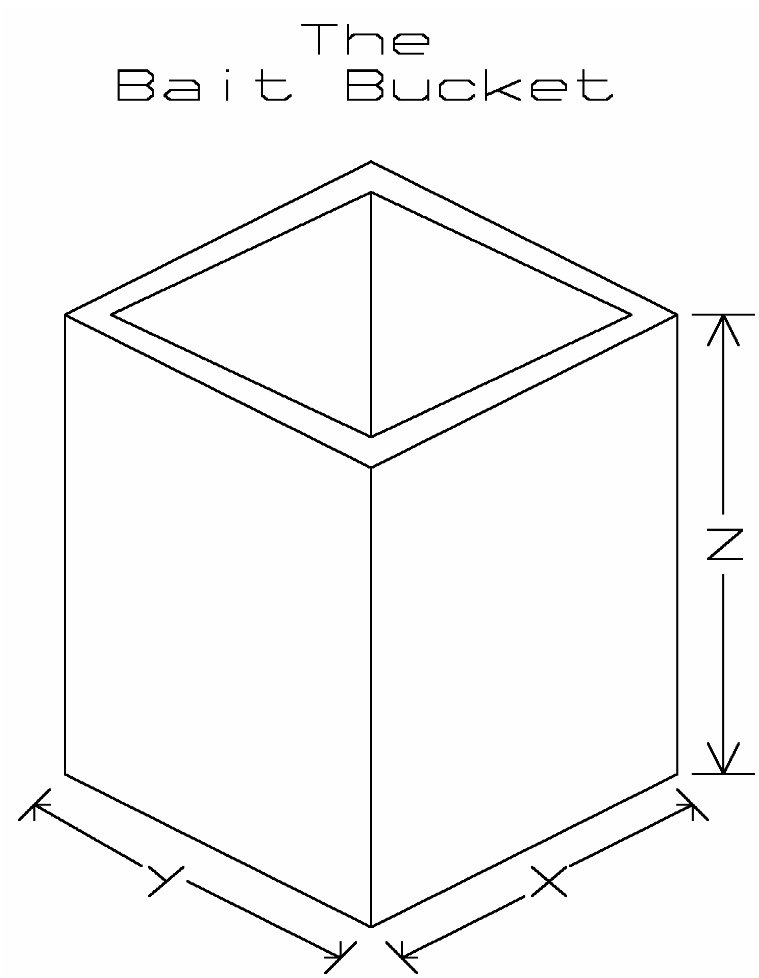
- Two yards of ripstop nylon[D]* (also called spinnaker cloth)

- One yard of ¾" Dacron[E] tape*
- Eight 1" split key rings
- One yard Velcro[F]
- One yard of thin clear vinyl

* Purchase these materials from a kite store, such as Into The Wind (www.intothewind.com)

Jacket Pattern, Marking and Cutting Ripstop

If you're good at visualizing geometry, you can measure the dimensions of your airframe and cut the ripstop to size. The pattern for a seven-inch cube bait bucket is presented in this section. There are three pieces in the pattern: the bottom jacket, the side jacket, and the hatch jacket. The side jacket forms a square tube that wraps around the bait bucket. The bottom jacket is sewn to the bottom of the side jacket after Dacron loops are attached to the side jacket. The hatch jacket fabric is wrapped tightly around the Styrofoam lid of the bait bucket and hand-stitched in place.



***Bait Bucket Dimensions** – For my bait bucket, x=7", y=7", z=6", however, I added 1" of foam rubber to the bottom to make z=7".*

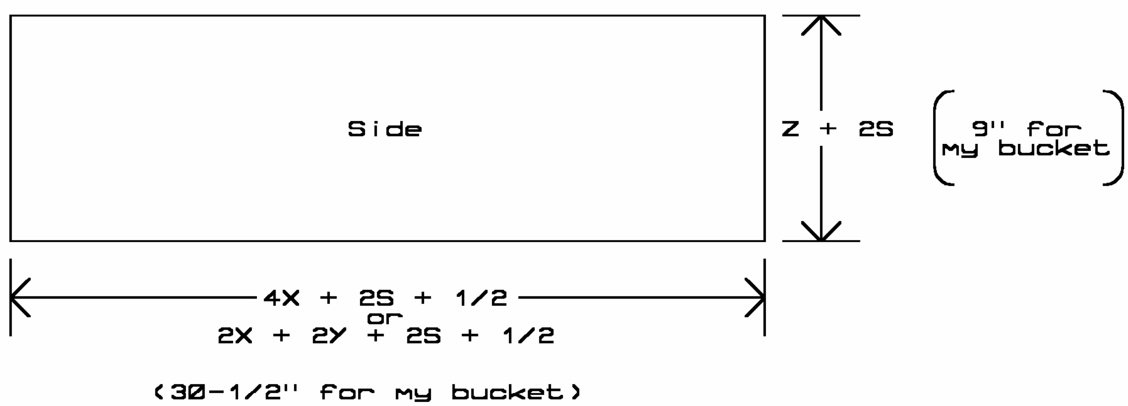
If you're unsure of your abilities to make a pattern, then cut experimental patterns with butcher paper. Don't forget to add at least 1 ½ -inch seam allowances to the dimensions of the bucket when drafting your pattern for the side and bottom jackets. For the hatch jacket, you will need a piece large enough to tightly wrap the lid gift-wrap style. Never sew raw edges together without first doubling over the seam ¼" at least once and preferably twice. When working with nylon fabrics, it's best to cut the fabric with a hot soldering iron. Some soldering irons come with cutting tips for this purpose. The hot cutter melts the raw edge of the fabric, preventing the raw edge from fraying. When possible, use a wooden ruler with a thin metal edge to guide the soldering iron. The metal on the ruler conducts heat away from the hot soldering tip. Form creases in the ripstop by running a finger nail over the folded fabric. If you decide to use an iron in place of a finger nail, use a low heat setting as high temperature settings make the fabric curl.

Cutting Tip *- The cutting tip looks like a small ball on the end of the soldering gun's tip.*

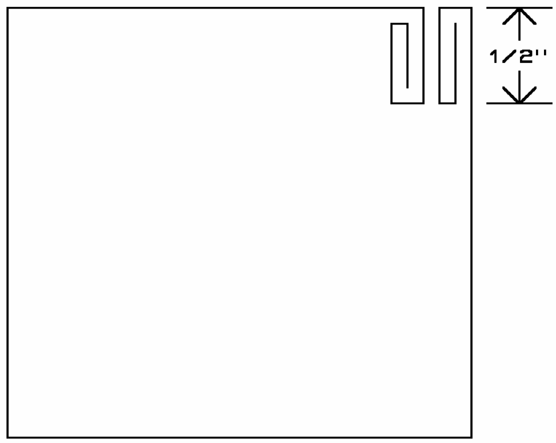
Draw the pattern onto the ripstop using a colored pencil contrasting with the color of the fabric. Cut out the three pieces of ripstop for the jacket. If you cut the fabric with scissors instead of a soldering iron, fold over the raw edges of the seam allowances about ¼" and stitch down, with a zig-zag stitch if you can. Creasing the fold with your fingernail before stitching will make the sewing easier. Be sure to backstitch at the beginning and ending of each seam. This step will prevent the cut edges from unraveling as you continue your work.

Side Jacket

First, select one long edge to be the top edge of the jacket. Turn this edge under by another ½", crease, and stitch down. Next, sew the opposite end of the side jacket together to form a tube. Wrap the fabric around the bucket wrong side out, then pin the ends together for a custom fit. Remove the fabric from the bucket and sew the side seam, turn it right side out, and test the fit again. If it fits too loosely, make a second seam just inside the first seam to take out some fabric. Remember, seam allowances for attaching the bottom piece of the jacket will project past the bottom of the bucket.

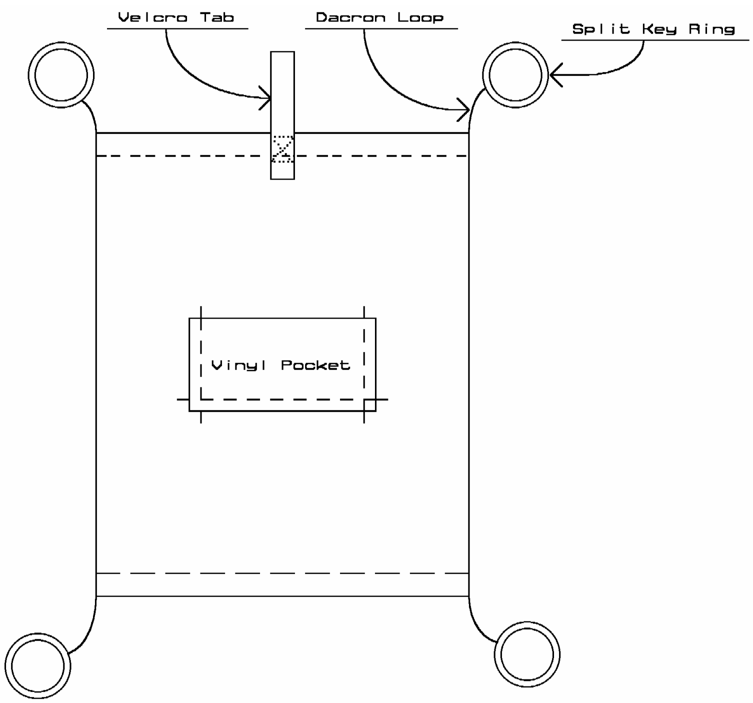


Side Jacket Pattern *- s = Seam. I make my seams 1" wide and double them over.*



Side Jacket Seams - *Top view (looking down) of side jacket.*

Next, lightly mark the location of the eight corners of the bucket on the side jacket, where the Dacron loops will be attached. The Dacron loops are attachment points for the parachute's shroud lines, as well as for link lines to a second module. I've always sewn my Dacron loops into the corners of the bag. If the Dacron loops are sewn to the center of each face, the link lines and shroud lines may tangle up the module's dipole antenna.



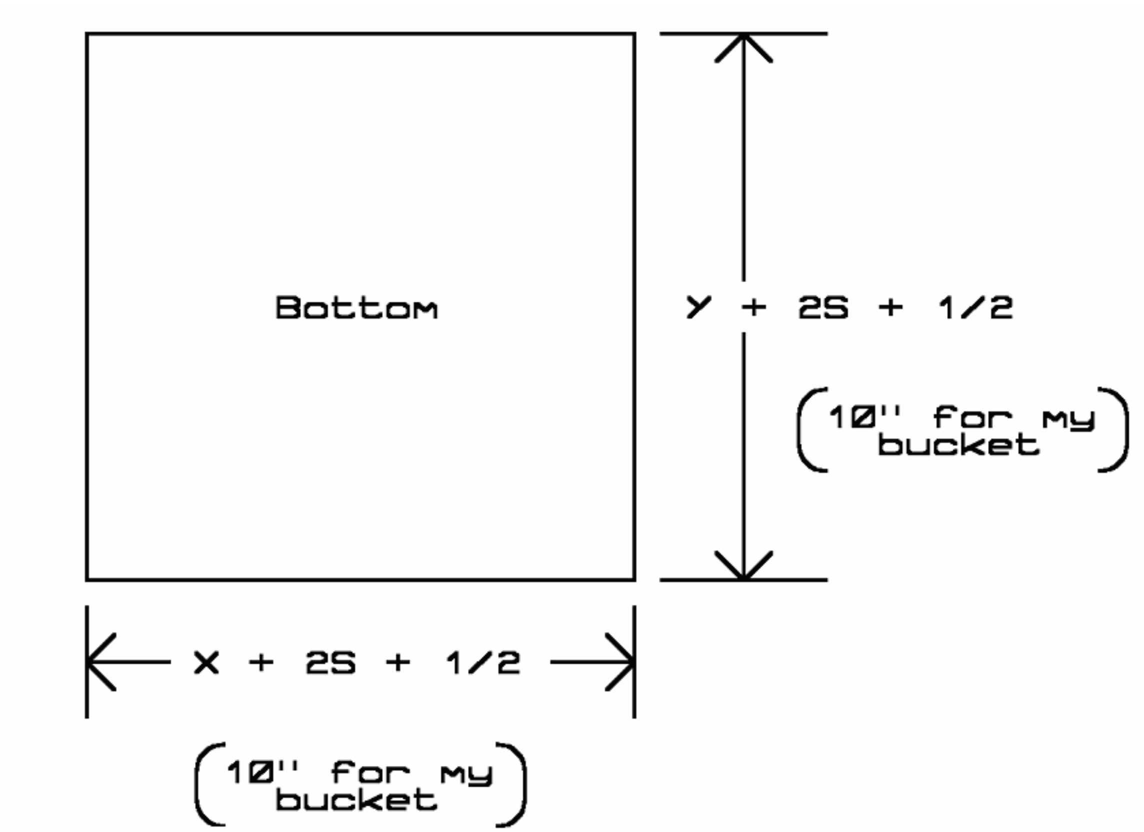
Dacron Loops *– Note: Since weight is not a concern, I don't sew Dacron down the sides or across the bottom of the jacket.*

Remove the side jacket from the bucket to sew the Dacron loops to the marked corners. Cut eight pieces of ¾" wide Dacron tape into lengths of four inches. Just like the ripstop nylon, it's best to cut the Dacron tape with a hot soldering iron. Fold the Dacron strips in half after they've been cut. Mark the folded Dacron at the one inch midpoint with a pencil. Place the folded Dacron on top of the side jacket, with the folded end of the Dacron rising above the edge of the bag. The open end of the Dacron is sewn to the bag. Align the Dacron's pencil mark with the top of the bag's edge, keeping all the Dacron loops uniform in height.

Sew the Dacron to the ripstop bag with stitches that extend beyond the edges of the Dacron. Use doubled stitches to sew an "X" through the middle of the Dacron, as you want this connection to be strong. Sew the remaining three folded Dacron strips to the remaining corners. Following the same procedure, with the open end of the Dacron loops sewn into the ripstop and the closed ends extending one inch below the side jacket's edges, sew four more Dacron loops into the bottom corners of the bag's side jacket. Be sure to avoid sewing the loops onto the seam allowance area at the bottom edge of the side jacket. Note that the Dacron loops are not sewn to the bottom jacket as the weight of lower module may pull the stitches out of the Dacron and ripstop.

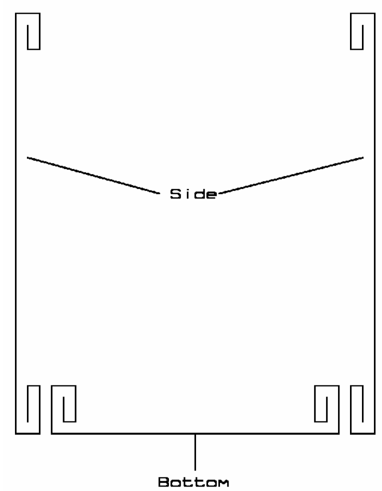
Bottom Jacket

The bottom jacket is sewn to the bottom of the side jacket after Dacron loops are attached to the side jacket.



Bottom Jacket Pattern *– s = Seam. I make my seams 1" wide and double them over.*

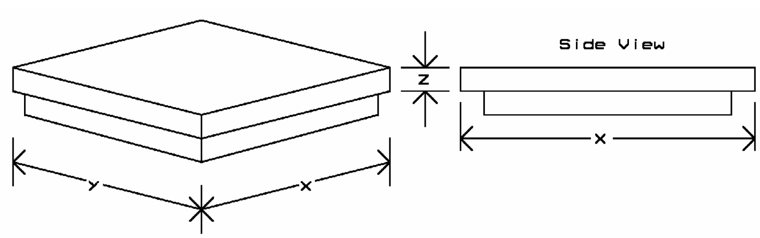
Bottom Jacket Seams *– Side view of bottom jacket seams.*



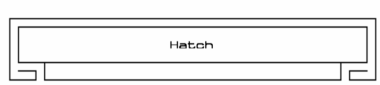
Side and Bottom Seams –
X-Ray view of jacket seams, as viewed from the side.

Place the bottom jacket against the bait bucket with the side jacket on it inside out. Check the bottom jacket's fit against the side jacket, and pin together their seam allowances. Next, remove the jacket from the bucket and sew the two jackets together. Be careful not to sew the Dacron loops into the bottom jacket as you sew the bottom jacket to the side jacket. Flip the jacket right-side out, so the seam allowances are inside and the Dacron loops are outside, and test fit it to the bait bucket. Slide the split key rings into the Dacron loops, with one split key ring per Dacron loop. The split key rings link the bag to the parachute's shroud lines or to other modules.

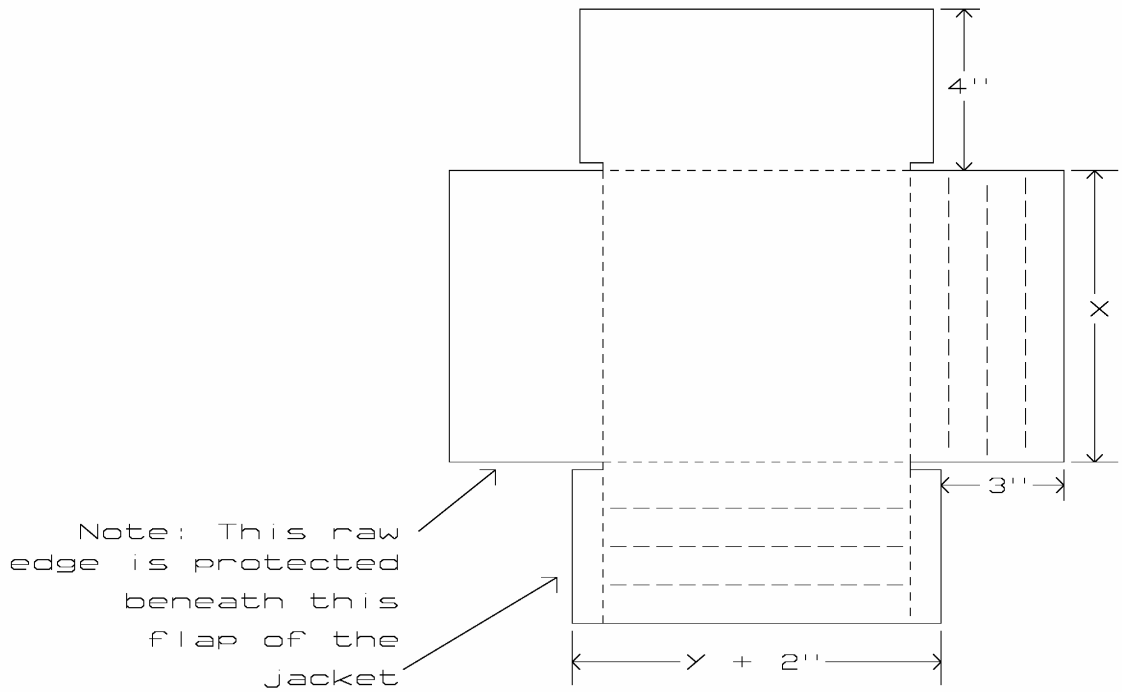
Hatch Jacket
Place the hatch jacket on top of the bucket, wrong side up. Test-fit the fabric by wrapping the lid as you would wrap a gift, with the fabric smooth and tight on the top and sides, with all the excess fabric in overlapping folds underneath. If it is a good fit, hem the edges under ¼" all around. (If not, cut a new piece of the appropriate size). Next, place the lid on top of the right side of the fabric, and trace very lightly with a colored pencil. Then mark the center of the sides of the hatch jacket.



Hatch Dimensions *– Measure your bait bucket.*



Hatch Seams – *Side view of hatch with seams.*



***Hatch Pattern** – Using 1" seams.*

The hatch is attached to the airframe with Velcro tabs. Cut four strips of Velcro to a length of 2-1/2". Select which face (fuzzy or hooks) to attach to the side jacket, and the other face sew to the hatch jacket. With the side jacket on the bait bucket, mark the center of the top edge of each face. These marks are where the Velcro strips are sewn. Remove the jacket and mark the center lines one inch below the top of the jacket. Place the first piece of Velcro on the center line and place its bottom end against the one inch mark. Be sure the fuzzy face of the Velcro is face down before sewing. After being sewn to this mark, the Velcro tabs extend 1-1/2" above the top of the side jacket, leaving enough Velcro tab to secure to the hatch. Sew the Velcro tab into place just like the Dacron strips were sewn. The other halves of these Velcro tabs will be sewn to the hatch jacket. Place each tab, fuzzy side up, over a center-side mark on the hatch jacket, with the bottom of the tab aligned with the traced edge of the lid. Sew the tabs down completely.

Because a tight fit is necessary, the hatch jacket is sewn onto the lid of the bait bucket by hand. Place the hatch jacket face down on a flat surface, and place the lid upside down on that, being careful to align it with the edges where the Velcro tabs were sewn. Wrap the fabric around the jacket tightly and neatly, as if you are wrapping a gift. Use strips of masking tape to secure the fabric in place while sewing the jacket on. Use simple over-hand stitches to hold the edges together, keeping the fabric taut. For extra security, put a drop of Fray Stop[G] or CA adhesive[H] on the knots in the thread when you are finished.

The name and flight history of the capsule is carried on a folded card. Make the folded size of the card the same size as a business card. The card is slipped into a clear vinyl pocket sewn into the jacket. (Use a business card if the name of the capsule is not yet printed.) Cut the vinyl ½" larger than the size of a business card, or 2-1/2 inches by 4 inches. Replace the side jacket on the bait bucket and mark a location for the name card of the capsule. Remove the jacket and sew the clear vinyl to the jacket face. Place the business card between the jacket fabric and vinyl. Then sew around the vinyl. This ensures the pocket is sewn large enough to hold the business card.

Velcro is also useful for attaching patches or small signs to the airframe. At this point decide if you want additional Velcro strips sewn to the side jacket. If so, slide the side jacket on the bait bucket and mark the location of any desired Velcro strips. Remove the jacket and sew the Velcro into place.

Because of the tight fit, the hatch jacket is sewn onto the lid of the bait bucket by hand. Use strips of masking tape to secure the Velcro closures of the jacket to the lid before beginning to sew the jacket on. Use a simple over-hand stitch. For extra security, put a drop of Fray Stop or CA adhesive on the knots in the thread.

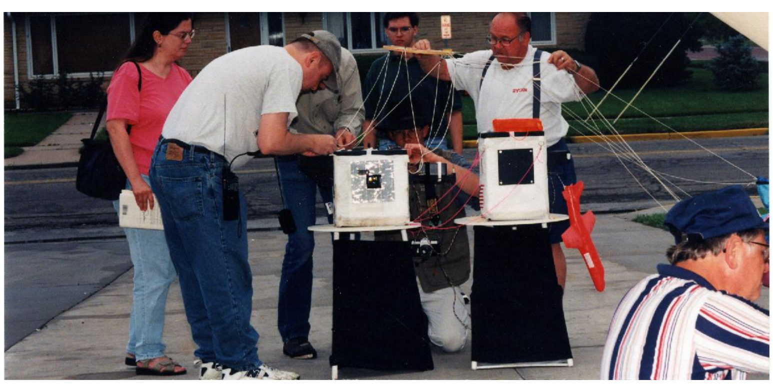
Completing the Bait Bucket Airframe

Cut a notch, approximately 1/8th of an inch on a side, at the top edge of the bait bucket centered on a side face. This is the location the antenna coax passes through. If the capsule uses a dipole antenna, than make a boom to hold the antenna and bolt it to the hatch. Read Chapter Five, Section Three for directions on making antenna booms from Styrofoam and 1/32" plywood. If instead of a dipole, the capsule uses a J-pole antenna, then an antenna boom is not required. Read Chapter Four, Section Three about making antennas. Read Chapter Two, Section Three on making a tracker for the bait bucket airframe.

Your airframe is now complete. This design gives the opportunity to quickly undertake your first mission. However, you may soon find that dimensions are too tight inside the bait bucket for many experiments. At that point, this airframe will make a fine back-up tracker as you move on to more complex missions.

2.0 The NearSys Airframe

The airframe described below was developed in the spring of 1999. It was the author's third generation airframe, after the Asimov (an unwieldy design) and Asimov II (made from Kevlar). The current NearSys design is lightweight, warm, and simple to construct. The airframe is constructed from inexpensive and commonly available materials (unlike the Kevlar in Asimov II). Most of the weight of a mission in a NearSys capsule is experiments and the flight computer, rather than airframe infrastructure. Temperatures inside the NearSys airframe drop no lower than freezing, except briefly during early descent when wind chill cools the interior.



NearSys Airframe *– Prepping a KNSP near spacecraft for launch at the Cosmosphere, Hutchinson, KS, Summer 1999. The near spacecraft consists of two modules tethered together.*

2.1. Overview of the NearSys Airframe

The goal is to design an airframe with the flexibility of the Space Shuttle (but nowhere near the cost!). Usually the Space Shuttle airframe requires no modification for each flight; instead, experiments are built to fit the Shuttle. Not having to make modifications for each flight prevents the Space Shuttle from being any more expensive to fly. The NearSys design outlined in this chapter has a similar flexibility. There is no need to cut up the airframe to add new experiments to the flight manifest. The NearSys airframe is constructed of Styrofoam sheets glued together to form a box. On each vertical side of the airframe is a square-shaped access port. Three are large experimental ports, which are places to mount experiments to the near spacecraft. The one smaller port, a control port, is used for controlling near spacecraft power and for programming the Central Computer/Programmable Sequencer (CC/PS), which is the capsule's flight computer.

Optional layers of aluminized Mylar[I] and scrim cover the exterior of the airframe. The layers add additional insulation to the airframe, the benefits of which are the subject of ongoing investigation. A layer of polyurethane foam on the bottom of the airframe provides shock absorption upon landing. Protecting the foam rubber and the outer layer of Mylar from abrasion is a jacket of spinnaker (ripstop) nylon. This abrasion jacket has square holes corresponding to the open ports of the airframe. Sewn at the eight corners (four on the top and four on the bottom) of the abrasion jacket are loops of 3/4-inch wide Dacron tape. The loops extend one inch beyond the edge of the abrasion jacket. One-inch split rings are fitted to the Dacron loops. Link lines use the split rings to connect either two modules together or to connect parachute shroud lines to the module. Finally, there are strips of Velcro sewn to the abrasion jacket. Velcro straps securely lock the module's hatch into place. Additional Velcro straps on the abrasion jacket attach mission patches to the near spacecraft and mount lightweight (usually passive) experiments to the outside of the near spacecraft.

2.2. Constructing the Airframe

The NearSys airframe is easy to design and build. In less than thirty minutes you'll get a feel for what your near spacecraft will look like. The NearSys airframe is designed to be lightweight and reasonably warm inside.

2.2.1. Lists of Materials and Tools

You'll need the following tools to construct the airframe:

- Exacto Knife with a long blade
- Straight Edge
- Pencil
- Hot Glue Gun
- Stationary Belt Sander (optional, but useful)

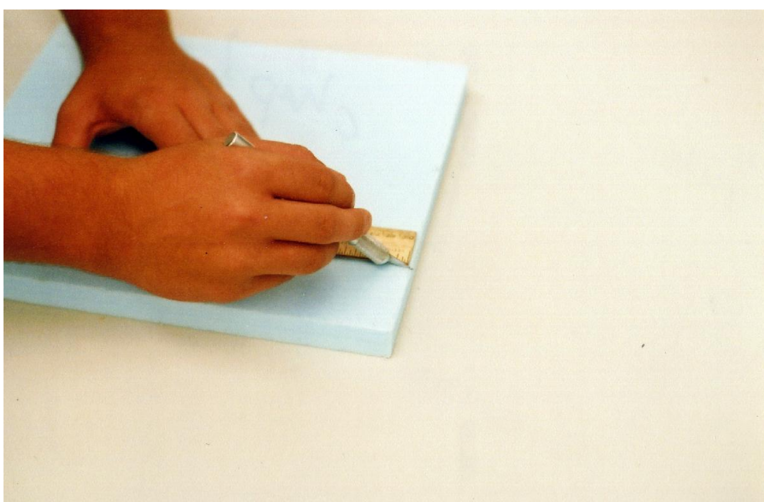
You'll need the following materials to put the above tools to work constructing airframes:

- One four foot by eight foot sheet[1] of 3/4" thick Styrofoam panel
- Roll of Styrofoam tape[2]

Notes:
1. This is the type of foam paneling used to insulate homes and is either pink or blue in color. Panels of several thicknesses are available, but the 3/4" sheets have a sufficient thickness. Thicker sheets will provide greater insulation, but are harder to cut with Exacto knives. The thinner sheets save only a little weight and money, while being more fragile. It is better to use thicker sheets if you cannot find 3/4" foam panels. The tiny increase in overall capsule weight offsets the increased fragility of thinner sheets. A sheet of polystyrene foam costs about twenty dollars and enables you to build a fleet of near spacecrafts. Personally I think the pink colored foam has a harder surface then the blue colored foam. If true, this makes the pink colored foam less likely to dent.
2. Styrofoam tape is used to wrap the bodies of Styrofoam stunt and combat gliders. It's available in many colors at your local hobby store.

2.2.2. Procedure

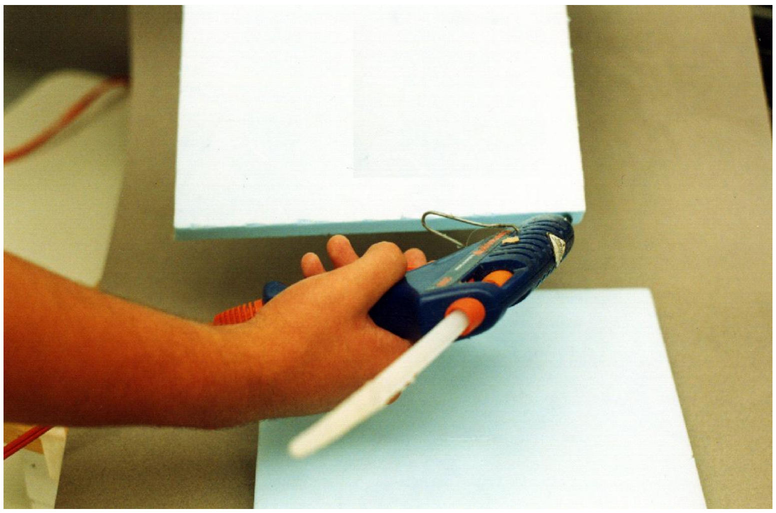
First remove the thin plastic film covering the foam panel. You will cut six pieces of foam to make an airframe. Four pieces are for the sides and two for the top and bottom. The top and bottom pieces have identical dimensions. It's easier to construct the airframe if the side panels have identical dimensions, but not necessarily those of the top and bottom. It is the author's experience that most experiments can be fitted to six-inch square panels. This necessitates port openings of 5.25 inches on a side. Six-inch port panels require airframes measuring at least ten inches on a side. Most of my early airframes are twelve inches tall. So, let me recommend making your first airframe with outside dimension of either twelve inches cubed or twelve inches tall and ten inches on a side. Airframes this size have sufficient volume for large devices like camcorders. Making airframes with larger dimensions encourages adding more than six pounds of weight in each airframe.



Cutting Foam *– Use a sharp, long blade for best results.*

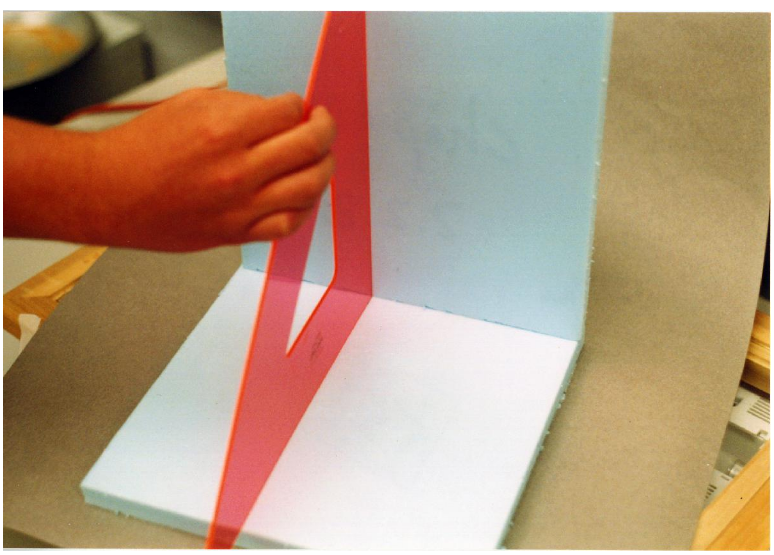
Once the plastic film is removed, mark the Styrofoam sheet with a pencil. Use a T-square and meter stick to get square corners and straight edges. Cut the panels with a sharp Exacto knife and straight edge. Use a long blade on the Exacto knife and make several passes through the foam to cut a smooth edge. Use a new blade (sharp) to prevent the blade from grabbing the foam as it is cut. Dull blades grab and fracture the foam, pulling little chunks out of the cut and creating a ragged edge. Make cuts with the knife held perpendicular to the surface of the foam. Label each panel as it's cut out from the foam. This is especially important if the airframe does not have equal depth and width. Cut out all the panels before gluing the airframe together. Do not cut out the airframe ports until after the airframe is glued together.

The airframe panels are glued together with hot glue. The hot glue gun and glue sticks are available at your local hobby or arts and crafts store. Read the glue gun's instructions before you start using hot glue. Most hot glue comes in 1/2-inch diameter plastic sticks. Sticks of glue are fed into an electric heater mounted into a pistol grip. Be careful with glue guns as the glue gets hot enough to cause serious burns. It's useful to have a temperature control on the glue gun, so that you can prevent the glue from getting so hot that it melts the foam. You will need to unplug the glue gun occasionally if it does not have temperature control.



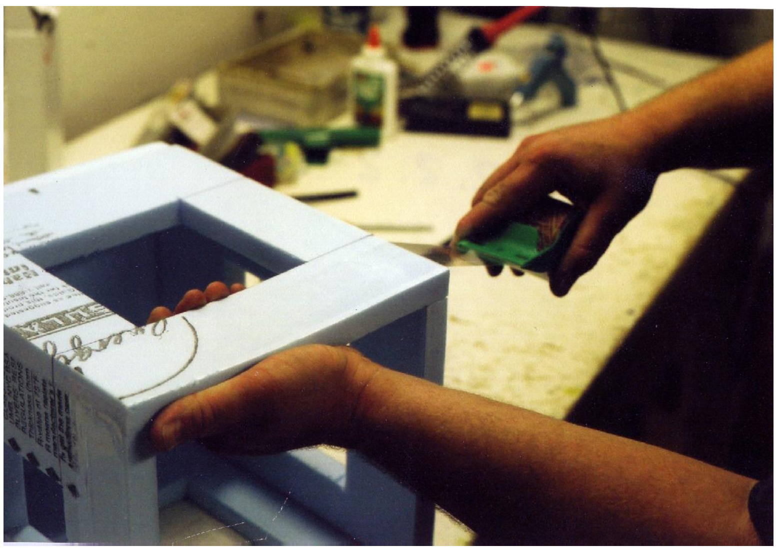
Gluing Styrofoam Panels – *Don't let the glue get so hot that it begins melting into the Styrofoam. Use a good bead of glue and wipe the corners, being careful not to burn your fingers.*

An extra set of hands is useful during the construction of the airframe. Melted hot glue does not cool too quickly, so there is sufficient time to assemble the panels. Find the first two panels to glue together, a side and bottom panel. Test fit their alignment before gluing them together. Now apply a bead of glue to one panel and stick it to its neighboring piece. Hold the panels perpendicular to each other as the glue cools.



Aligning Panels - *Use a square or similar tool to true up the airframe as the hot glue cools.*

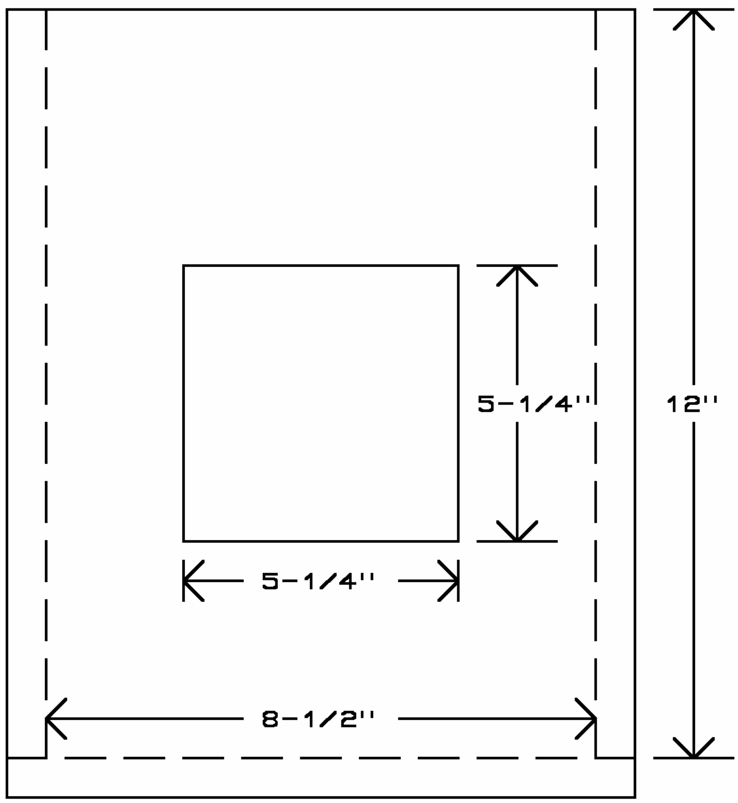
I find that a small triangle is useful for squaring up the panels as I glue them together. Glue the remaining three side panels to the bottom panel. Be sure to glue the side panels to each other when gluing them to the bottom panel. DO NOT glue the top panel (the hatch) to the airframe. Trim the edges of the airframe after the glue has cooled. Better still is to trim the airframe edges with a stationary belt sander. Wear a filter mask when trimming the airframe box with a sander. You will end up with a rigid and lightweight box with smooth joints. To further strengthen the airframe, wrap a length of Styrofoam tape around the top of the airframe. This keeps the top edges of the airframe from pulling apart over time.



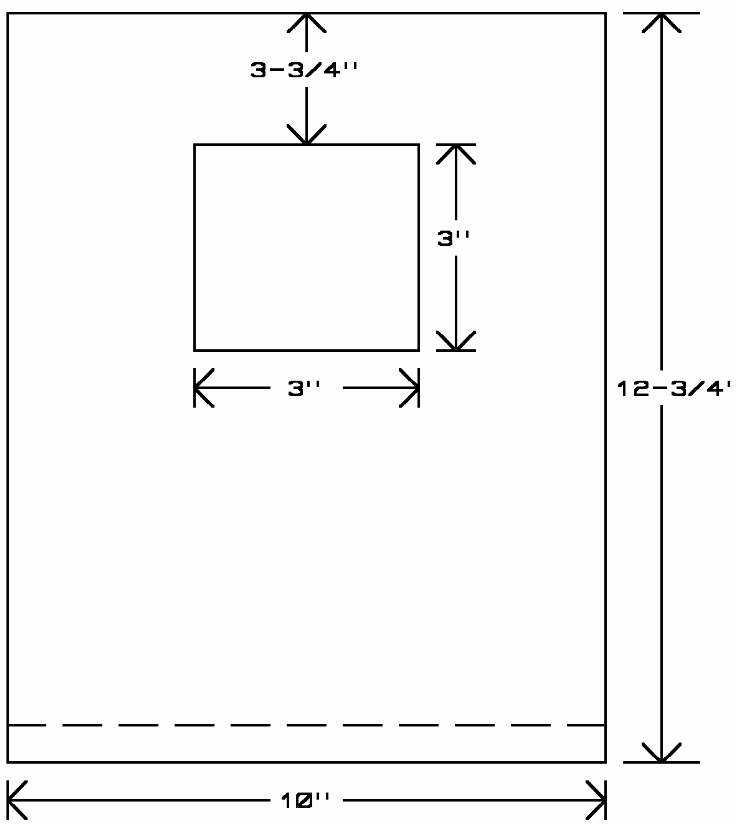
Taping a NearSys Airframe - *Only the top really needs a wrap of tape, the bottom is solidly glued to the base.*

2.3. Cutting Access Ports

Now cut the access ports into the airframe. Access ports must to be high enough off the bottom of the airframe for the avionics to have sufficient clearance. I recommend cutting the access ports at least two inches from the bottom of the airframe. Wait until after you construct your first near spacecraft before deciding you need lower access ports. If you need lower ports, place them on sides that are away from the avionics (the avionics can be located away from the center of the airframe). The access ports in my airframes are centered on the sides of the airframe. Though not a requirement, I recommend the ports be centered on your first airframe. It is the author's personal preference to cut the top of the control port flush with the top of the three experimental ports. The diagram below illustrates the recommended dimensions and locations of ports. Use a T-square to draw the locations of the ports and use a sharp Exacto knife to cut out the access ports. Save the cut-out squares to make port covers.



Large Access Ports *– Cut these holes into three sides of your airframe.*



Control Port *– Cut this smaller hole in the remaining side.*

The control port is where the power and programming panel is mounted. To secure this panel, epoxy a plywood-reinforcing frame to the foam around the control port. Use 1/32" modeling plywood for the frame. Construct the reinforcement frame by cutting a four inch square piece of 1/32" modeling plywood. Then remove a three-inch square from the middle of the plywood. Epoxy this square frame inside the airframe, centered on the control panel. This creates a square frame with a 1/2" border inside the airframe. Use small strips of masking tape to hold the frame in place while the epoxy sets.

3.0 Covering Airframes with Multi-Layer Insulation (MLI)

At this point you have a Styrofoam box with an opened top. Cut out of its four sides are three large square holes and one small square hole. The next step is to cover it in a jacket of multilayer insulation (MLI). A similar type of MLI is used to insulate spacecraft. In spacecraft construction, a jacket of MLI acts like a lightweight and unbreakable Dewar (thermos for you non-techies). MLI works best in a hard vacuum as is found in space. Near space does not obtain this level of vacuum, so the MLI may not be as effective as I hope. Ideally, adding MLI to the airframe keeps the interior of the module warmer (see the Good to Know section of this chapter) by preventing thermal radiation from escaping from the airframe. In science labs, inexpensive MLI substitutes like this are used to insulate cryogenic pipes, or pipes carrying liquid gases like nitrogen. Space certified MLI is very expensive, on the order of one dollar per square inch, but I can show you an inexpensive substitute.

3.1. List of Materials

If you decide to use MLI, you'll need the following materials:

- A package of space blanket
- Two yards of plastic wedding veil material
- Transparent tape, ¾" and 2" wide

3.2. Making the MLI

Near space MLI is constructed from alternating layers of aluminized Mylar and scrim. The source of aluminized Mylar is a space blanket, and the scrim is plastic wedding veil material. These materials are available from your local Wal-Mart. A few dollars purchases enough materials to insulate an entire near space fleet.

Aluminized Mylar forms the walls of a Dewar while the scrim maintains the separation between the layers. The aluminum coating on the Mylar cuts down on the amount of radiation cooling by reflecting thermal radiation back into the airframe. The scrim minimizes thermal conduction by maintaining physical separation between the layers. A vacuum between the layers reduces the amount of heat loss by convection.

3.2.1. Covering the Sides of the Airframe

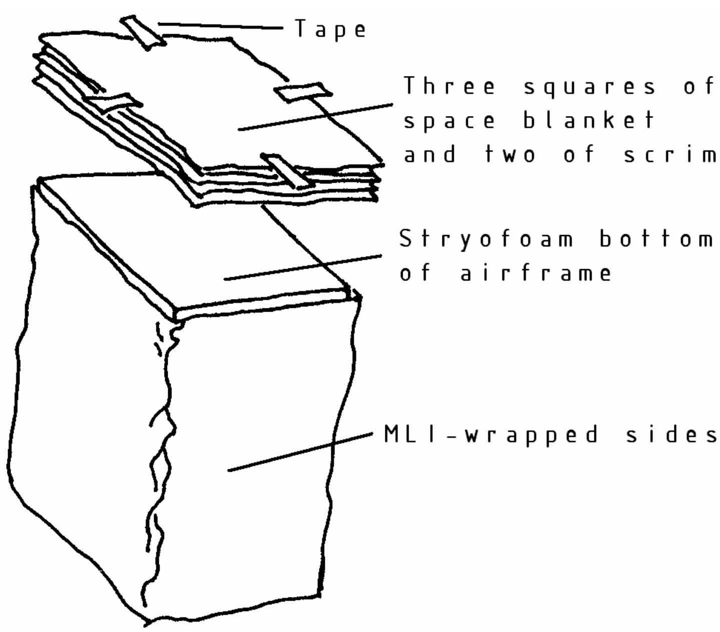
Wrap the bottom and sides of the airframe with at least three layers of Mylar and two layers of scrim. Wrapping the sides of the airframe is easier if you lay the airframe on its side. Do not unroll the space blanket yet. Instead lay the roll of space blanket up against the side of the airframe with some space blanket extending above the top of the airframe and below the bottom of the airframe. Now cut the roll of space blanket to the proper length. The proper length is about one inch above and below the top and bottom of the airframe. By cutting the rolled up space blanket, you have quickly cut a rolled up length of space blanket to the proper width. Roll up the scrim material and cut it in the same way. You'll trim the space blanket and scrim to the proper length later.

Wrapping airframe in MLI - *Wrap the airframe in a strip of space blanket and scrim.*

Unroll some of the space blanket and scrim. Use a few, short lengths of ¾" transparent tape and tape the end of the space blanket to an edge of the airframe. Keeping the space blanket tight, wrap a single layer around the airframe. Now lay the end of the roll of scrim on the space blanket. Use a few pieces of ¾" tape and tape the scrim to the space blanket. The scrim doesn't tape well, so rub the tape down. Continue wrapping the space blanket and scrim around the airframe. Keep a layer of scrim between successive layers of space blanket. Stop wrapping scrim after two layers. Finish the MLI with an outer layer of space blanket. When complete, you will have two layers of scrim between three layers of aluminized Mylar (space blanket). Hold the last wrap of space blanket to the airframe with a few pieces of tape as you wrap. You may find that a second piece of scrim or space blanket is needed. If so, tape the second pieces to the first pieces with just a little bit of tape.

3.2.2. Covering the Bottom of the Airframe

Repeat the same process of cutting scrim and Mylar for the bottom. But instead of wrapping the bottom of the airframe, you'll places several sheets of Mylar and scrim on the bottom of the airframe.



Covering the Airframe Bottom with MLI

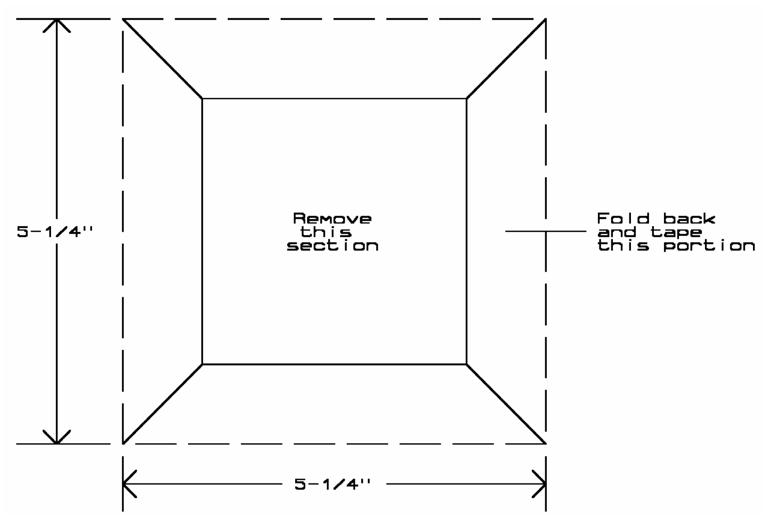
After cutting the scrim and Mylar to width, unwrap them and cut the proper sized squares out of the material. Layer a piece of scrim between two layers of Mylar. Repeat this until you have three layers of Mylar separated by two layers of scrim. Use a minimum of tape to hold the layers in place.

3.2.3. Taping Up the Loose Edges

Carefully trim up the excess length of MLI that is hanging over the edges of the airframe. Use the wider tape to tape the side and bottom MLI together. Also run tape over the top edge of the sides MLI. There should be no open ends of the MLI at the bottom of the airframe and the top edge should be reinforced with tape.

3.2.4. Cutting Ports

Use an Exacto knife to poke a hole in the MLI at each corner of a port. Then use scissors to cut across the open port diagonally, leaving an "X" cut into the MLI covering each port location. Trim away most of the excess MLI, leaving about a two-inch border. Wrap and tape the remaining two-inch border of MLI over the edges of the port. Tape the open MLI with two-inch wide transparent tape to the edges of the port. Now the airframe is covered and the ports opened up again.



Cutting Ports into the MLI – *Cut an "X" through the corners and trim about half of the MLI in the center.*

4.0 A Simple Landing Bag

Now it's time to add the landing bag. I added a landing bag to my near spacecraft Asimov II about one year after the Mars Pathfinder landed on Mars in July 1997. I did so because I became concerned about the force of landing possibly denting or cracking the airframe, especially if the near spacecraft recovered on cement or asphalt. Originally I wanted to design an inflatable landing bag, but determined it would add too much weight and complexity (however, it will be a project for the future, see Chapter 13). I didn't want to add a previously inflated bag to the bottom of the capsule as the low pressures of near space would cause it to expand and possibly burst. I then came up with the idea of using a foam rubber filler between two sheets of fabric, similar to the Therm-a-rest[J] camping mattress and somewhat similar to the deployed landing bags of the Mercury space capsules. Air is free to leave the bag as the air pressure drops during a flight (when the protection is not needed), but returns to the bag during descent to help cushion the capsule at landing.

4.1. List of Materials

You'll need the following three items to make a landing bag:

- One-inch thick foam rubber sheet
- One-quarter inch thick foam rubber sheet
- Silicone glue

Landing Bag *- The foam rubber of the landing bag. We chose not to wrap this airframe in MLI as part of an experiment.*

4.2. Procedure

Cut a piece of one-inch foam rubber to fit the bottom surface of the airframe. Since an entire sheet isn't required, cut holes out of the foam rubber sheet, with each one about two inches across. The foam rubber looks like a piece of Swiss cheese after being cut and has less weight. Attach the sheet of foam rubber to the bottom of the airframe, over the MLI, with small dabs of Silicone glue (RTV). Next seal the holes with a 1/4" sheet of foam rubber. Do this by cutting a second piece of foam rubber the same size as the first sheet (the size of the bottom of the capsule). Use RTV to glue the second sheet over the first sheet (the one-inch thick layer). Leave the airframe upside down and put a sheet of Styrofoam on top of the foam rubber. Add a little bit of weight on the Styrofoam sheet to press the foam rubber down and let the RTV set up.

5.0 The Abrasion Jacket

The MLI covering the airframe will not last many recoveries without tearing. To protect the MLI, cover the airframe with a bag of spinnaker (ripstop nylon) kite sail fabric.

5.1. List of Materials

You'll need the following materials to make the abrasion jacket

- Two yards of spinnaker (ripstop) nylon[1]
- One yard of ¾" Dacron tape[2]
- Eight 1" split key rings[3]
- Package of sew-on Velcro tape
- One yard of clear plastic vinyl[4]

Notes:
1. **Purchase the spinnaker fabric from a kite store like, Into the Wind (www.intothewind.com)**
2. **Purchase the Dacron tape from Into the Wind, also. It comes in two colors, black and white**
3. **The split rings are the type used for key rings. They're available from hardware or arts and crafts stores.**
4. **The clear plastic is available at fabric stores, where it's used to make items like plastic seat covers.**

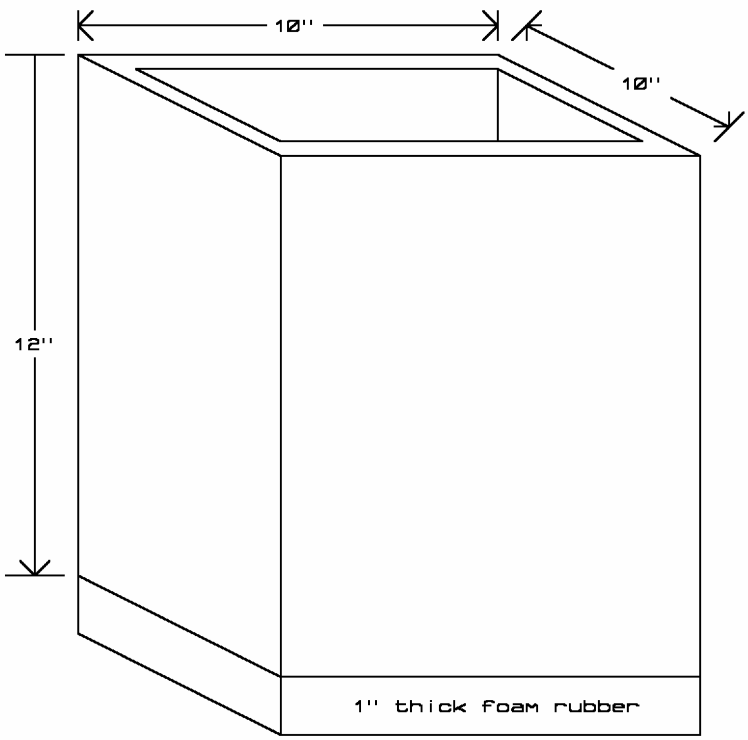
Note: Kite sail spinnaker comes in a multitude of colors, allowing for some pretty wild color schemes.

5.2. Procedure

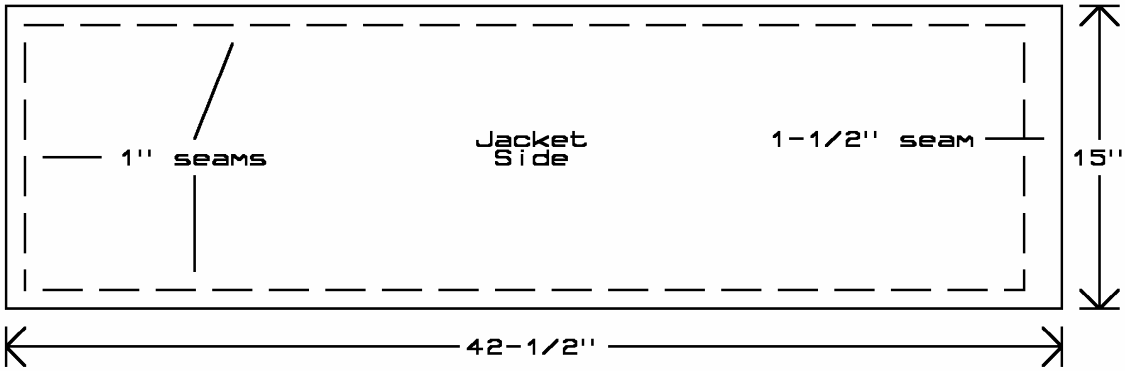
After buying the spinnaker, iron it to flatten it and to remove the wrinkles. Be careful to use the proper iron setting so you don't melt the fabric.

5.2.1. Jacket Construction

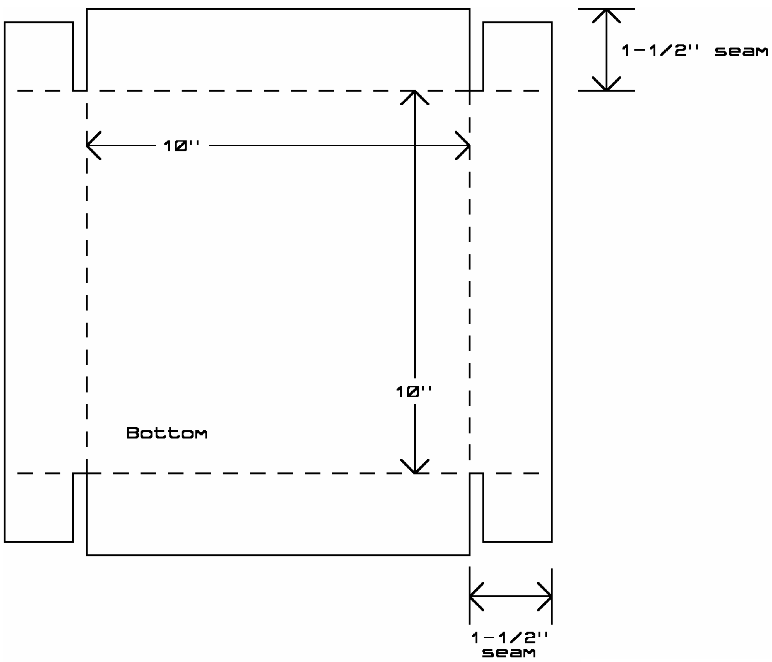
Draw a simple pattern for a cube that fits the airframe. Don't forget the foam rubber on the bottom of the airframe or else you won't make your cube large enough for the landing bag. Also don't forget that you'll need to add extra fabric for a seam allowance, at least one inch. This gives enough fabric to double the seam over twice. Below is a typical pattern for an airframe.



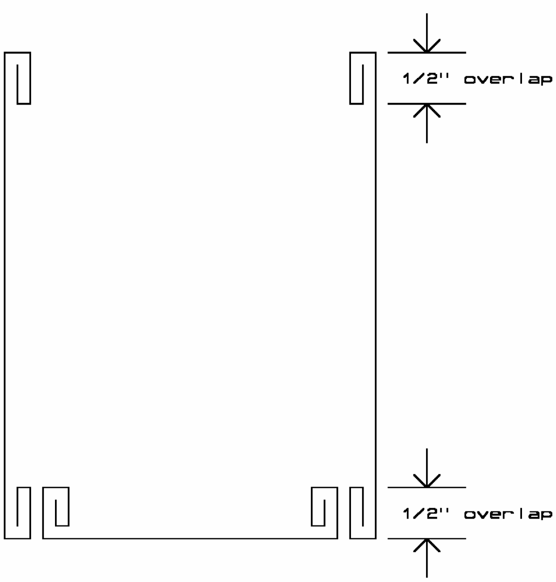
Airframe Dimensions *– This airframe is 10"x10"x12" PLUS 1" foam rubber on bottom.*



Side Pattern *– Cutting the jacket a little large lets you trim the jacket to the exact size by taking it in a little.*



Bottom Pattern



Seam Detail *– X-Ray side view of sewn jacket.*

Spinnaker marks easily with colored pencils. Whatever the color you choose to make the abrasion jacket, use a contrasting color to mark on it. Be sure you only mark on the back of the fabric and not on the surface that will show on the outside of the airframe. Cut spinnaker using a soldering gun with a cutting tip. This creates a hot cutter that melts and seals the strands of nylon woven into the fabric. Into The Wind, Wal-Mart, and some hardware stores sell soldering irons with hot cutting tips. Use a metal straight edge, or other heat resistant straight edge, as a guide when cutting the fabric. If you don't have access to a hot cutter, then cut the spinnaker with scissors. Don't attempt to melt the ends of the spinnaker with a lighter or candle, as doing so results in uneven edges in the cut fabric.

After cutting out the pattern, fold the seams over and run your finger nails over them to crease the spinnaker. I find this easier and faster than ironing the creases in. Hem the edges first, and then you can begin sewing the abrasion jacket into a box. Remember, you don't have to keep a uniform color for your near spacecraft. For example, use black fabric for the sides and white for the top and bottom.

5.2.2. Dacron Link Loop Construction

Barrel swivels and split rings on the abrasion jacket connect modules together or attach the shroud lines of the parachute to a module. Folded loops of ¾" wide Dacron tape secure the one-inch split rings to the abrasion jacket. Purchase the Dacron tape from a kite store when you order the spinnaker nylon. Use the soldering iron to cut eight strips of Dacron, each four inches long. Now fold them in half and crease the fold. Sew the eight Dacron strips into the top and bottom corners of the abrasion jacket. Lay half of the first Dacron loops along the edge of a corner of the abrasion jacket, with half the loop extending beyond the edge of the jacket. Now sew the Dacron onto the abrasion jacket. I like to sew the Dacron down with a square with an "X" through its middle. When finished sewing the Dacron, pull on it to make sure it won't pull loose. Now do the other seven strips. Later you'll slip the split rings on these loops.

***Dacron Link Loop** - A four inch strip (of doubled over) Dacron is sewn into all eight corners of the abrasion jacket. One-inch split rings are slipped into the Dacron loops so that modules can quickly be linked together with link lines.*

5.2.3. Velcro Hatch Closures

Four strips of Velcro secure the hatch to the airframe. The strips extend above the top edge of the abrasion jacket and wrap partway around the sides of the hatch. Velcro on the hatch sticks to the closures, securing the hatch. Four strips are sufficient because of the hatch's low weight.

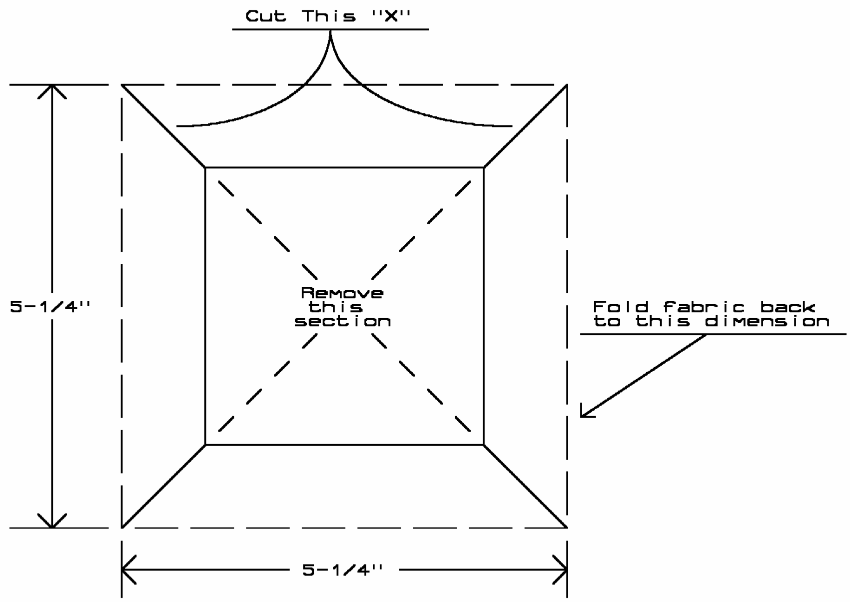
Place the airframe inside the abrasion jacket. At the top edge of the abrasion jacket, mark the center of each face. Because of the position of the Dacron loops in the corners of the abrasion jacket, sew the Velcro strips in the middle of the airframe sides. Cut four strips of Velcro to a length of three inches. Sew only the bottom one inch of each strip of Velcro to the abrasion jacket. Be sure to place the latching side of the Velcro against the abrasion jacket. The two inches of Velcro above the jacket go over the sides of the hatch leaving about two inches to wrap over the top of the hatch. After sewing the Velcro hatch closures, tug on them and make sure they're secure.

Velcro Closure *- Centered at the top of each face of the abrasion jacket is a Velcro tab. It is used to secure the hatch to the airframe.*

5.2.4. Making the Ports

Test fit the jacket on the airframe. Notice that when it's covered with the abrasion jacket, the foam rubber on the bottom of the airframe forms a cushioning landing bag. Using a fine tip felt marker, mark the corners of the port openings. Use the hot cutter and cut an "X" through the middle of each port opening. You can do this while the abrasion jacket is on the airframe.

Remove the abrasion jacket from the airframe and set it back down on your cutting surface. With the hot cutter, remove some of the excess material from inside the open ports. Make sure however, to leave a one inch seam allowance to hem. Now fold back the port seams and crease their edges. Sew around the open ports, sealing the seam allowances inside the abrasion jacket. I like to make two laps around the port openings.



Cutting Pattern for Ports

5.2.5. Optional Items to Add to the Abrasion Jacket

Next decide if your airframe is to have any of the following items sewn to it: removable mission patches, clear plastic pockets for cards, or items like a flag. You may want to place sponsor's logos or other temporary flight patches on the outside of the airframe. You can print mission patches on a color printer and afterwards, laminate them. On the back of the lamination put sticky Velcro patches. Another item to add is a clear plastic pocket. The pocket can hold a business card sized card with the capsule's name and flight record. The card lets you add professional lettering to the airframe. Finally, embroidered patches can be added to the airframe. Patches like the nation's or state's flags are good. Another option is to have an embroidery shop make a custom patch for the airframe.

Velcro for Mission Patches

If you decide to add Velcro strips for mission patches, then select good locations for them on the airframe and mark them with a pencil. A good location is at least two inches away from the edges of a port, where the Velcro cannot interfere with panels used to attach experiments to the airframe. It's best to locate patches either above or below ports, and not to their sides. You'll be sewing Velcro strips at these locations to hold the patches. Four-inch long Velcro strips seem to be long enough. Cut as many strips of Velcro as needed. Watch which type of Velcro you use here. All Velcro strips for mission patches must be the same face or type of Velcro.

Vinyl Pocket

Use a business card as a pattern. Cut a rectangle of soft vinyl ½" larger than the business card. Lay the business card on the abrasion jacket in the position desired. Lay the vinyl on top of the card and sew the vinyl to the jacket around 3 sides of the card. The card is a guide to prevent you from sewing the pocket too small to hold a business card.

Now create a capsule name in a word processor and print it on card stock. Cut the card twice the size of a business card and fold it over. When cutting the card, place the capsule name on the bottom half of the card. When folded, the card's open end is at the bottom of the card, and at the bottom of the pocket. If the card fold is at the top of the card, then the card continuously pushes the pocket open.

Inside the card, I record each flight a capsule makes. The mission name, date, and altitude are recorded. I also add a build date for the capsule.

Patch and Vinyl Pocket *- The vinyl pocket in the abrasion jacket. The pocket can hold information and a phone calling card instructing a finder to call the owner. In this case, the pocket holds a card with the name of the module and its flight statistics.*

Embroidered Patches

I like to sew a permanent American flag on one face of my airframes. I use either four-inch cloth flags from small Fourth of July decorations or more substantial embroidered patches. Flag decorations come stapled to thin wooden dowels. I remove the staples and cut the excess fabric free of the flag. These are cloth flags and they are likely to fray. Treat them gingerly until after sewing them to the abrasion jacket.

Embroidered patches come with either a sticky backing, iron-on backing, or without any backing. Do not use the sticky backed patches as the adhesive gums up the needle on the sewing machine. I don't believe the iron-on backing will stick well to the smooth spinnaker. If you're planning to sew a flag to the abrasion jacket, place it on the jacket now and mark the locations of its corners.

5.2.6. Finishing Up

Put the abrasion jacket back on the airframe and try it for fit again. Everything on the jacket should line up with everything on the airframe. Slip a one inch split ring on all eight of the Dacron loops. If you need to put additional lettering on the airframe, use a laundry marker, as they are permanent markers. I suppose there's no reason you couldn't create nose art, like the WW II bombers.

Completed Airframe, sans Hatch *- The completed airframe. You'll add the power and programming panel after assembling the flight computer.*

6.0 The Module Hatch

The hatch consists of a sheet of Styrofoam covering the open top of the airframe. It's held in place with Velcro straps for quick and easy doffing and donning. The outside face and the edges of the hatch are covered in spinnaker while the inside may be covered with colored plastic. Mounted to the top of the hatch is a handle to make lifting and positioning of the hatch easier.

6.1. List of Materials

You'll need the following materials to complete the hatch

- Styrofoam sheet, ¾" thick
- Sheet of colored Mylar[1]
- Ripstop Nylon
- Four inch plastic handle and mounting hardware[2]
- 1/16" plywood sheet
- Sew-on Velcro
- One sheet of poster board

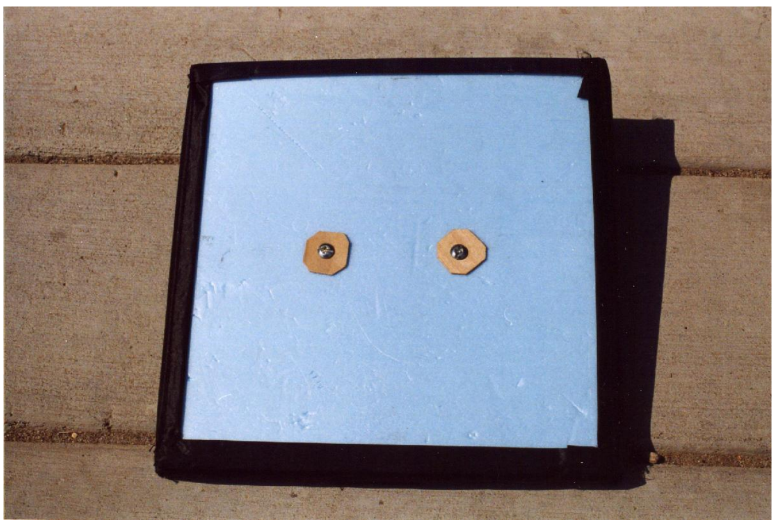
Notes:
1. Do not use aluminized Mylar on the hatch if there is a GPS receiver inside the near spacecraft. Tests performed by the Treasure Valley near Space Program (TVNSP) have shown that the Garmin Etrex GPS receiver gets a satellite lock through many inches of Styrofoam, but cannot get and maintain a lock through a layer of aluminized Mylar.
2. Plastic handles are available at hardware stores. Use a plastic handle, as it is lighter than a metal one.

6.2. Procedures

6.2.1. Handle Reinforcement

When bolted to just Styrofoam, a hatch handle soon breaks out of the Styrofoam. To prevent this from occurring, the hatch requires reinforcement where the handle is bolted to it. Create the handle reinforcement as outlined below.

- √ Mark the center of the hatch, on both the top and bottom surfaces.
- √ Draw a one-inch by five-inch rectangle on the Styrofoam, centered and aligned with the hatch's sides.
- √ Draw this rectangle on the other face of the hatch, and aligned in the same direction.
- √ Cut two pieces of one-inch by five-inch rectangle of 1/16-inch thick plywood.
- √ Epoxy the plywood to the Styrofoam on the drawn outline.
- √ After the epoxy sets, determine the location of the handle's bolt holes.
- √ Drill two holes through the hatch and reinforcing plywood.
- √ Test fit the handle and screws to the hatch.



***Handle Reinforcement** - Underside of hatch. Note the two plywood "fender" washers.*

6.2.2. Interior Face

If a GPS receiver is located inside the airframe, then do not cover the interior face of the hatch with aluminized Mylar, as it blocks signals from Navstar satellites. In this case, you may want to consider leaving the interior face of the hatch uncovered. Before covering the interior face, test the material for GPS compatibility by placing a couple of layers of the material over a GPS receiver and observing the number of satellite locks and their signal strengths. As long as the before and after measurements do not change significantly, the material is GPS safe. As mentioned earlier, a space blanket is not GPS safe. A single layer was observed by the Treasure Valley Near Space Program (TVNSP) to block Navstar signals while several inches of Styrofoam was not. Personally, I prefer to use either gold or silver colored wrapping plastic for my hatch interiors. Follow the steps below to make an interior lining.

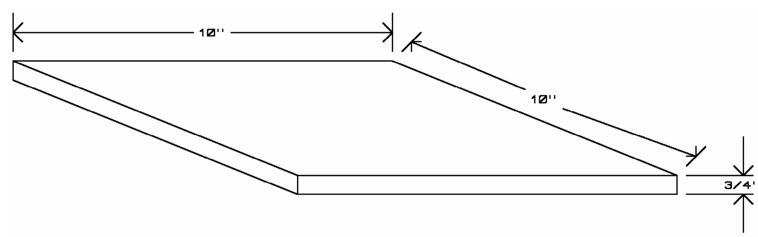
- √ Select the lining material.
- √ Test for GPS compatibility.
- √ Cut a square of lining material several inches larger than the hatch in both dimensions.
- √ Lay the material out on a flat surface, with the outer face down.

√ Place a border of double-stick tape on the hatch, located on its bottom face and near the edges of the hatch. Note: I have had trouble finding a good adhesive for gluing Mylar to Styrofoam, so I rely on tape.
√ Carefully place the hatch centered on top of the material.
√ With an Exacto knife, cut the lining material from the corners of the hatch to the edges of the material.
√ Wrap the exposed edges of the lining material over the sides of the hatch.
√ Tape the ends of the lining material to the hatch top.

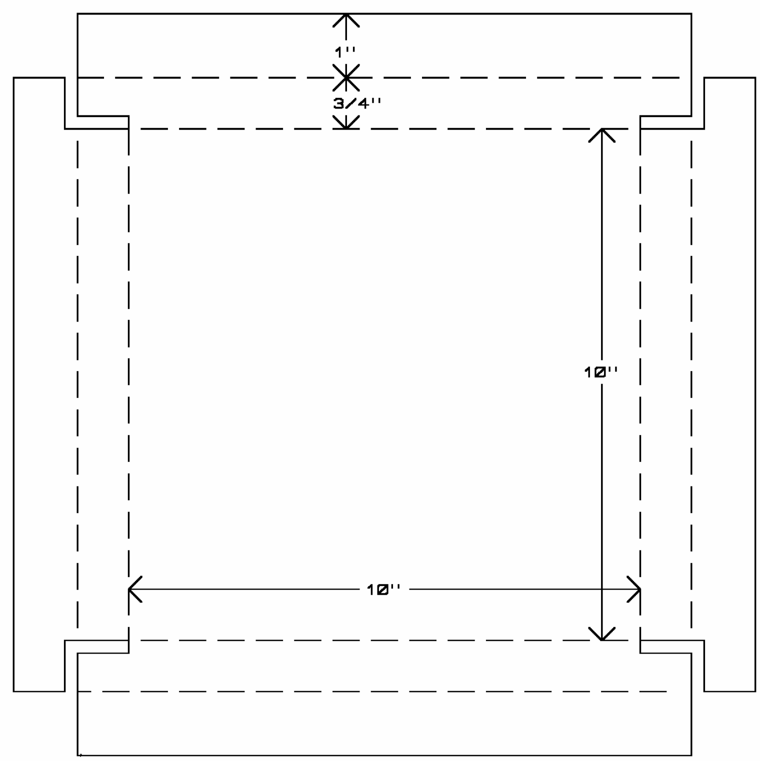
6.2.3. Fabric Jacket

Next up, cutting and sewing spinnaker to cover the top and sides of the hatch. The completed spinnaker jacket must cover the top face, wrap around the sides, and part way across the bottom of the hatch. I cover about 1/2" of the inside bottom edge with spinnaker. I use the following procedures to make a hatch jacket.

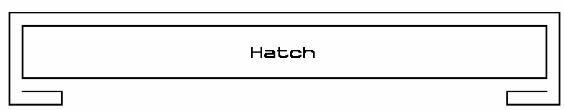
√ Select a spinnaker fabric to cover the hatch.
√ Make a pattern for the jacket on poster board. Note: The pattern below is used on ten-inch by ten-inch hatches. If you decide to draw your own pattern, do not forget there's a seam allowance folded into the edges.
√ Transfer the pattern onto the spinnaker with a colored pencil.
√ Use a hot cutter to cut the fabric (or scissors if you don't have access to a hot cutter).
√ Fold the spinnaker and crease the folds with a fingernail.
√ Sew the raw edge of the hatch jacket over to prevent fraying.



Hatch Dimensions



Hatch Pattern



***Seam Detail** – X-Ray side view of hatch and its jacket.*

The hatch is secured to the airframe with four Velcro strips. The strips can be sewn to either the sides of the hatch or to the top, along the edges. A second option is to sew Velcro at both locations to add additional strength to the closure.

√ Cut four (or eight) lengths of Velcro, two inches long. Note: Be sure to use the second half of the Velcro strips used to make the closures on the abrasion jacket.
√ Find and mark the center of the edges of the hatch cover.
√ Sew the Velcro strips to the hatch jacket, centered on the centering marks.

You may want to sew more Velcro strips to the jacket to secure experiments. If so, determine a location for them, and their length. Take into account the presence of the hatch handle when determining a location for the additional Velcro strips.

√ Locate and mark the location for the additional Velcro.
√ Cut Velcro to the desired length.
√ Sew the Velcro to the hatch cover.
√ Place the hatch jacket over the exposed face of the hatch.
√ Cut or melt holes through the jacket for mounting the pull handle.
√ Mount the handle to the hatch with the screws included in the handle.
√ Neatly wrap the jacket around the hatch.
√ Use masking tape to temporarily attach the jacket to the hatch.
√ Hand sew the corners of the hatch covering together.
√ Remove remaining masking tape.

√ Test fit the hatch to the airframe. Note: The abrasion jacket Velcro closure straps should cover the Velcro patches on the hatch, securing the hatch to the rest of the airframe. The abrasion jacket Velcro closure straps should not interfere with any Velcro patches you may have sewn to the hatch jacket for lightweight, external experiments.

***Completed Hatches** – Ready to go.*

6.2.4. Airframe Quality Assurance

Here's a list (by no means comprehensive) of inspection items for the airframe:

√ Airframe is square.
√ Airframe is rigid.
√ Styrofoam tape is not peeling.
√ Ports are cut to identical size, except for the control port.
√ No fabric covers the port openings.
√ No loose strings hang from the spinnaker or Velcro.
√ Link loops can be pulled on hard without ripping seams.
√ Velcro closures can be pulled on without ripping seams.
√ Velcro closures do not interfere with additional Velcro patches.
√ Airframe's name card can be removed from its clear plastic pocket.

7.0 Making Link Lines

The FAA allows us to fly the greatest amount of weight if we split the payload up (actually, you can fly heavier single payloads, but it adds a complication). So what does this mean? It means it is time to build your second airframe. The second airframe goes faster since you have experience building an airframe. A single sheet of Styrofoam lets you construct a fleet of near spacecraft.

7.1. Function of Link Lines

Near space modules are completed airframes filled with electronics. The module containing the telemetry equipment is the primary module while the supporting modules are the secondary modules. A near spacecraft is one or two modules (usually two) linked to perform a mission. Modules are linked together with link lines. Link lines attach the top corners of the bottom module to the bottom corners of the top module. Using four link lines between modules keeps the modules level with respect to each other and also prevents a module from falling from near space should a single link line break during flight. The link lines described below are durable, reusable, and quick to link.

List of Materials
To make a set of link lines, you'll need the following items:

- A spool of 100 pound test Spectra kite line
- Eight #3 or larger barrel swivels*
- Eight inches of identically colored heat shrink tubing
- Scissors
- Heat gun or lighter

*** Do not use snap swivels, as they will open up during a flight, releasing the modules from each other.**

7.2. Procedure

There are two important notes about making link lines. First, make link lines from four identical lengths of Spectra kite line. I find twenty inch long link lines to be good, but you can cut them to whatever length you prefer. However, do not make them too long, or else you'll be making long electrical umbilicals later. Second, there may be times you'll need additional sets of link lines, each of a different length. In that case, make each set of four link lines with the same color heat shrink tubing and different length link lines with a different color of heat shrink tubing. This way launch crews are assured of identifying four identically long link lines by looking at their color.

√ Cut four identical lengths of Spectra
√ Melt the ends of the Spectra with a lighter to keep the lines from unraveling. Use just enough heat to seal the ends, but not to change their lengths significantly.
√ Mark three inches from each end of a link line with a laundry marker.
√ Cut eight pieces of one inch long heat shrink tubing.
√ Slide two pieces of heat shrink tubing onto the link line.
√ Slide two barrel swivels onto the link line.
√ Center the loop of a swivel over a 3" mark on the link line and tie an overhand knot with the doubled-over string. Make sure to keep the laundry mark centered in the swivel loop while you tie the knot.
√ Trim up the excess string from each knot. The excess string doesn't have to be very long, less than 1/2" will do.
√ Melt the new ends of the nylon string, being careful not to damage the rest of the link line.
√ or, use a drop of CA glue on the new ends of the nylon string.
√ Slide a piece of heat shrink tubing over the knot and center it.
√ Slide the second piece over the knot at the other end.
√ Apply heat with a heat gun (or lighter) and shrink the tubing securely over each knot. Try not to excessively heat up link line material itself.
Note: The heat shrink tubing helps keep the knot from pulling loose.
√ Repeat the same process on the other three link lines.
√ Give the completed link lines a good yank to verify they won't pull apart.

Two Link Lines *- The colors of their heat shrink tubing indicates their lengths.*

7.3. Using the Link Lines

- √ Identify the top and bottom modules of a near spacecraft.
- √ Position the modules on a launch tower in their flight configuration. Note: Using a launch tower ensures link lines are not twisted.
- √ Select four identical link lines.
- √ Slide the one ring of a barrel swivel into a split ring in the link loop.
- √ Slide the other end of the link line into the corresponding link loop of the other module.
- √ Inspect all the link lines after they are linked. Note: Be sure the Dacron loops are fully inserted into the split rings. Linking modules has a tendency to begin unlinking the Dacron from the split rings.

Your near spacecraft is just an empty box. It's now time to fill it with avionics. Read the next chapter on creating and programming near space trackers and the CC/PS flight computer.

Good to Know: A Short Introduction to Thermodynamics

The temperature of a body depends on three factors: the amount of energy contained within the body, the mass of the body, and the body's specific heat. The more thermal energy within a body, the greater its measured temperature when compared to the same body with less thermal energy. The more massive a body, the more energy is needed to raise its temperature to a given point. Finally, the specific heat of a material determines the amount of energy needed to raise the temperature of a unit mass of the material by one degree. Two bodies at the same temperature don't necessarily have the same amount of thermal energy within them. However, if brought in contact, the heat flow between the two bodies is equal in both directions. This is what happens when you use a thermometer to measure a temperature. Speaking of heat flow, let's look at how the ways thermal energy can flow between two or more bodies.

There are three methods to move heat energy between bodies: conduction, convection, and radiation. Conduction occurs between two bodies of different temperatures when they are brought into contact. There is a net flow of thermal energy from the warmer body into the cooler body. I say net, because there is some flow of thermal energy from the cooler body into the warmer body, which will further cool the colder body. The amount of thermal energy being transferred this direction is less than the amount of thermal energy flowing into the cooler body. So regardless of their relative temperatures, there will always be heat flow in both directions, but the heat flow from the warmer body to the cooler body is greater in amount.

The second method of thermal energy flow between bodies is by convection. Convection is the movement of warmer material to regions containing cooler material. This is the method you observe when a pot of water boils. The hot water at the bottom of the pot rises to the top, displacing cooler water to the bottom where it warms up and repeats the cycle. Convection occurs in the lower layer of the atmosphere (troposphere), where the majority of our weather occurs, making this layer turbulent.

The final method by which thermal energy flows is radiation. Radiation occurs when a body emits radiation in the electromagnetic spectrum. Every body with a temperature greater than zero degrees Kelvin emits radiation. The higher the temperature of the body, the greater the amount of radiation it emits and the higher its peak frequency. As an example, a barely warm pot of water emits a little bit of radiation that peaks in the infrared portion of the spectrum. Meanwhile, very hot material falling into a black hole gives of vast amounts of energy that peaks in the X and gamma ray portion of the spectrum. Needless to say, it's safer to stand next to a pot of hot water than to the accretion disk of a black hole. Both warm and cool bodies in near contact emit radiation, but the warmer body emits more radiation, making the net emitted radiation from the warm body into the cool body. One high tech use of thermal radiation is that the radiation emitted by a warm body allows for a non-contact method for measuring temperature. These devices determine the temperature by measuring the peak-emitted frequency of radiation given off by a warm body.

Some Thermodynamic Concerns of Near Space

Some electronics are designed to be cooled by conduction with the surrounding air. Still warmer devices use a fan to move the air, putting the device in contact with even more air. In near space there's very little air, so you need to leave fan-cooled devices on the ground. Devices with heat sinks may need larger ones to cool properly.

MLI insulates both satellites and cryogenic equipment. MLI acts as a Dewar surrounding the equipment. The layers of reflective material prevent objects from changing temperature by reflecting thermal radiation emitted by the object back into the object. Scrim separating the layers of Mylar prevents a physical contact between the layers, thereby preventing conduction. Once in a vacuum, there is no air to move between the aluminized Mylar layers and carry away energy by convection. MLI has the benefit of being lightweight and is not fragile like glass.

Near Space Humor: Ten Signs that your First Near Space Mission is Not Going Well…

1. The Secret Service is at the launch site to observe.

2. You notice sparks and a trail of smoke leaving the near spacecraft just after you release it.

3. Mike Wallace and the 60 Minutes news crew are waiting for you at the recovery site.

4. Every one of the chase vehicles breaks down within the first 15 minutes of the chase.

5. The last you saw of the near spacecraft was a fiery streak falling from the sky.

6. You keep finding pieces of the near spacecraft on the ground during the chase.

7. You lost one of your balloon crews because he was tangled in the load line as the balloon was released.

8. One of the launch crews finds he is still holding onto the near spacecraft primary telemetry antenna after the balloon has been released.

9. The military police are waiting for you when you go to recover your near spacecraft that landed in Area 51.

10. The flight batteries die ten minutes into a flight which is predicted to reach 100,000 feet. You also remember that there is no message on the near spacecraft to tell finders who to call.

[A] Styrofoam is a trademark of The Dow Chemical Company.
[B] Spectra® is a registered trademark of Honeywell Performance Fibers.
[C] Coroplast™ is a trademark of the Coroplast™ company.
[D] Spinnaker cloth is also referred to as ¾ ounce ripstop nylon/polyester, meaning one square yard weighs ¾ of an ounce.
[E] DACRON® is a registered trademark of INVISTA.
[F] Velcro® is a registered trademark of Velcro Industries B.V.
[G] Fray Stop Spray is manufactured by Sullivans USA (www.sullivans.net)
[H] Cyanoacrylate adhesive, also known as Super Glue.
[I] Mylar® is a registered trademark of DuPont Teijin Films.
[J] Therm-a-Rest® is a registered trademark of Cascade Designs.

CHAPTER TWO

Near Space Avionics, Part One

Simple Near Space Trackers and Telemetry Systems

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

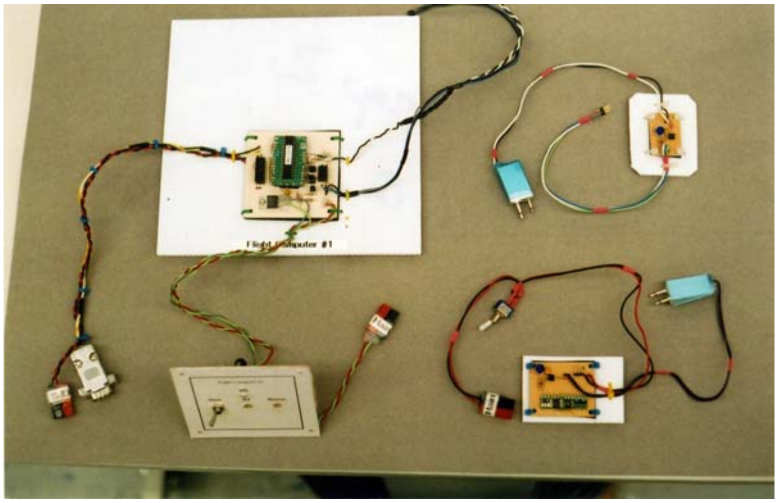
Chapter Objectives

1.0 Selecting Near Space Avionics

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

- Beacon
- Tracker
- Flight Computer

This chapter presents complete step-by-step instructions for building each of the avionics shown below.



***Beacons and A track** – Clockwise from left – Tracker, Simple Beacon, and Stand-alone beacon.*

1.0.1 Beacon

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

1.0.2 Tracker

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

1.0.3 The Flight Computer

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

1.1. Redundancy

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

1.2. Before You Begin Construction

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

1.2.1 Soldering Iron and Soldering Components

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

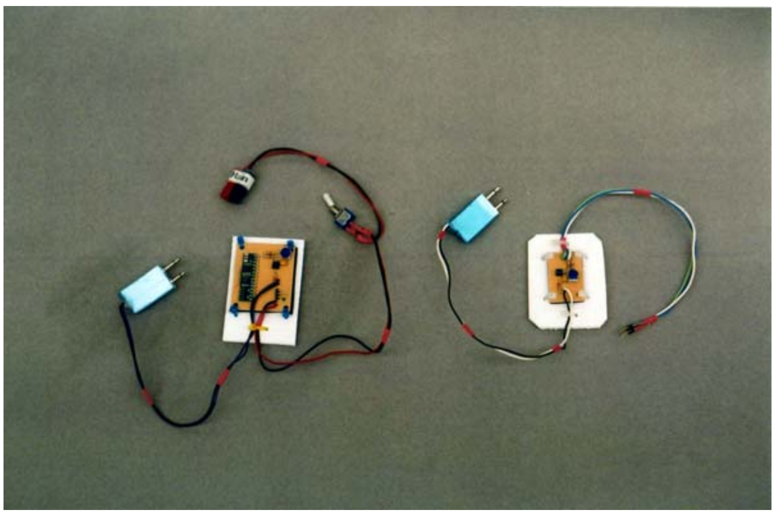
While at an electronics store, pick up a lead bending tool and wire snips. The lead-bending tool allows resistor leads to be bent accurately to 0.4" with minimum strain on the component. After soldering component leads and verifying the solder joint is good, snip away excess component lead. Be cautious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

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

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

2.0 Beacons

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



Beacons *– The stand-alone (left) and simple (right) beacons.*

2.1. <u>Theory of Operation</u>

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

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

2.2. Materials

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

2.2.1. Simple Beacon

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

2.2.2. Stand-Alone Beacon

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

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

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

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

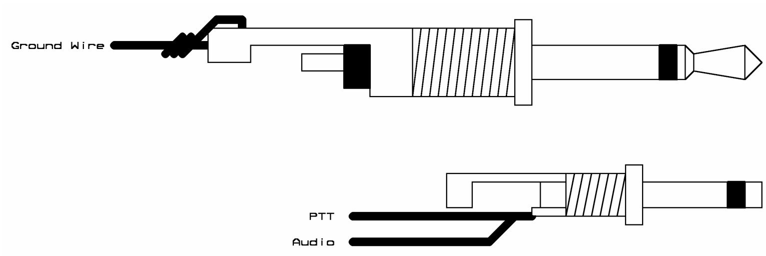
* Foamies® is the name of a brand of neoprene foam manufactured by Darice Inc. and is available at crafts stores.
** Coroplast™, a form of corrugated plastic, is available at plastic suppliers. Coroplast™ is a trademark of the Coroplast™ company (www.coroplast.com).
*** Powerpole® connectors are made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

2.3. Construction

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

2.3.1. HT Cable

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



Mic and audio jack connections

Wiring the MIC and Audio Jacks

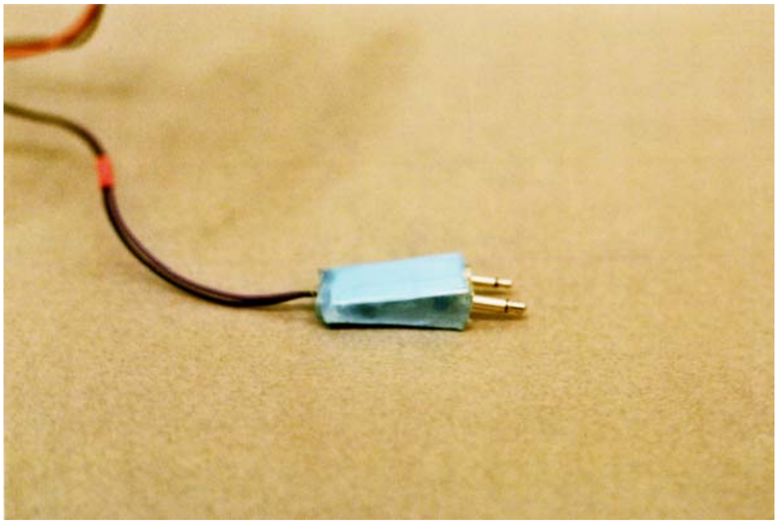
- √ Cut twelve inches of #22 or #24 AWG stranded wire, one length of black wire, and one length of a different color.
- √ Strip ¼" of insulation from one end of each wire and ½" of insulation from the other end.
- √ Solder the ½" bare ends of the wires to the phono jacks as directed below:
  - o Black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

Making the Plastic Housing for the MIC and Audio

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

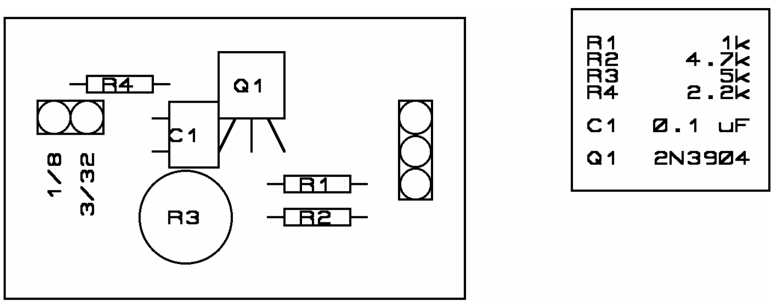
Note: At some time you may want to use external power on the HT. So, plug a DC power plug into the HT (4.0mm X 1.7mm for the DJ-S11) when plugging in the phono jacks. I do not recommend making the power connector a part of the phono housing, as you can't run the HT on internal power if a power plug is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

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



Completed Jack Housing *– Not beautiful, but solid and easy to assemble.*

2.3.2. Assembling the Beacon Board



Simple Beacon *– Parts placement.*

Solder the following components into the PCB:

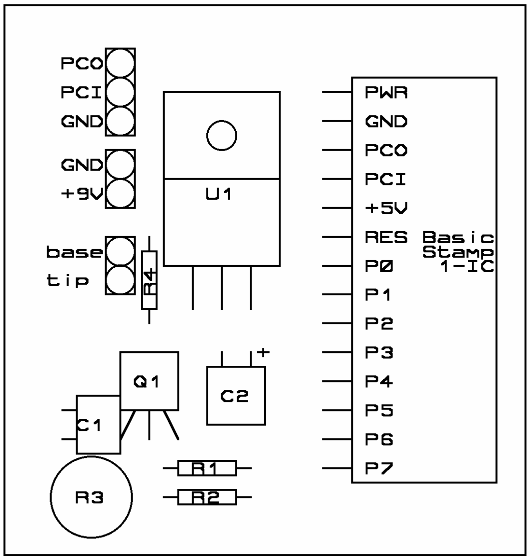
- C1 0.1uf capacitor (use a small dimension polyester cap)
- R1 1k resistor
- R2 4.7k resistor
- R3 5k trimmer
- R4 2.2k resistor
- Q1 2N3904 NPN transistor
- HT cable into the pads labeled 1/8” phono and 3/32” phono

Additional Steps for the Simple Beacon

Adding a Control Cable to the Simple Beacon

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

Additional Steps for the Stand-Alone Beacon



R1	1k
R2	4.7k
R3	5k
R4	2.2k
C1	0.1 uF
Q1	2N3904

Stand-alone Beacon *- Parts placement.*

Additional Parts for the Stand-Alone Beacon

- J1 Three pin male header

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

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

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

2.4. Testing

2.4.1. Testing a Simple Beacon

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

Now go to Section Five, Software.

2.4.2. Testing a Stand-Alone Beacon

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

2.4.3. Final Assembly of the Stand-Alone Beacon

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

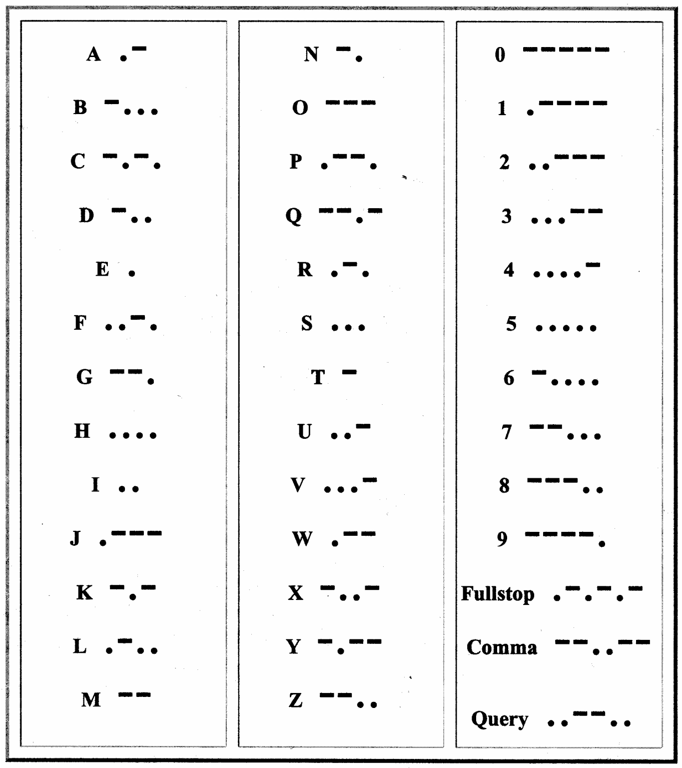
2.5. Software

2.5.1. Directions for the Stand-Alone Beacon Test Software

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

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

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



Morse Code

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

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

Stand Alone Beacon Code

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

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

timer = 0

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

  Space:                                    'leave a pause
  PAUSE 500
  GOTO EndCW

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

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

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

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

2.5.2. Directions for the Simple Beacon Software

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

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

Modify the Simple Beacon code to reflect your call sign.

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

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

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

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

Simple Beacon Code

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

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

2.5.3. Final Assembly of the Simple Beacon

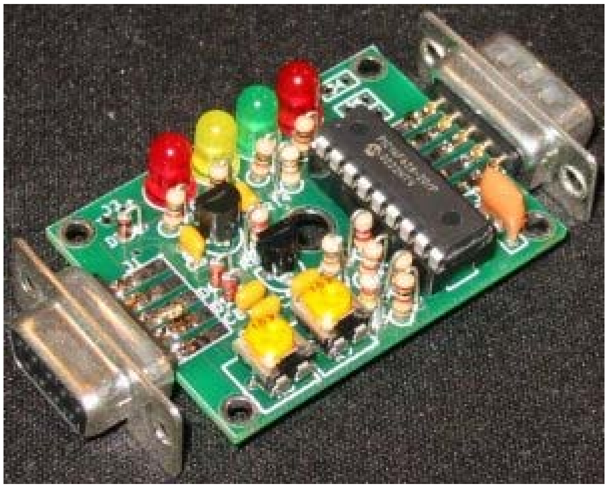
- √ Cut a rectangle of Foamies® to fit the dimensions of the PCB.
- √ Place the Foamies® pad beneath the PCB.
- √ Attach the PCB to a sheet of Coroplast™ with nylon wire ties. Note: This is an easy method to "bolt" PCBs to a base that protects the underside of the PCB from shorts, while still making it possible to get at the traces to fix a problem.
- √ Create strain reliefs for beacon cables by zip-tying the beacon cables to the Coroplast™.
- √ Cut the Coroplast™ large enough to rubber band to the back of the HT.
- √ Build a Styrofoam box to house the HT and beacon. Note: Design the box to prevent HT buttons from being pressed during the mission.

3.0 Trackers

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

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

3.1. Tiny Trak II Near Space Tracker



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

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

3.1.1. Theory of Operation

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

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

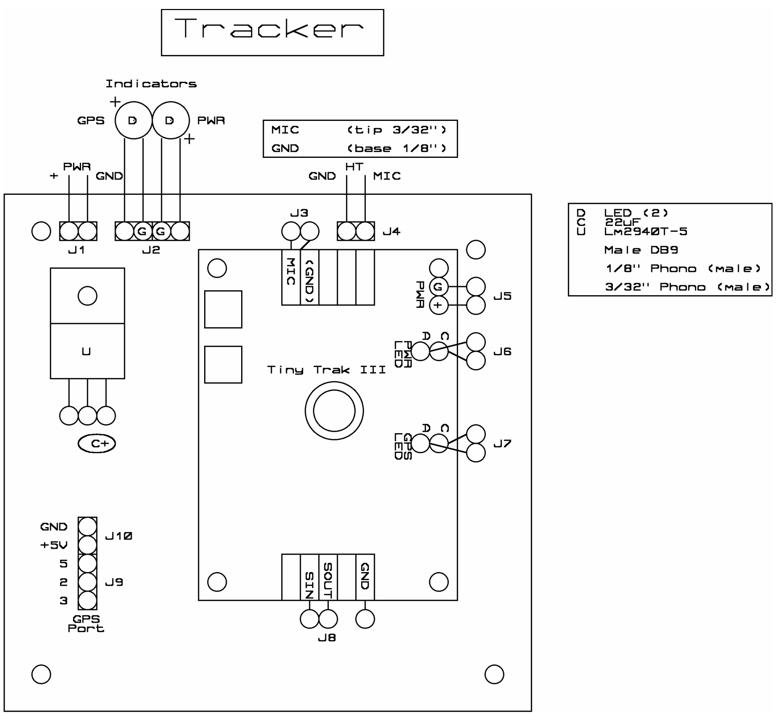
3.1.2. Materials

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

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

3.1.3. Procedures

First assemble the Tiny Trak II according to the directions below and then mount it to the Tracker PCB. When done, complete assembly of the PCB.



***Tiny Trak III Near Space Tracker** – Parts placement.*

Assembling the Tiny Trak II

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

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

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

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

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

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

3.1.4. Completing the Tracker PCB

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

- 22 uF capacitor
- LM2940T-5 voltage regulator

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

LED Power Indicator

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

Serial Cable

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

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

GPS Power Cable

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

HT Cable

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

DJ-S11 MIC, Audio, and Power Connectors

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

MIC and Audio

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

Power

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

PCB Power Cable

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

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

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

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

3.1.5. Programming the Tiny Trak II

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

I suggest you program the Tiny Trak II as follows:

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

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

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

The APRS standard for a posit has the following fields:

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

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

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

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

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

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

4.0 More Capable Terminal Node Controllers (TNCs)

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

4.1. <u>Kantronics KPC-3+</u>

***Kantronics KPC-3+** - Photo by Kantronics.*

The first tracker described is a Kantronics KPC-3+ Packet Communicator (www.kantronics.com/kpc3+.htm). For our purposes, this TNC (terminal node controller) will be connected to a GPS receiver and HT. The directions in this section are written specifically written for the KPC-3+ with version 8.3 firmware loaded in its EEPROM. Older versions of the firmware can function as a tracker, but they are not as capable. One feature of the KPC-3+ (and other TNCs) is its ability to retransmit digital signals that it receives. Called digi-peating, this allows a TNC to extend the communications range of a packet station. However, for near spacecraft it is not recommended to use your primary telemetry method to send other peoples' communications. If you want to digi-peat from near space, use a second TNC on a separate frequency. There are two ways to send telemetry from the KPC-3+, either using TNC buffers or by placing the TNC into transparent mode.

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

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

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

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

4.1.1. Making Hardware Changes to the KPC-3+

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

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

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

Wiring the Radio Port

The TNC needs a radio to communicate with the ground stations. There are two points to be aware of before wiring up the HT. First, the KPC-3+ is capable of receiving transmissions as well as sending transmissions. From near space, the KPC-3+ hears transmissions from over 300 miles away in all directions. This means the KPC-3+ hears packet transmissions from thousands of square miles and potentially transmissions from over 100 packet stations. This creates the risk of accidental or malicious tampering with TNC settings. For this reason, I recommend that a remote login be setup and that the TNC be programmed to disconnect everyone else. Second, I recommend programming the KPC-3+ to not hold off transmissions when it hears other transmissions. Remember, the KPC-3+ is hearing transmissions from hundreds of miles away while chase crews are only hearing transmissions from a few miles away. If the near spacecraft is within 300 miles of a major city with lots of packet traffic, the KPC-3+ may never transmit. Besides, I believe a $1000 capsule at 100,000 feet has priority over ground stations.

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

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

List of Components

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

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

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

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

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

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

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

Procedure to make the GPS Cable

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

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

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

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

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

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

List of Materials

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

Wiring Access to TNC I/O

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

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

Wire Up Access to the TNC's ADCs

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

```
Vx = N/51
```

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

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

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

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

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

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

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

Procedure to Wire the ADCs

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

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

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

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

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

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

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

List of Materials

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

Procedure

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

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

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

External Power

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

List of Materials

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

Procedure

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

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

Set KPC-3+ Jumpers

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

Procedure

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

Test

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

4.1.2. Programming the KPC-3+

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

Command List

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

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

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

TELEMETRY 12

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

```
LTP 1 GPSPO VIA WIDE3-3

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

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

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

GPSPORT 4800 NORMAL
INTFACE TERM
```

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

4.1.3. General Commands

Here are some details about the following commands.

`ABAUD 4800`

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

`CD SOFTWARE`

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

`CTEXT “your disconnect message here”`

The specified message is sent to packet stations trying to connect.

`CMSG DISC`

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

`DIGI OFF`

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

`HEA OFF`

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

`UNPROTO APRS VIA WIDE3-3`

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

`MYALIAS NONE`

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

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

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

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

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

Where:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2. APRS Micro Interface Module (MIM) Flight Computer

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

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

4.2.1. Theory of Operation

The MIM has the following connections:

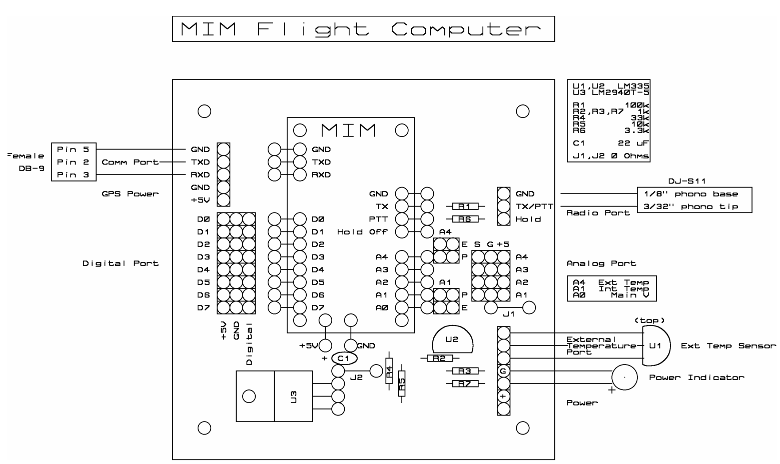
Pad Function	Location on PCB
Power and ground	Top of the MIM
Five ADC inputs	Top left of the MIM
Eight digital inputs	Top right of the MIM
Four HT connections	Left middle of MIM
Three serial connections	Bottom right of MIM

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

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

4.2.2. Mounting the MIM to the Flight Computer PCB

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



***MIM Based Tracker** – Parts placement.*

Mechanically Mounting the MIM to the PCB

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

Materials Needed to Mechanically Mount the MIM to the PCB

- 3mm neoprene foam rubber*
- Nylon zip ties
- Four mounting bolts and nuts ½" long (use #1 hardware) **

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

Procedure to Mechanically Mount the MIM to the PCB

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

Electrically Connecting the MIM to the MIM PCB

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

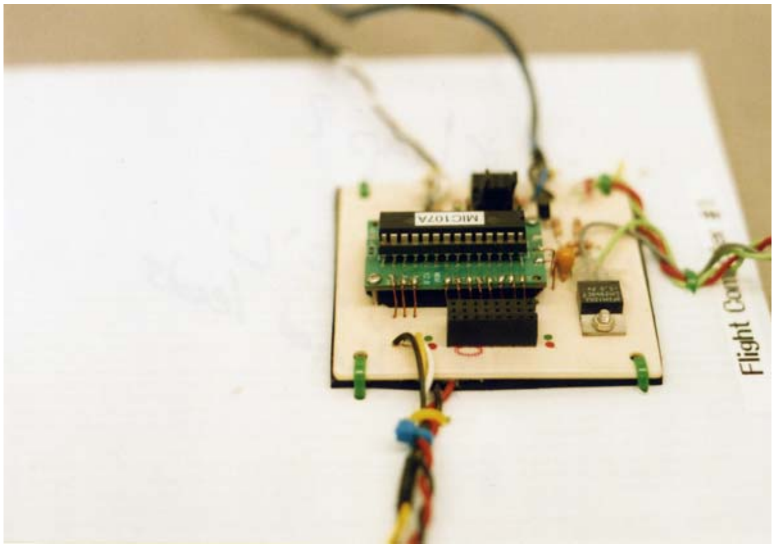
Components Needed to Electrically Mount the MIM to the MIM PCB

- Tweezers
- Wire

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

Procedure to Electrically Mount the MIM

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



"L" Leads Close-up *- Leads are made from bare copper wire.*

Note: This will drive you crazy, so be sure to have lots of spare time. And please, don't come looking for me if this step drives you over the edge.
Note: There are three solder pads related to power on the MIM. One solder pad is for ground and must be used. The other two are for positive power and only one of these is used. Since five volts will be made available for the MIM, the PCB only uses the pad marked +5V.

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

4.2.3. Procedure for Assembling the MIM PCB

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

Materials to Complete the PCB

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

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

Procedure for Completing the PCB

Resistors and Jumpers

Bend resistor leads to a length of 0.4" with a lead bender. After soldering the resistors, clip the extra leads. Use either 0 ohm resistors or short lengths of insulated wires for the jumpers. For extra security against shorts, keep the jumper wires insulated for as much of their length as possible.

- R1
- R2
- R3
- R4
- R5
- J1
- J2

Capacitors

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

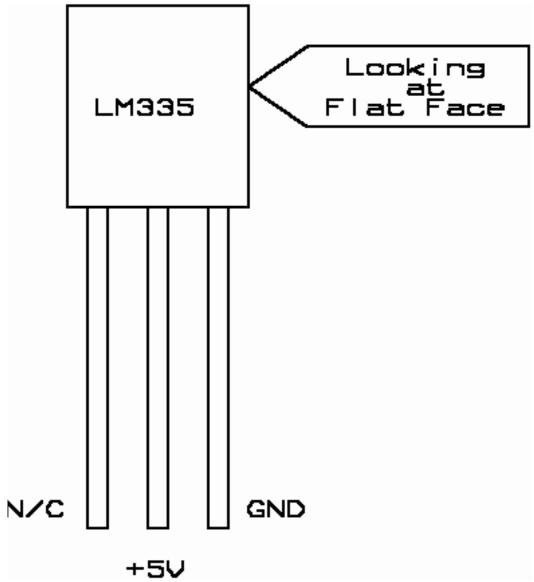
- C1

Semiconductors

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

- U2
- U3

Directions for Cabling U1 (LM335)



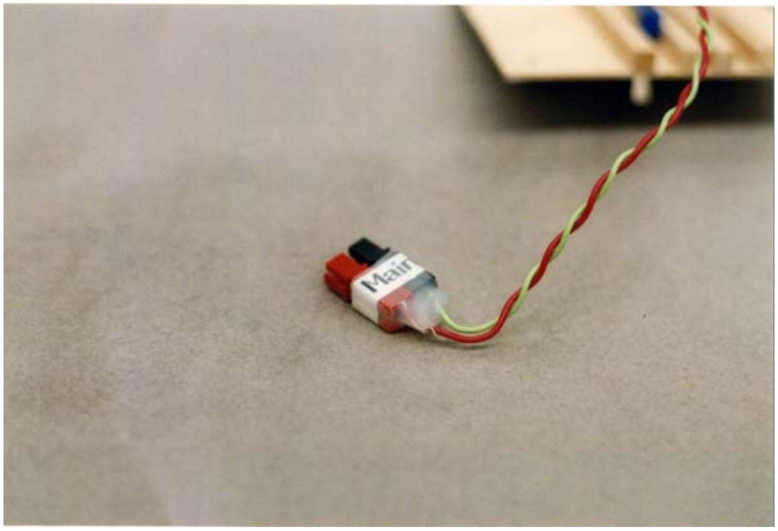
***LM335*.**

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

Male Headers

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

PCB Power Connector



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

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

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

LED Power Indicator

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

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

DJ-S11 MIC, Audio, and Power Connectors

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

MIC and Audio

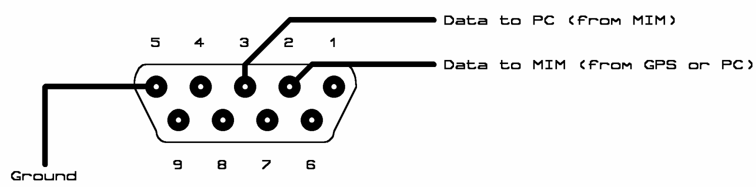
- √ Strip back ¼” of insulation from one end of a black wire and a colored wire.
- √ Solder the black wire to the GND pad of the HT pads and the colored wire to the TX/PTT pad of the PCB.
- √ Solder the other end of the GND wire to the base of the 1/8” phono jack.
- √ Plug the Ground plug into the HT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

Power

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

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

DB-9 Connector



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

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

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

4.2.4. Notes on Design

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

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

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

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

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

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

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

Materials to Make the Avionics Pallet

- Sheet of Coroplast™
- Neoprene foam
- Nylon wire ties
- Drill bit to punch holes

Procedure to Make the Avionics Pallet

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

4.2.6. Software Changes

I recommend programming the MIM with the following settings:

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

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

4.2.7. General Comments

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

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

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

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

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

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

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

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

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

```
POS 10
```

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

`STR GPGGA`

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

`TELE 10 5`

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

`B 20`

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

`BT (name of your flight computer)`

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

`CW 30`

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

`CWI your call sign-11`

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

4.2.8. Example of Telemetry

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

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

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

Good To Know: Upper-air Soundings with Radiosondes

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

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

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

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

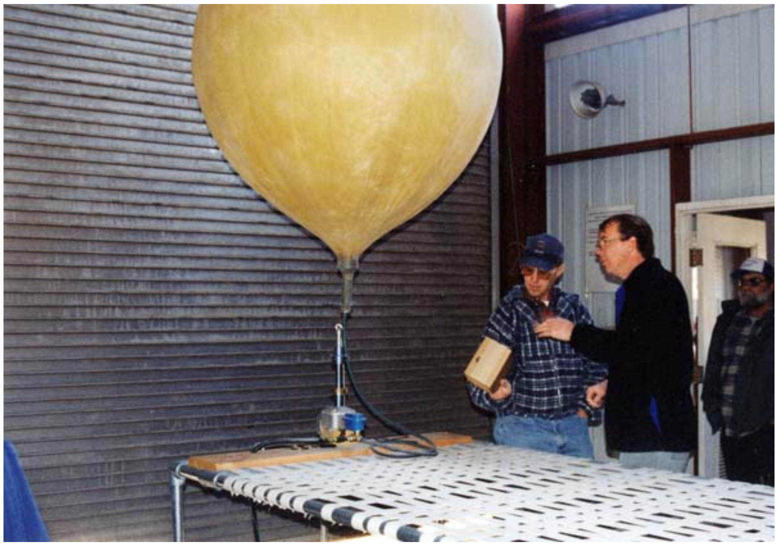
In the upper-air sounding system are as following elements:

- Flight Subsystem
- Surface Subsystem

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

- Balloon
- Flight Train
- Radiosonde

Balloon



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

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

Flight Train

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

Radiosonde

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

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

Surface Subsystem
The Ground Subsystem consists of the following parts:

RDF Wind-finding Antenna
Receiver and Sensor Processing Unit

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

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

A Radiosonde Launch

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

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

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

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

Near Space Humor

Fourteen Near Space Bumper Stickers

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

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

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

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

CHAPTER THREE

Near Space Avionics, Part Two

Two NearSys Central Computer/Programmable Sequencers (CC/PS)

" Alas poor Newton! Late for learning fam'd,
No more shall thy researches e're be nam'd:
For greater Newtons, now, each day shall soar,
High up to Heaven, and new worlds explore."
- Mary Alcock

Chapter Objectives

1.0 Introduction to the NearSys Flight Computers

The near spacecraft requires a set of electronics in order to complete a mission. This set of electronics can be as simple as a beacon to as complex as a flight computer. The NearSys flight computers are called the Central Computer/Programmable Sequencer, or CC/PS. As a central computer the CC/PS responds to system and environmental conditions by detecting both analog and digital inputs. After collecting and processing data, the CC/PS formats telemetry for transmission to ground stations. As a sequencer the CC/PS operates near space experiments and events in a simple, repetitive cycle.

The CC/PS functions in all phases of a near space flight from Systems Checkout, Prelaunch Activities, through Flight and Recovery. Upon power up, the CC/PS can be programmed to exercise experiments and display current GPS data. While waiting for a change in altitude, or for the launch command, the CC/PS can keep ground crews informed on capsule status. During flight, the CC/PS can operate near spacecraft equipment, collect science and status data, and send telemetry to ground stations. When balloon burst is detected, the CC/PS can terminate experiments and change its position, reporting frequency as an aid to recovery. The CC/PS is mounted inside the near spacecraft and has external connections to batteries, HT, GPS receiver, and possibly a TNC.
The CC/PS has several levels of intelligence. At the basic level, the CC/PS can monitor the status of the capsule's individual systems like power, internal temperature, and GPS position. At a higher level, the CC/PS operates experiments based on programmed conditions. In the highest level of intelligence, the CC/PS responds to system failures or ground commands during a flight.

The source of intelligence in the CC/PS is one of the BASIC Stamp 2 (BS2) microcontrollers from Parallax, Inc. The microcontroller is programmed to fetch and interpret PBASIC instructions stored in its EEPROM. EEPROM doesn't require battery power to store programs. In this way the EEPROM behaves like a hard drive, storing the program to be executed when the microcontroller starts up. While 2k of memory may not seem like a lot, it's enough memory for about 600 lines of instructions. Typically an entire mission is operated on a single 2k program. In addition to EEPROM, the BS2 has 32 bytes of internal RAM for storing variables that can be updated during program execution. The BS2 uses software UARTs, allowing any I/O pin to function as a simple serial port. This gives every I/O pin on the BS2 the ability to communicate with GPS receivers and TNCs.

Programs for the BS2p are entered on a PC using the free programming software developed by Parallax. On the PC, BS2p programs are checked for syntax and memory usage before being downloaded into EEPROM. In EEPROM the program exists in a tokenized format that the BS2p's microcontroller fetches and interprets.

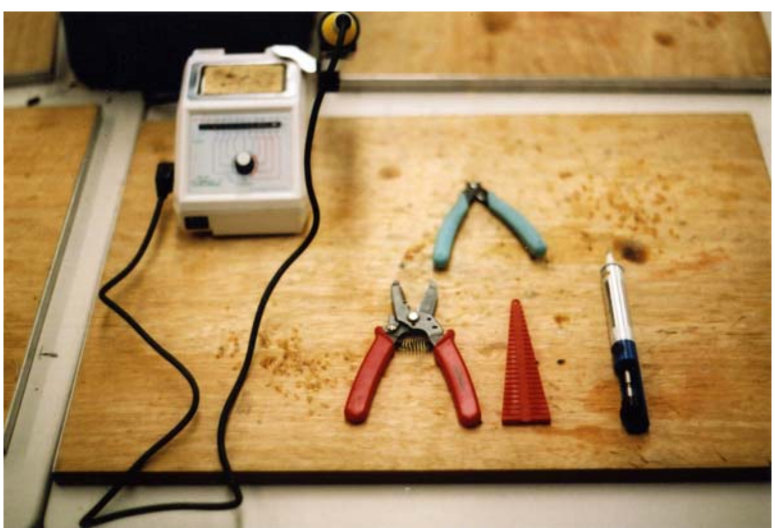
1.1. Block One and Block Two CC/PS

Two flight computers are described in this chapter, the Block One CC/PS and the Block Two CC/PS. Both blocks contain a BASIC Stamp 2, MAX186 ADC, ULN 2803 Darlington pair, and Servo Controller. The difference between the two blocks is that the Block Two has a built-in TNC, whereas the Block One's TNC is external.

the Block Two CC/PS contains a TNC on the PCB (a MIM) and should be considered experimental. The Block One CC/PS depends on an external TNC. Both flight computers are capable of performing the same experiments during a mission.

1.2. Before You Begin Construction

Before you begin constructing the CC/PS, please review Section 1.2 of Chapter 2 for a refresher of recommended soldering tools and techniques. The time you invest in practicing soldering may save you time, money, and aggravation as you build your CC/PS. The soldering tools listed in that section will be necessary to complete your CC/PS.



***Construction** – Tools for soldering the CC/PS PCB.*

1.1

1.2.1. Other Tools

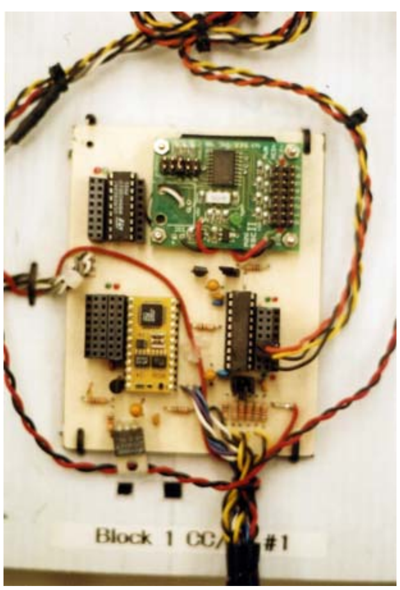
In addition to your soldering tools, you will need these two listed below to complete your CC/PS:

- Hot glue gun
- Jeweler's screwdrivers
- Hot air gun (heat gun)

Tools *– Hot glue gun, jeweler's screwdrivers, and hot air gun.*

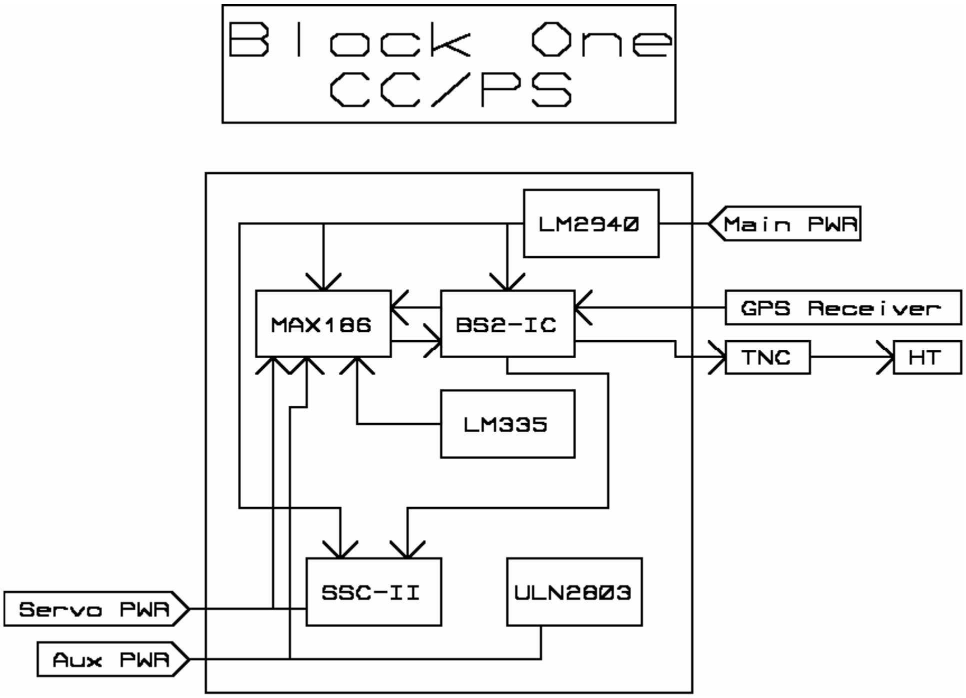
The jeweler's screwdrivers are used to bolt the daughter boards to the CC/PS PCB. The hot air gun is used to shrink heat shrink tubing. Never use a soldering iron to shrink heat shrink tubing. Other than that, enjoy building the CC/PS for your near spacecraft and don't burn your fingers in the process.

2.0 The Block One CC/PS



The Block One CC/PS *– The completed flight computer. Detailed instruction on how to build it are given in the following sections.*

The diagram below shows components and their relationships.



Block Diagram *–Conceptual view of Block One CC/PS.*

In the Block One CC/PS, the BS2p controls the following devices onboard the CC/PS:

- MAX186 Analog-to-Digital Converter (ADC)
- SSC II Serial Servo Controller
- ULN2803 Darlington Pair

The MAX186 digitizes voltages from sensors which output a voltage dependent on the condition they measure. Voltages from 0 to 4.096 Volts are digitized with a resolution of 1mV. The MAX186 can digitize the voltage difference between two channels. The SSC II positions servo motors to a precision of less than one degree. A total of eight servos can be controlled during a mission. The ULN2803 switches on and off devices requiring higher voltage or current levels than the BASIC Stamp can source. A source of additional voltage, the Aux Pwr, is recommended for these devices so they cannot discharge the main battery.

The Block One CC/PS requires an external TNC, like the Kantronics KPC-3+, so there is no TNC mounted on the PCB.

GPS receivers can be connected to the Block One CC/PS in two different ways. In the first way, the GPS talks to both the BASIC Stamp and the TNC simultaneously. This configuration increases the reliability of missions by preventing a communications lock-up should the CC/PS fail. The second way is to connect the GPS receiver to only the BASIC Stamp, which requires the BASIC Stamp to forward GPS sentences to the TNC.

While any 24-pin BASIC Stamp 2 can be used in the Block One CC/PS, I recommend a BS2p because of its scratch pad RAM (SPRAM). An entire GPS sentence can be read into SPRAM for later processing.

2.1. Theory of Operation

The following topics are covered under Theory of Operation

1. CC/PS Ports
2. Devices Internal to the CC/PS
3. External Devices Interfaced to the CC/PS
4. Function of Each Discrete Component on the CC/PS

2.1.1. CC/PS Ports

Ports provide a means to interface real world data to the BS2p. The seven ports function as either input or output, and some operate as both input and output. External devices can be connected to these ports for control instructions and/or data input.

BS2p Inputs
The following inputs are available to the BS2p:

- Eight channels of ADC, each with twelve bits of resolution
- GPS sentences from the GPS receiver
- Ground commands sent through the TNC
- Eight I/O ports

BS2p Outputs
The following outputs are available to the BS2p:

- Telemetry to the TNC
- Commands to the SSC II to position up to eight servos
- Eight channels of high power (up to 12 Volts at 1 amp) digital output
- Eight I/O ports

Now the ports in greater detail:

I/O Expansion Port
Data Type: Digital (Analog when filtered)
Data Direction: Input and Output

The CC/PS contains eight expansion ports. Each port contains its own BS2p I/O pin, +5 Volts, Ground, Clock line, and Data line. Each expansion port allows commands to be sent to devices through protocols like serial, I^2C, SPI (serial peripheral interface) and 1-Wire. Expansion ports also operate low power devices like electric switches on cameras. Each expansion port can also collect data from sensors like Geiger counters and light-to-frequency converters. With the combination of pins available at each I/O port, a single cable can power, command, and collect data from a sensor connected to the expansion port

ULN2803 High Power Port
Data Type: Digital

Data Direction: Output

The BS2p drives high power loads (up to one amp at twelve Volts) through a ULN2803, Darlington pair IC. An additional battery is required onboard the near spacecraft as the source of auxiliary voltage.

Jumper wires make the connection between BS2p I/O pins and the inputs of the ULN2803. A command to activate a ULN2803 output is made by setting the corresponding I/O pin high. When activated, auxiliary power is available to the corresponding output of the ULN2803.

SSC II Servo Port
Data Type: PWM Digital
Data Direction: Output

The SSC II allows the BS2p to position up to eight servos. The serial connection between the BS2p and SSC II is hard wired into the CC/PS PCB.

ADC Analog Port
Data Type: Analog
Data Direction: Input

The ADC ports convert analog voltages into digital values upon command from the BS2p. Analog voltages are digitized with 12 bits of resolution and the maximum input voltage is 4.096 Volts. The analog ports are typically used to record the results of sensors, but can be configured to digitize near spacecraft voltages and temperature through the use of four jumpers.

ADC Jumpers
Jumpers one through three are located above the MAX186 and jumper four is located below it. When the jumpers are shorted with a shorting block, the corresponding sensor is connected to the MAX186 through a specific ADC channel. When shorted, no external sensor can be attached to that particular ADC channel. When the shorting block is removed, that particular ADC channel can accept external sensors. The table below is a list of jumpers, sensors, and ADC channels for the four jumpers.

Jumper	Sensor	ADC
1	Main V	3
2	Aux V	2
3	Servo V	1
4	Temperature	4

GPS Port
Data Type: Digital
Data Direction: Input and Output

The BS2p receives GPS sentences through the GPS Port. In most cases the CC/PS is programmed only to read GPS sentences in order to determine the altitude at which experiments are performed. However some GPS receivers have the capability to act on commands sent to them. The Block One CC/PS is designed to allow the BS2p to send commands to a GPS receiver.

TNC Port
Data Type: Digital

Data Direction: Input and Output

The BS2p may need to send telemetry to ground stations. Ground stations may find it necessary to send commands to the CC/PS through packet radio. Depending on the TNC and how it is wired into the Block One CC/PS, the TNC Port may allow two-way digital communications between ground stations and the near spacecraft.

2.1.2. Devices Onboard and Interfaced to the CC/PS

BS2p (Programmable Microcontroller)
The CC/PS is built on a double-sided printed circuit board measuring four inches by six inches. At the heart of the CC/PS is a Parallax BS2p. The BS2p has 32 bytes of RAM and 16k bytes of EEPROM. In addition, there are 128 bytes of Scratch Pad RAM (SPRAM). One step in configuring an near spacecraft for a mission is programming the BS2p onboard the CC/PS with the necessary flight code.

Serial Servo Controller 2 (SSC II)
The SSC II positions up to eight servos in accordance to commands from the BS2p. The servos require their own battery in the near spacecraft. The use of a separate servo battery prevents a bad servo from discharging the main battery and shutting down the CC/PS.

The BS2p sends commands to the SSC II at 2400 baud, N81. The commands specify which servo is to be placed to which position. Serial commands to the SSC II begin with a start byte 255h, followed with a servo number (1 to 8), then followed with a position byte. Some servos are capable of rotating 180 degrees while others can rotate only 90 degrees. With 255 available positions, servos can be positioned with a precision of less than one degree. After the command to position a servo is received, the SSC II maintains the servo's position without further instruction. Power to operate servos is provided by the servo battery (Servo V).

ULN2803 (Darlington Pair Transistor Switch)
The BS2p places input pins of the ULN2803 high, activating outputs. The ULN2803 is an eight pair Darlington transistor IC. A Darlington pair consists of two transistors. Energizing the base of the first transistor lets current flow into the base of the second transistor, increasing the gain of the transistor pair. Darlington pair transistors allow the BS2p to source voltages and currents in excess of the BS2p's limit of 5 Volts at 20 mA. Auxiliary Power provides voltage and current for the ULN2803. By using a separate battery for Aux V, problems with devices using it cannot drain the main battery (Main V), thus preserving flight functions in case of in-flight accidents.

MAX186 Analog to Digital Converter (ADC)
The MAX186 is the primary analog to digital converter for the CC/PS. The MAX186 digitizes eight analog inputs whose voltages do not exceed 4.096 Volts. The resolution of the MAX186 is 12 bits, yielding a precision of one millivolt. Results of the A to D conversion are either relayed to ground stations or used by the BS2p.

The MAX186 is a SPI serial device. To begin a conversion, its chip enable pin is brought low. Then the commands for which channel the MAX186 is to digitize is shifted out by the BS2p (the commands for the MAX186 are stored in a lookup table). Afterwards the results of the conversion (twelve bits) are shifted back to the BS2p

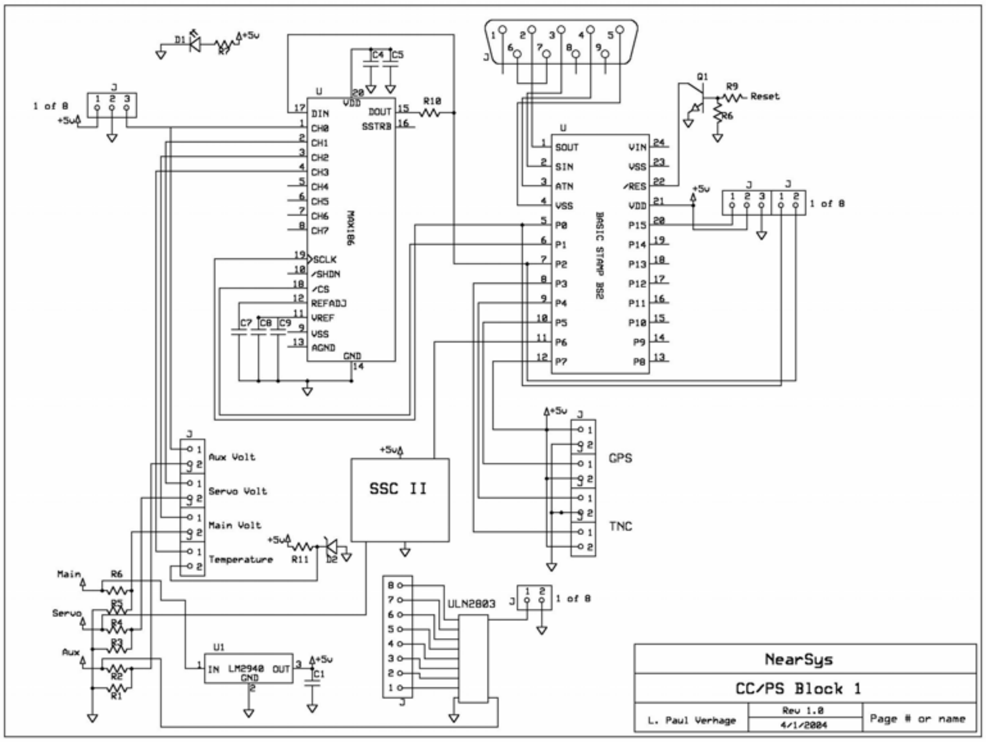
The BS2p communicates with the MAX186 via SPI, a synchronous serial protocol using either two or three wires for communication and one wire to activate the IC. The first wire sends the clock signal, which synchronizes the flow of data. The last two are data in and data out, although in the CC/PS the two data wires are shared. To begin a communication session to digitize a voltage and return the results to the BS2p, the BS2p first asserts the CE pin of the MAX186 high. Now the MAX186 is ready to receive serial data from the BS2p. Commands are sent to the DI pin of the MAX186 over the DATA_IO pin of the BS2p and clocked by the CLK pin of the BS2p. Every pulse of serial data to the MAX186 is "signaled" by the clock pulse. Eight clock pulses are required to instruct the MAX186 as to which pin to digitize. There are other options available with the MAX186, but they are not used with the CC/PS. The BS2p then clocks twelve more times, reading bits from the MAX186. The result is 12 bits, or 1.5 bytes, long. A one-word variable is required to store the result of the conversion.

2.1.3. Function of Each Component

The function of each discrete component on the CC/PS is listed in the table below.

Component	Function
R1 & R2	Voltage divider for Servo Voltage for the ADC
R3 & R4	Voltage divider for Auxiliary Voltage for the ADC
R5 & R6	Voltage divider for Main Voltage for the ADC
R7	Current limiting resistor for LED
R8	Pull-down resistor for BS2p reset
R9	Current limiting resistor for reset transistor (Q1)
R10	Current limiting resistor for ADC data-out
R11	Current limiting resistor for temperature sensor (D2)
C1	Filtering capacitor for voltage regulator (U1)
C2	Filtering capacitor for voltage regulator (U1)
C3	Filtering capacitor for ADC Port
C4 – C9	Filtering capacitors for ADC
D1	Power ON indicator of CC/PS
D2	Temperature sensor
U1	Low dropout voltage regulator
Q1	Switch to force BS2p reset

2.2. Construction of the Block One CC/PS



Schematic of CC/PS Block 1

First inspect the CC/PS PCB for shorted or broken traces. Then collect the following components listed in the table below.

2.2.1. Components

Part	Value	Quantity
Resistor	1k	3
Resistor	10k	6
Resistor	15k	1
Resistor	22k	1
Capacitor	0.01 uF	1
Capacitor	0.1 uF	5
Capacitor, Tantalum	4.7 uF	2
Capacitor, electrolytic	22 uF	1
Temperature sensor	LM335	1
Voltage Regulator	LM2940T-5	1
Darlington Pair IC	ULN2803	1
Transistor	2N3904	1
ADC	MAX186	1

Miscellaneous Parts

Part	Value	Quantity	Supplier	Part Number
DIP Socket	18 pins, 0.3" wide	1		
DIP Socket	20 pins 0.3" wide	1		
DIP Socket	24 pins 0.6" wide	1		
.025" female receptacles (0.1" between centers)	8 pin double row headers	4	Jameco	70720
.025" female receptacles	8 pin single row headers	3		70754
.025" male headers	8 pin double row pins	1	Jameco	160881 117196
Shorting Block		4		

2.2.2. Daughter Boards

Apart from the components, the following completed daughter boards are needed to complete the CC/PS.

Part	Quantity
BASIC Stamp 2	1
SSC II	1

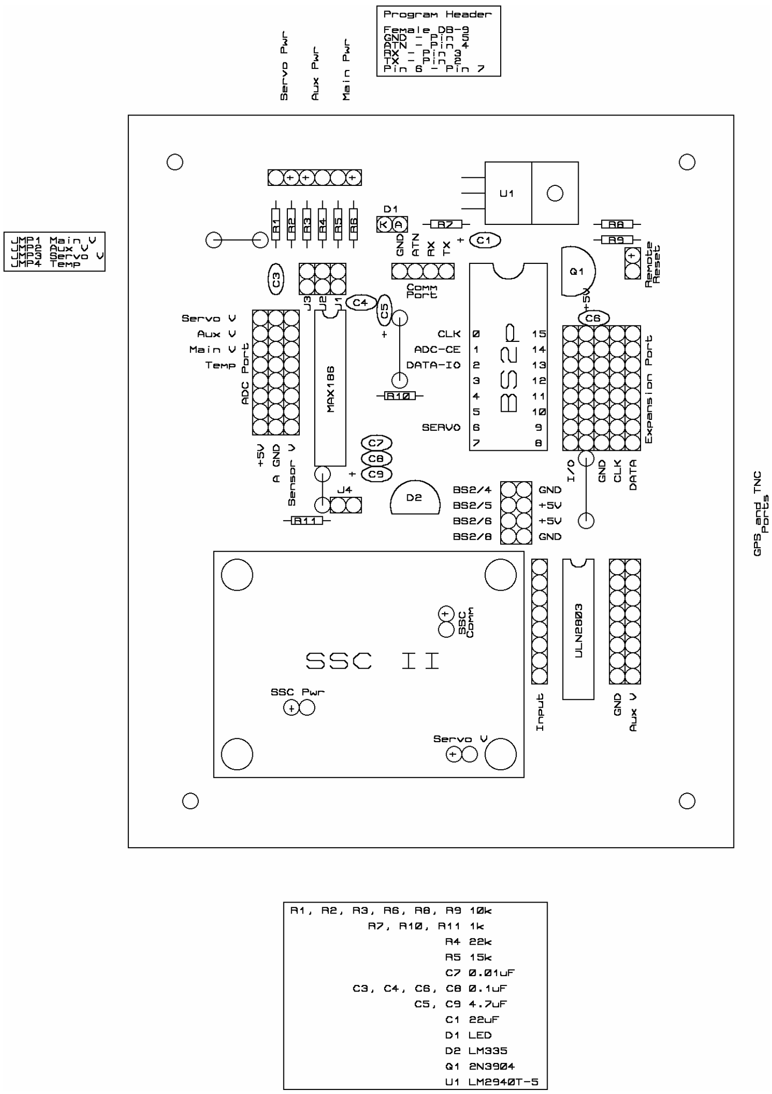
2.2.3. CC/PS Cables

Eight cables interface power and data to and from the CC/PS. The next table lists components required to make these cables.

Part	Value	Quantity	Supplier
Powerpole® Connectors[A]		3 pairs	Hobby and electronic shops
Mini Toggle Switch	SPST or SPDT	3	Jameco #26315
D-Subminiature Connector	9-Position female	1	
D-Subminiature Connector	9-Position male	1	
D-Subminiature Connector	25-Position male	1	
#24 AWG Stranded Wire	Assorted colors		
Heat Shrink Tubing	Assorted diameters		
Nylon wire ties			

2.3. Sequence of Construction

Refer to the following diagram when placing components on the PCB.



***Component Placement** – Parts Placement for Block One CC/PS*

2.3.1. Jumpers

First solder the jumper wires. Jumper wires make electrical connections across copper traces without causing shorts. There are four jumper wires on the Block One CC/PS. To make a jumper wire, first cut a solid #22 or #24 AWG wire to ½” longer than the length of the jump. Strip ¼” of insulation from both ends, and then bend the ends at right angles to the wire. After soldering the wire into the via hole, snip the protruding ends of the via lead. An alternative is to use zero ohm resistors in place of jumper wires. Do not use bare wires (like cut resistor leads) to form the jumpers. Using insulated wire instead prevents dropped objects from shorting out the CC/PS, another one of those events that occurs at 100,000 feet rather than on the ground.

2.3.2. SSC II

The SSC II on the CC/PS is a daughter board that offloads some of the work from the BS2p. In this case, it is control of the servos that the SSC II takes care of, at the command of the BS2p. Four connections are needed to connect the SSC II to the CC/PS, one mechanical and three pairs of electrical. One electrical pair is the servo battery connector and is already soldered to the SSC II. The second electrical pair is power for the SSC II. It arrives attached to the SSC II with a nine-volt battery snap at the end. The remaining pair needs to be added.

• Communication Connection

√ Cut two 2” lengths of #24 AWG wire, one red and the other black or green.
√ Strip ¼” of insulation from both ends of all the wires and set aside for a few minutes.
√ Modify the SSC II by removing the RJ-11 phone jack from the board:
√ Cut the plastic tabs holding the RJ-11 jack to the PCB.
√ With a solder sucker and soldering iron, remove the four solder joints of the RJ-11.
√ Carefully lift the RJ-11 as you continue to heat its solder pads.
√ Discard the RJ-11 jack.

Beneath the former location of the RJ-11 jack you’ll notice four solder pads aligned in two diagonal pairs. Two of the solder pads are connected to each other with a thin copper trace. These two pads are ground connections. The remaining two solder pads are the signal connections.

√ Solder a wire into one of the signal solder pads.
√ Solder the second wire into the ground solder pads.

• SSC II Power Connection

Before you begin, note which SSC II solder pad has the ground wire (black wire) of the nine-volt battery snap.

√ Remove the red wire of the nine-volt battery snap from the SSC II with a soldering iron.
√ Located a solder pad marked +5V.
√ Solder the red wire to this solder pad.
√ Cut off the nine-volt battery snap, making the wire lengths about 2” long.

• Servo Battery Power

Two wires provide voltage for servos and are located at the bottom of the SSC II. Cut these wires to a length of two inches.

After modifying the SSC II (and voiding its warranty), strip ¼” of insulation from the ends of the wires. Some wires can be passed through the holes remaining from the RJ-11 jack; however, it’s not necessary to do this. Note carefully which CC/PS pads are for which electrical connection. Solder the wires to their appropriate pads in the PCB.

• Mechanical Connection

A three-millimeter thick sheet of foamed neoprene rubber is the easiest way to mount the SSC II to the CC/PS. The foam is available at craft and hobby shops and is sold under the name Foamies®. [B]They come in a variety of colors, so I suppose you can color coordinate your CC/PS. Cut the foam sheet to size then cut holes in it for the SSC II crystal and mounting holes.

Foamies® *– Foam neoprene.*

Fold the SSC II wires and place the neoprene sheet under the SSC II. Use 2-56 hardware to bolt the SSC II to the CC/PS PCB. Bolt lengths of 3/8" suffice, but I have only found ½" long bolts. I haven't needed washers, as the nuts are sufficiently large.

2.3.3. Sockets

The CC/PS has three sockets for ICs. Insert the sockets into the CC/PS as indicated on the CC/PS diagram. This means the notches of all three sockets are oriented towards the top of the PCB. Electrically it doesn't matter if the socket is placed upside down or right side up, but by correctly orienting the sockets, it's easier to properly orient their ICs, which must be placed in the correct orientation. To solder IC sockets, use this procedure: First solder the IC sockets only at two diagonally opposite pins. Press on the socket with your finger and then reheat each diagonal pin with the soldering iron. The IC socket will snap down on the PCB if it's not properly seated. Now finish soldering the socket by soldering its remaining pins.

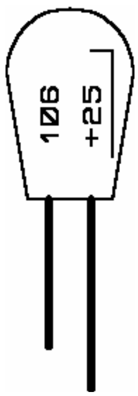
2.3.4. Expansion Ports

The expansion ports occur in rows eight receptacles wide. The female receptacles needed are five double rows of headers eight pins long. Three single sided rows of headers eight pins long are required to build the ports. To save money, purchase longer receptacles and cut them to length.

- √ Cut the receptacles to length using a sharp Exacto knife.
- √ Insert all the receptacles of an entire port before soldering any of them.
- √ Press the receptacle bases down firmly to the PCB.
- √ Ensure the receptacles are snug to the CC/PS board and vertical to the PCB and parallel to their neighbors.
- √ Solder the receptacles. Note: If the receptacles are loose, hold them down to the CC/PS with a piece of masking tape before flipping the CC/PS over on its back.
- √ After soldering the receptacles, make sure no solder bridges were formed.

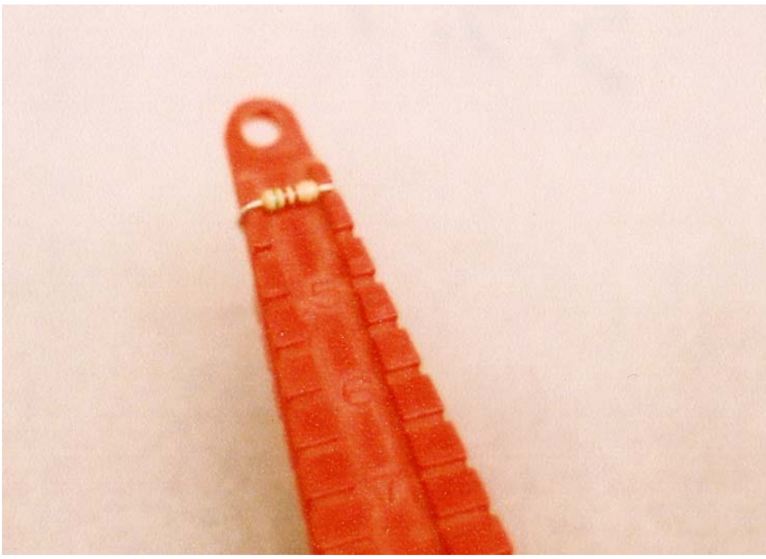
2.3.5. Discrete Components

Place components into the CC/PS PCB according to Diagram 2-1. The most important items are the electrolytic capacitors. If you put them in backwards, the CC/PS will probably let you know by exploding the caps. There are three electrolytic capacitors: C2, C5, and C9. Watch the polarity markings on the caps and the CC/PS diagram.



***Tantalum Capacitor** – The positive lead is the one indicated – not the negative, as in an aluminum electrolytic capacitor.*

Bend resistors to a length of 0.4 inches with a lead bender, available at Radio Shack. Q1 and D2 are in identical looking TO-92 form factors. Read their faces carefully before installing them into the CC/PS. The CC/PS diagram shows their proper orientation. After soldering each component, clip the excess leads.



***Lead Bender** – This tool allows component leads to be bent to the perfect length and angle.*

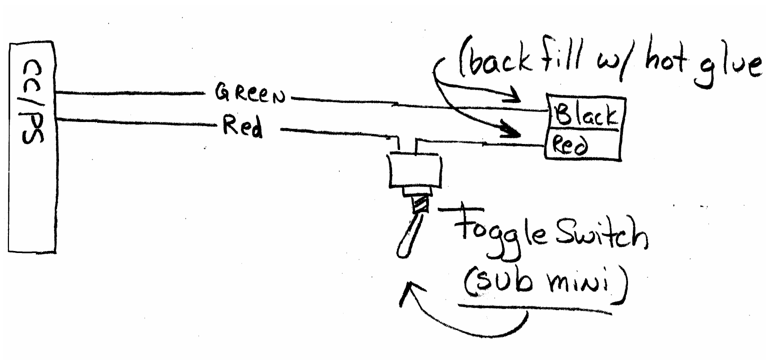
Component Checklist

- R1 10k
- R2 10k
- R3 10k
- R4 22k
- R5 15k
- R6 10k
- R7 1k
- R8 10k
- R9 10k
- R10 1k

- R11 1k
- C1 0.1 uF
- C2 22 uF or greater tantalum
- C3 0.1 uF
- C4 0.1 uF
- C5 4.7 uF
- C6 0.1 uF
- C7 0.01 uF
- C8 0.1 uF
- C9 4.7 uF
- D1 LED
- D2 LM335
- U1 LM2940T-5
- Q1 2N3904

2.3.6. Power Cables

Three cables are needed to provide external power to the CC/PS -- the Main Power, Servo Power, and Auxiliary Power cables. Each cable is identically constructed.



Power Cable *– The toggle switch is inline with the positive power lead (red wire).*

Completed Power Cable *–The toggle switch is in the positive line and Powerpole® connectors terminate the cable. The Powerpole® housings are backfilled with hot glue.*

√ Cut six red colored #24 AWG stranded wires to a length of at least 12 inches.
√ Cut three black colored #24 AWG stranded wires to a length of at least 24 inches.

√ Strip ¼" of insulation from one end of each black wire and three of the red wires. Note: this end solders to the PCB.
√ Strip one inch of insulation from the other ends of the wires. Note: This end solders to either a Powerpole® or toggle switch.
√ Solder the ¼" end of pairs of wires to the CC/PS pads marked Main Pwr, Aux Pwr, and Servo Pwr. Note: These pads are located at the top left of the CC/PS and be sure to solder the red wire to the pads marked "+".
√ Slide a short length (at least ½") of heat shrink tubing on the three red wires.
√ Twist the end of each red wire to the center terminal of the SPST or SPDT mini-toggle switches, one wire per toggle switch.
√ Solder the red wires to the toggle switches.
√ Twist one end of the remaining red wires to the outside terminal of the SPST or SPDT mini-toggle switches.
√ Solder the remaining red wires to the toggle switches.
√ Slide a short length of heat shrink tubing over the remaining red wires.
√ Cover both soldered terminals of each switch with heat shrink tubing and shrink.
√ Double over the ends of the remaining one inch stripped wires.
√ Crimp a Powerpole® terminal to the remaining ends of the red and black wires.
√ Solder the crimped terminal to the wire.
√ Slide the crimped terminal into a Powerpole® housing, being sure to match the color of the Powerpole® housings to its wire.
√ Slide the Powerpole® housings together into a unified connector. Note: There is more involved in this that it initially seems. A standard alignment must be determined so that any battery pack can attach to any power cable. Select a standard for the program, document it, and stick with it.
√ Twist pairs of the wires together to keep the power cables neat and under control.
√ Finish by back-filling the Powerpole® connector with hot glue.

2.3.7. Programming/Communication Cables

The BASIC Stamp uses a female DB-9 (D-subminiature) connector and the GPS requires a male DB-9 connector. The BS2p requires four wires connected to its DB-9 connector, and the GPS requires two wires connected to its DB-9 connector (other wires, like RX and 1 PPS are optional). Make the cables as follows:

√ Cut six stranded wires to a length of 12 inches. Note: Use different colors of wires to differentiate between them. Also, since each DB-9 needs a ground, there should be at least one black wire per DB-9.
√ Strip back ¼ inch of insulation at both ends of each wire.
√ Solder wires to the pins of the DB-9 connectors as listed below:
  - The BS2p cable uses DB-9 (female) pins 2,3,4,5
  - The GPS cable uses DB-9 (male) pins 2 and 5

Note: Since pin 5 on a DB-9 connector is ground, make this one a black colored wire.

√ Solder wires to the DB-9 connector pins as indicated above.
√ Slide short lengths of heat shrink tubing over the wires and cover the soldered pins.
√ Shrink the tubing down, covering the exposed solder.
√ On the BS2p DB-9 connector, short together pins 6 and 7 with a piece of resistor lead.
√ Use hot glue and cover all of the backs of the pins of the female DB-9 connectors.

√ Place the male GPS DB-9 connector into a plastic housing.

Note: If the GPS is to connect to a device (like the KPC-3+) that allows serial cables to screw to the port, then place locking screws into the DB-09 housing at this point. If the GPS is not to connect to such a device, then leave out the locking screws from the DB-9 housing.

Before closing the housing, cover the interior of the housing and the connector pins of the DB-9 with hot glue. Do this before the glue gets hot enough to melt the plastic housing.
Quickly close the housing and bolt it closed. Use more glue and seal the opened end in the back of the housing.

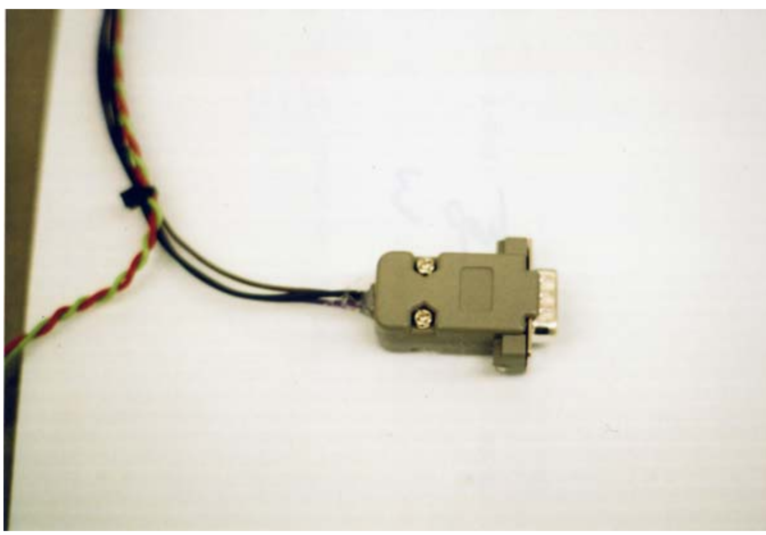
Connect the following pins of the BS2p programming connector to the CC/PS:

- GND to pin 5 of the BS2p DB-9
- ATN to pin 4 of the BS2p DB-9
- RX to pin 3 of the BS2p DB-9
- TX to pin 2 of the BS2p DB-9

Connect the following pins of the GPS connector to the CC/PS:

- GND to pin 5 of the GPS DB-9
- Signal to pin 2 of the GPS DB-9

Twist the programming and communication cables into three neat bundles.



DB-9 Connector *– Housing for GPS DB-9 connector. Interior volume is filled with hot glue.*

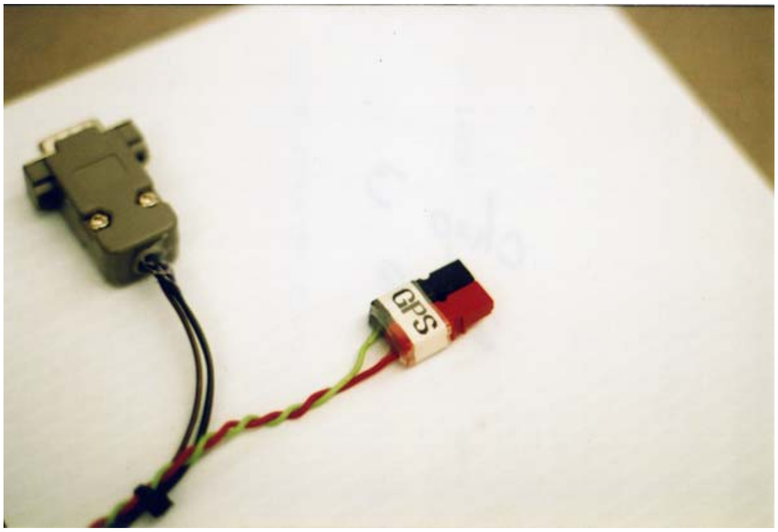
2.3.8. Power Indicator Cable

√ The two-wire cable of the LED power indicator solders to the CC/PS pads marked D1.
√ Cut the two lengths of stranded #24 AWG wire twelve inches long. Note: Use two different colors of wire, making the ground wire either black or green.
√ Strip ½ inch of insulation from one end of each wire and tin the ends.
√ Trim the leads of the LED to ½" and tin. Note: The ground wire connects to the LED lead closest to the flat spot on the LED case.
√ Press a wire and LED lead together and then heat them with a solder iron.
√ Remove the iron after the solder on both the LED lead and wire melts and flows together.

- √ Do the same for the other LED lead and wire.
- √ Slide one-inch lengths of heat shrink tubing over the wires, covering the exposed leads of the LED and shrink the tubing.
- √ Slide a second piece of heat shrink tubing over the covered leads and shrink that down.
- √ The wire soldered to the rounded side of the LED is soldered to the D1 pad marked with a +.
- √ Solder the wire connected to the flat side of the LED (the black colored wire) to the other side of the D1 pad.

2.3.9. Labeling

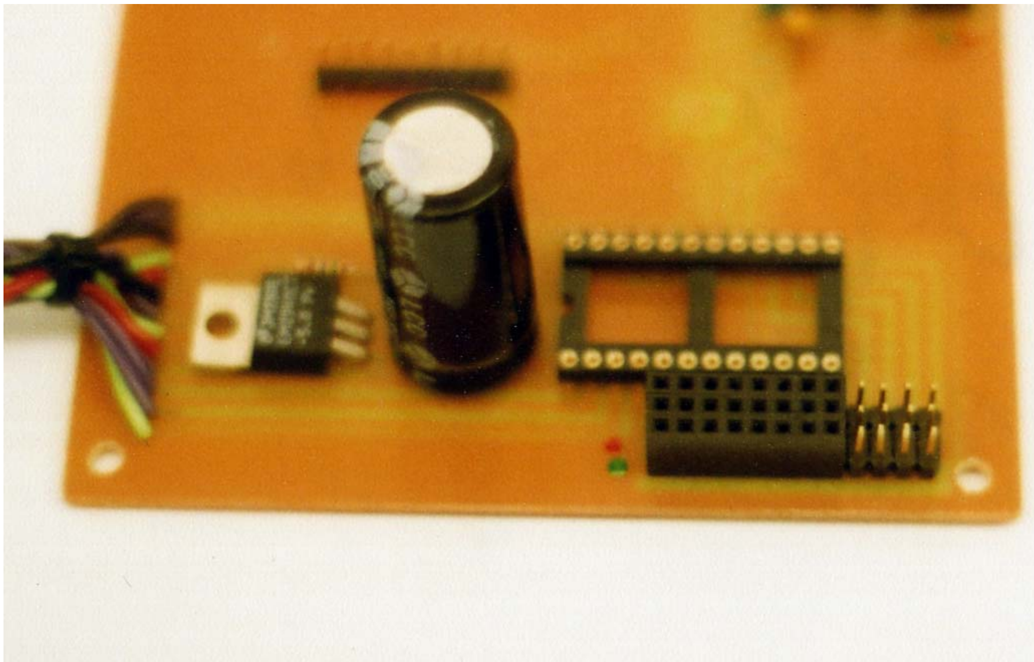
Make sticky labels for the Powerpole® connectors, with each label indicating the function of the connector. Use a label maker like the Casio EZ-Label Printer to make professional looking labels. Label the connectors as Main, Servo, and Aux. Tape them around the Powerpole® connectors. Cover the labels with a short length of clear heat shrink tubing to make them more durable. One inch diameter clear heat shrink is large enough to cover the Powerpole® connectors.



Labeled Powerpole® *– Cover the label with clear heat shrink (1" diameter) to protect the label.*

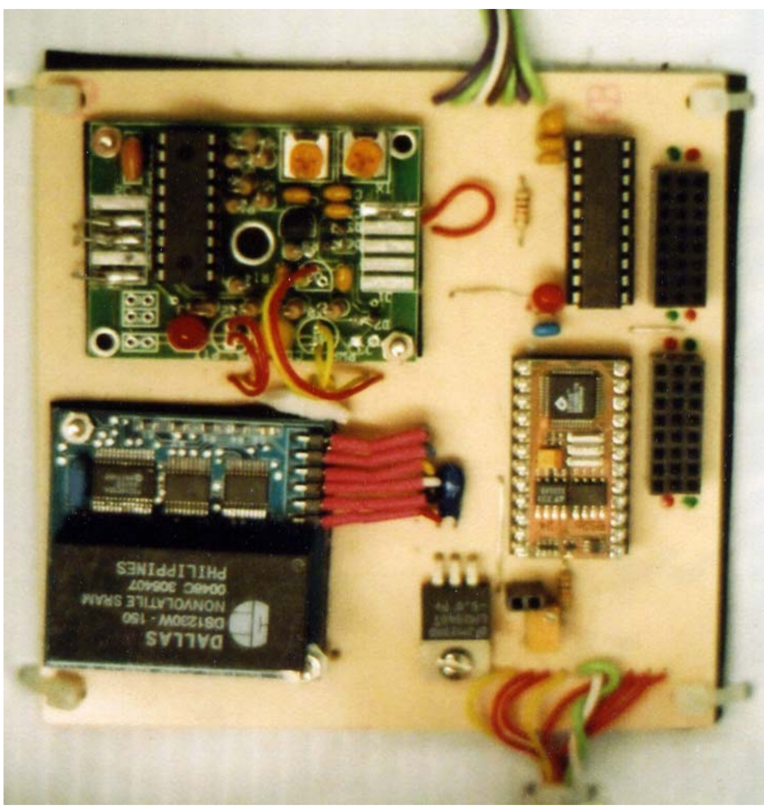
Using a toothpick, apply small dots of model paint to the CC/PS Expansion Ports. Place a small drop of red paint next to all the columns of pins with +5V, and a small dot of green paint next to all the columns of pins with Ground.

An alternative to painted dots is to use rub-on lettering or colored "sticky" dots. If you use rub-on lettering, cover the letters with a thin drop of clear paint applied with a toothpick.



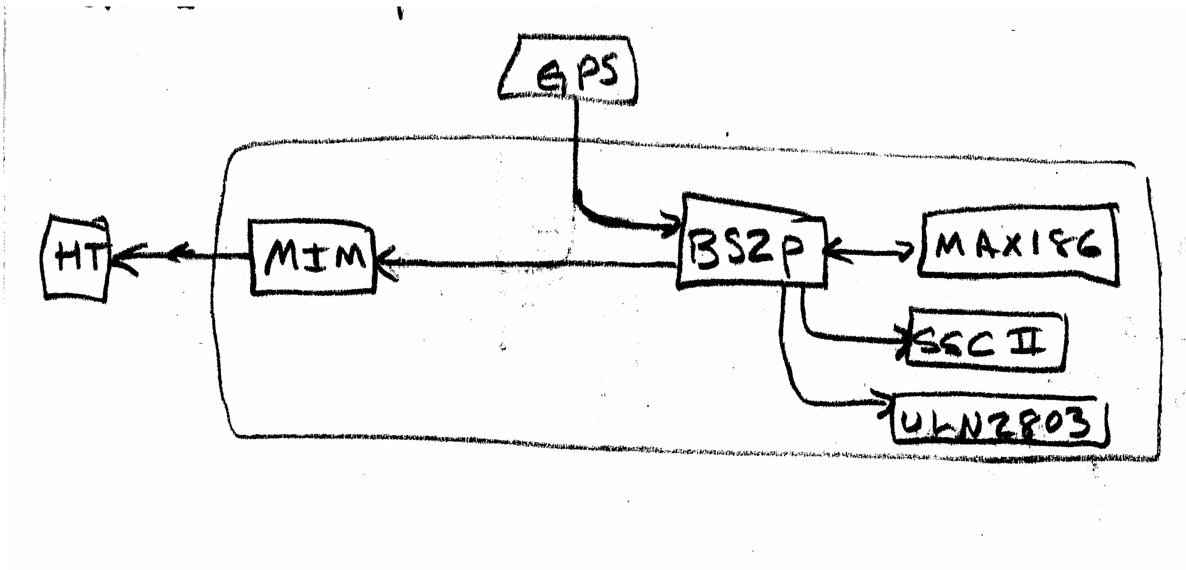
Labeled Expansion Ports *- Note the red and green dots.*

3.0 The Block Two CC/PS



Block Two CC/PS *– The completed Block Two flight computer.*

The Block Two CC/PS should be considered experimental at this time since the author has only tested a variation of this flight computer on two flights before it was lost. Below is a simple block diagram of the Block Two CC/PS, showing components and their relationships.



Block Diagram *– Conceptual view of Block Two CC/PS*

In the Block Two CC/PS the BS2p controls the following devices onboard the CC/PS:

- MIM Single Board TNC
- MAX186 Analog-to-Digital Converter
- SSC II Serial Servo Controller
- ULN2803 Darlington Pairs

The BS2p uses the MIM to generate telemetry to ground stations. The MAX186 digitizes voltages from sensors that output a voltage dependent on the condition they measure. Voltages from 0 to 4.096 Volts are digitized with a resolution of 1 mV. The MAX186 is also able to digitize the difference in voltages between two channels. The SSC II positions servo-controlled experiments with a precision of less than one degree. A total of eight servos are controllable during a mission. The ULN2803 is used to control devices requiring higher voltage and/or current levels that the BASIC Stamp can source. A source of additional voltage, the Aux Voltage, is recommended for these devices so they cannot discharge the main battery.

The Block Two CC/PS is larger than the Block One CC/PS because a TNC is mounted to the PCB; hence no external TNC is needed.

Operating the Block Two CC/PS requires the larger scratch pad RAM (SPRAM) of the BS2p microcontroller. Entire GPS sentences are read into SPRAM before going to the MIM.

3.1. Theory of Operation

The following topics are covered under Theory of Operation:

1. CC/PS Ports
2. Devices Internal to the CC/PS
3. External Devices Interfaced to the CC/PS
4. Function of Each Discrete Component on the CC/PS

3.1.1. CC/PS Ports

Ports provide a means to interface real world data to the BS2p. The seven ports can function as either input or output, and some can operate as both input and output. External devices can be connected to these ports for control instructions and/or data input. Two ports are fixed, and cannot be reconfigured.

BS2p Inputs
The following inputs are available to the BS2p on the CC/PS:

- Eight channels of ADC, each with twelve bits of resolution
- GPS sentences from a GPS receiver
- Eight I/O ports
- Main bus voltage
- Status Ports

MIM Inputs
The following inputs are available to the MIM Module on the CC/PS:

- Four channels of ADC, each with eight bits of resolution
- Eight channels of digital data
- Telemetry from the BS2p

BS2p Outputs
The following outputs are available to the BS2p on the CC/PS:

- Telemetry to the MIM Module
- Commands to the SSC II to position up to eight servos
- Eight channels of high power (up to 12 Volts at 1 amp) digital output
- Eight I/O ports

MIM Outputs
The following outputs are available to the MIM on the CC/PS:

- GPS Sentences
- Main, Servo, and Aux battery voltages
- CC/PS temperature
- Eight digital values
- CW ID

I/O Expansion Ports
The CC/PS contains eight expansion ports. Each port contains its own BS2p I/O pin, Clock line, Data line, +5 Volts, and ground. The expansion ports allow commands to be sent to serial devices using protocols such as, I^2C, SPI and 1-Wire. They also allow low power devices to be operated or

signaled, like electric switches on cameras. Each expansion port can also collect data from sensors like Geiger counters and light-to-frequency converters. With the combination of pins available at each I/O port, a single cable can power, command, and collect data from a sensor connected to the expansion port.

ULN2803 High Power Port
Data Type: Digital
Data Direction: Output

The BS2p drives high power loads (up to one amp at twelve Volts) through a ULN2803, Darlington pair IC. An additional battery is required onboard the near spacecraft as the source of auxiliary voltage.

There is a direct connection between BS2p I/O pins 8 through 15 and the inputs of the ULN2803. A command to activate a ULN2803 output also puts the corresponding BS2p pin high. If no auxiliary power is available onboard the near spacecraft, then this is not a problem. If auxiliary power is available onboard the near spacecraft, it is recommended that a BS2p I/O pin be used for only an expansion port or a high power driver on the ULN2803 but not both functions on the same mission.

SSC II Servo Port
Data Type: PWM Digital
Data Direction: Output

The SSC II allows the BS2p to position up to eight servos. The serial connection between the BS2p and SSC II is hard wired into the CC/PS PCB.

MIM Digital Ports
Input only, detects the digital status of eight inputs

ADC Analog Port
Data Type: Analog
Data Direction: Input

The ADC ports convert analog voltages into digital values upon command from the BS2p. Analog voltages are digitized with 12 bits of resolution and the maximum input voltage is 4.096 Volts. The analog ports are typically used to record the results of sensors, but can be configured to digitize near spacecraft voltages and temperature through the use of four jumpers.

MIM Analog Port
Input only, reports on three battery voltages and CC/PS board temperature. This is the first port that cannot be reconfigured.

Main Bus Voltage
This is the second BS2p I/O pin that cannot be reconfigured. A voltage divider on the CC/PS reduces the main bus voltage as input to the BS2p. This voltage divider lets the BS2p detect a low voltage condition on the main power bus as a logic low on the I/O pin.

3.1.2. Devices Onboard And Interfaced To The CC/PS

Parallax BS2p Microcontroller
The heart of the CC/PS is a Parallax BS2p-24 (BS2p for the rest of these directions). The BS2p has 32 bytes of RAM, 128 bytes of scratch pad RAM (SPRAM), and eight program slots, each with 2k bytes of EEPROM. A part of configuring an near spacecraft for a mission is programming the BS2p onboard the CC/PS with the necessary flight code.

MIM Module
The MIM Module is programmed to telemeter all serial data it receives from the BS2p. Telemetry to the MIM is sent at 4800 baud, N81. The MIM is also programmed to send four analog and eight digital values. Finally it is programmed to send a CW ID beacon as an aid to direction finding. The analog values telemetered are: Main Bus Voltage, Servo Bus Voltage, Auxiliary Bus Voltage, and CC/PS Temperature.

The MIM Module is built around a PIC microcontroller. It has the memory to store 65 characters of data. In the raw state, the MIM Module can telemeter five voltages, but as a part of the CC/PS, one of those voltages (A3) is used instead to force a transmission by bringing the A3 pin low (to ground).

There are two connections between the MIM and the BS2p. One connection is for the serial transmission of text data and the other connection is a command to transmit the data. The MIM is preprogrammed to record into RAM any text prefixed with the characters `$GP` and post-fixed with an `*`. This is the same format as NMEA standard GPS sentences. So, a direct connection between the GPS and the MIM results in the transmission of every GPS sentence from the GPS receiver (there is a limit to how fast the MIM can record data and transmit it). However, since the BS2p controls the text the MIM sees, the MIM does not transmit every sentence the GPS outputs. Telemetry sources for the MIM are GPS sentences and BS2p generated data.

To force the MIM transit, its A3 line (third analog to digital pin) must be grounded. To accomplish this, the A3 pad is connected to the collector of Q1 (a 2N3904 NPN transistor). The emitter of Q1 is connected to ground. The collector is connected to ground only when HIGHing the MIM_TX of the BS2p energizes the base of Q1. The last sentence loaded into the MIM's RAM is then transmitted as telemetry.

GPS sentences are first read into BS2p SPRAM. The GPS data is then sent one ASCII character at a time to the MIM for transmission. Since the MIM only has RAM space for 65 characters, only the first 65 characters of each sentence are sent to the MIM. After data is sent via serial to the MIM, the BS2p pulls its MIM_TX pin low. This forces the MIM to transmit its last received text.

BS2p generated text includes things like voltage levels and number of pulses from sensors. The BS2p can also be programmed to send telemetry concerning the occurrence of events.

Serial Servo Controller 2 (SSC II)
The SSC II positions up to eight servos in accordance to commands from the BS2p. The servos require their own battery in the near spacecraft.

The BS2p sends commands to the SSC II at 2400 baud, N81. The commands specify which servo is to be placed in which position. Position precisions below one degree are possible with the servos.

Commands to the SSC II are instructions to position a specific servo to a specified position. Serial commands to the SSC II begin with a start byte 255h, followed with a servo number (1 to 8), and followed with a position byte. Some servos are capable of rotating 180 degrees while others can rotate only 90 degrees. With 255 available positions, servos can be positioned with a precision of less than one degree. After the command to position a servo is received, the SSC II maintains the servo's position without further instruction. Power to operate servos is provided by the servo battery (Servo V). By using a separate battery for the servos, a problem with the servos cannot discharge the flight battery and thereby terminate mission operations.

ULN2803 (Darlington Pair Transistor Switch)
The BS2p places input pins of the ULN2803 high, activating outputs. The ULN2803 is an eight Darlington pair transistor IC. A Darlington pair consists of two transistors. Energizing the base of the first transistor lets current flow into the base of the second transistor, increasing the gain of the transistor pair. Darlington pair transistors allow the BS2p to source voltages and currents in excess of the BS2p's limit of 5 Volts at 20 mA. Auxiliary Power provides voltage and current for the ULN2803. By using a separate battery for Aux V, problems with devices using it cannot drain the main battery (Main V), preserving flight functions.

MAX186 Analog to Digital Converter (ADC)
The MAX186 is the primary analog to digital converter for the CC/PS. The MAX186 digitizes eight analog inputs whose voltages do not exceed 4.096 Volts. The resolution of the MAX186 is 12 bits, yielding a precision of one millivolt. Results of the A to D conversion are either relayed to ground stations or used by the BS2p.

The MAX186 is a SPI serial device. To begin a conversion, its chip enable pin is brought low. Then the commands that indicate which channel the MAX186 is to digitize are shifted out by the BS2p (the commands for the MAX186 are stored in a lookup table). Afterwards the results of the conversion (twelve bits) are shifted back to the BS2p.

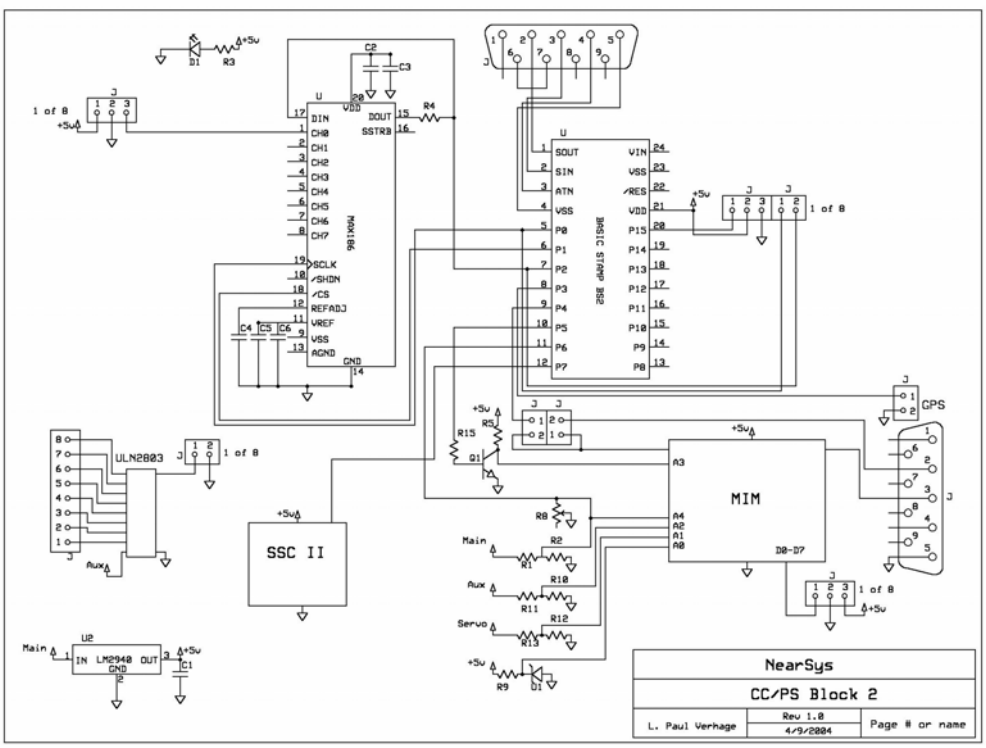
The BS2p communicates with the MAX186 via SPI, a serial protocol using either two or three wires for communication and one wire to activate the IC. The first wire sends the clock signal, controlling the flow of data. The last two are data in and data out, although in the CC/PS the two data wires are shared. To begin a communication session to digitize a voltage and return the results to the BS2p, the BS2p first asserts the CE pin of the MAX186 high. Now the MAX186 is ready to receive serial data from the BS2p. Commands are sent to the DI pin of the MAX186 over the DATA_IO pin of the BS2p and clocked by the CLK pin of the BS2p. Every pulse of serial data to the MAX186 is "signaled" by a clock pulse. It requires eight clock pulses to instruct the MAX186 which pin to digitize. There are other options available with the MAX186, but they are not used with the CC/PS. The BS2p then clocks twelve more times, reading bits from the MAX186. The result is 12 bits or 1.5 bytes long. A one-word variable is required to store the results of the conversion.

3.1.3. Function of Each Component

The following table lists the function of each discrete component on the CC/PS:

Component	Function
R1 & R2	Voltage divider for the Main Voltage for the MIM Module
R3	Current limiting resistor for the power indicator LED
R4	Current limiting resistor for ADC data-in pin
R5	Current limiting resistor for the base of Q1
R8	Voltage divider of Main Voltage for the BS2p
R9	Current limiting resistor for U1
R10 & R11	Voltage divider for the Auxiliary Voltage for the MIM Module
R12 & R13	Voltage divider for the Servo Voltage for the MIM Module
C1	Bypass capacitor for U2
C2 – C6	Filtering for MAX186 ADC
D1	Power ON indicator of CC/PS
U1	Temperature controlled zener (temperature sensor)
U2	Low dropout voltage regulator
Q1	Switch to force the MIM to transmit

3.2. Construction of the Block 2 CC/PS



Schematic of Block 2 CC/PS

First inspect the PCB for shorted or broken traces. Then collect the following components listed in the table below.

3.2.1. Components

Part	Value	Quantity
Resistor	0 Ohms	1
Resistor	1k	5
Resistor	10k	7
Resistor, Trimmer	10k	1
Capacitor	0.01 uF	1
Capacitor	0.1 uF	2
Capacitor, Tantalum	4.7 uF	2
Capacitor, electrolytic	22 uF	1
Temperature sensor	LM335	1
Voltage Regulator	LM2940T-5	1
Darlington Pair IC	ULN2803	1
Transistor	2N3904	1
ADC	MAX186	1

Miscellaneous Parts

Part	Value	Quantity
DIP Socket	18 pins, 0.3" wide	1
DIP Socket	20 pins 0.3" wide	1
DIP Socket	24 pins 0.6" wide	1
.025" male headers	double row headers	80 pins total
.025" male headers	single row headers	24 pins total
Female DB-9 solder connector		2
Male DB-9 solder connector		1
Shorting Block		1

Note:
The .025" male headers (0.1" between centers) are available at Jameco as part numbers 160881 and 117196. To make cables for devices connected to the expansion ports, use female crimp pins, non-polarized housings, and a pin crimper tool. They are available at Jameco as part numbers 100765, 103157, and 159265 respectively.

3.2.2. Daughter Boards

Apart from the components listed above, the following, completed, daughter boards are also a part of the CC/PS.

Part	Quantity
BASIC Stamp 2P	1
MIM Module	1
SSC II	1

3.2.3. CC/PS Cables

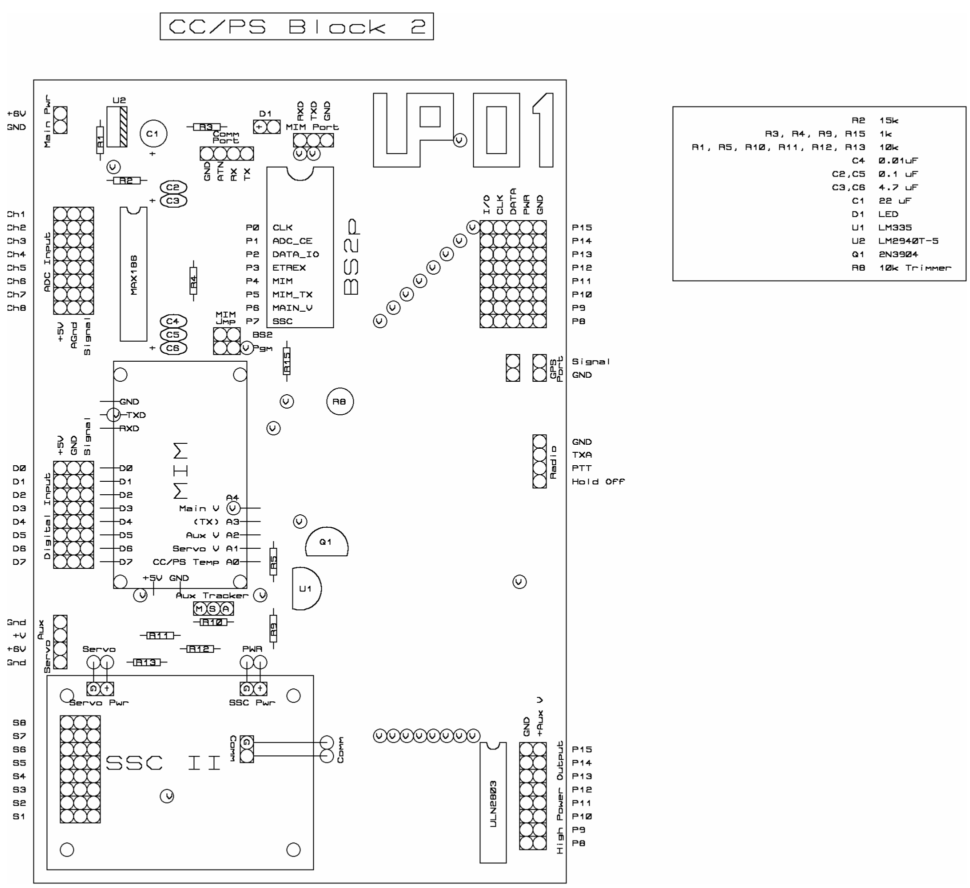
Eight cables interface power and data to and from the CC/PS. The table below lists the components required to make these cables.

Part	Value	Quantity
Capacitor	0.1 uF	1
Resistor	2.2k	1
Phono Jack	3.5 mm	1
Phono Jack	2.5 mm	1
DC Power Plug	4.0 X 1.7 mm	1
LED	Any color	1
Powerpole® connectors	3 pairs (red and black)	

Note:
The phono jacks are a part of a kit that allows you to solder wires to them. They are available at Radio Shack as part number 274-287A and 274-286A. The DC Power Plug is also available at Radio Shack as part number 274-1532.

3.3. Sequence of Construction

Refer to the parts layout diagram below when placing components on the CC/PS PCB.



***Parts Layout** – Block Two CC/PS*

3.3.1. Vias

First solder the vias. Vias are wires that make electrical connections between copper on the top and copper on the bottom of the PCB. There are 30 vias in the CC/PS. Three of the vias unite ground planes on the top and bottom of the board. The remaining 27 vias electrically connect copper traces on the top of the CC/PS to copper traces on the bottom of the CC/PS. It is more convenient to use short lengths of resistor or capacitor leads to make the vias than to cut and strip short lengths of wire.

- √ Cut ¼” lengths from the resistors and capacitors.
- √ Stick a lead wire into a via hole, ensuring the lead protrudes from both sides of the PCB.
- √ Solder one end of the lead to the copper pad and make certain that the lead did not slip from the via hole.
- √ Flip the PCB over and solder the lead wire on the other side.
- √ After soldering the via wire, snip the protruding ends of the via lead.

3.3.2. Daughter Boards

The MIM Module and SSC II on the CC/PS are daughter boards that offload some of the work from the BS2p. Note that the MIM Module is mounted upside down in relation to the CC/PS. Either stand-offs, plastic frames, or foam pads mount the daughter boards to other PCBs. If you decide to use stand-offs, use short lengths of tubing and #2 hardware (i.e. 2-56 nuts, bolts, and washers) for the SSC II and #1 hardware for the MIM Module. Use plastic washers on the bottom of the PCB to prevent short circuits from the hardware. Thin polystyrene sheets make inexpensive washers. Use 0.010” thick polystyrene sheets, which are available from Evergreen and available at your hobby shop.

An alternative to stand-offs is to use polystyrene plastic to form a bed or platform beneath the daughter boards. If you decide to use polystyrene sheet, use two lengths of 3/8” square tubes for the MIM Module and a piece of 0.020” sheet for the SSC II. The square tubes make two rails for the MIM Module and the flat sheet makes an insulating bed for the SSC II. The MIM Module rails are 1.75” long and plastic bed has dimensions of 1.4” by 1.9”. After cutting out the polystyrene, mark the placement of holes and drill them with a drill bit or Exacto knife. Test fit the plastic and the daughter boards before gluing the plastic to the PCB. Use model cement to glue polystyrene to the PCB. Then mount the daughter boards to their plastic bases with the #1 and #2 hardware (no tubes in this case). Don’t forget to use plastic washers to protect the bottom of the PCB from the hardware. The square tubes and sheet are available at hobby shops. The tubes are number 90622 by Plastruct and the sheet is available as an assortment as item number 9008 by Evergreen.

The last alternative is to use stacked layers of neoprene foam beneath the daughter boards. Foamies® is the name of a brand of neoprene foam manufactured by Darice Inc. and is available at crafts stores.

3.3.3. MIM Module

- √ Cut 22 lengths of thin gauge solid (24 gauge or smaller) wire, each measuring ½ inches long.
- √ Strip 1/8 inch of insulation from both ends of all the wires.
- √ Bend each wire at the beginning of the insulation at one end to a right angle. Note: This creates 22 little “L” shaped wires.
- √ Leave the other end of the wire straight.
- √ Tin the bent end of the 22 wires. Note: An alternative is to use bare wires for the “L” shaped wires, but this does add a risk of loose washers shorting out the MIM during a mission.
- √ Carefully place a small bead of solder on each solder pad of the MIM.

- √ One at a time, place a small wire into the MIM solder pads of the CC/PS, with the bent end of the wires resting on top of the MIM Module's solder pads.
- √ Use a soldering iron to melt the solder on the pad and wire, connecting the pad to the wire.
- √ Have fun completing the other 21 wires.
- √ Flip the CC/PS on its back and solder the other ends of 22 wires to the CC/PS.

3.3.4. SSC II

The SSC II is connected to the CC/PS using three pairs of wires. One pair is the servo battery connector and is already soldered to the SSC II. The remaining two pairs need to be added.

- √ Cut four pieces of a thin gauge wire (24 gauge or less), each one inch long. Note: The servo power wires in the SSC II will be reused, so you only need to prepare four additional wires.
- √ Strip less than ¼" of insulation from both ends of all the wires.
- √ Use these four wires are used in the next two steps.

Communication Connection

Modify the SSC II by removing the RJ-11 phone jack from the board. Beneath the former location of the jack you'll notice four solder pads aligned in two diagonal pairs. Two of the solder pads are connected to each other with a thin copper trace. These two pads are ground connections. The remaining two solder pads are the signal connections. Solder a wire into one of the signal solder pads and the second wire into the ground solder pads.

Power Connection

Note which solder pad of the SSC II has the ground wire (black wire) of the nine-volt battery snap.

- √ Using a soldering iron, remove both wires of the nine-volt battery snap from the SSC II.
- √ Solder one wire to the ground solder pad.
- √ Solder one wire to the power solder pad.

Note: Do not solder a wire to the old solder pad of the nine-volt battery snap. Located closer to the center of the SSC II is a solder pad marked +5V. Connect the second wire to this solder pad.

Servo Battery Power

The two wires that provide voltage for servos are located at the bottom of the SSC II. Cut these wires to a length of one inch and strip less than ¼" of insulation from their ends.

Mount the SSC II to the CC/PS and solder its six wires into the CC/PS at the locations marked Servo, PWR, and Comm.

3.3.5. Sockets

The CC/PS has three sockets for ICs. Insert the sockets into the CC/PS as indicated on the CC/PS diagram. This means the notches of all three sockets are oriented towards the top of the PCB. Electrically it doesn't matter if the socket is placed upside down or right side up, but by correctly orienting the sockets, it's easier to properly orient their ICs, which must be placed in the correct orientation. Solder the IC sockets only by two diagonally opposite pins. Press on the socket with your finger and reheat each diagonal pin with the soldering iron. The IC socket will snap down on the CC/PS PCB if it's not properly seated. Now finish soldering the socket by soldering its remaining pins.

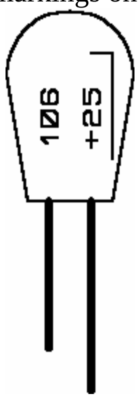
3.3.6. Expansion Ports

The expansion ports occur in rows eight receptacles wide. The female receptacles needed are five double rows of headers eight pins long. Three single sided rows of headers eight pins long are required to build the ports. To save money, purchase longer receptacles and cut them to length.

- √ Cut the receptacles to length using a sharp Exacto knife.
- √ Insert all the receptacles of an entire port before soldering any of them.
- √ Press the receptacle bases down firmly to the PCB.
- √ Ensure the receptacles are snug to the CC/PS board and vertical to the PCB and parallel
- √ to their neighbors.
- √ Solder the receptacles. Note: If the receptacles are loose, hold them down to the CC/PS with a piece of masking tape before flipping the CC/PS over on its back.
- √ After soldering the receptacles, make sure no solder bridges were formed.

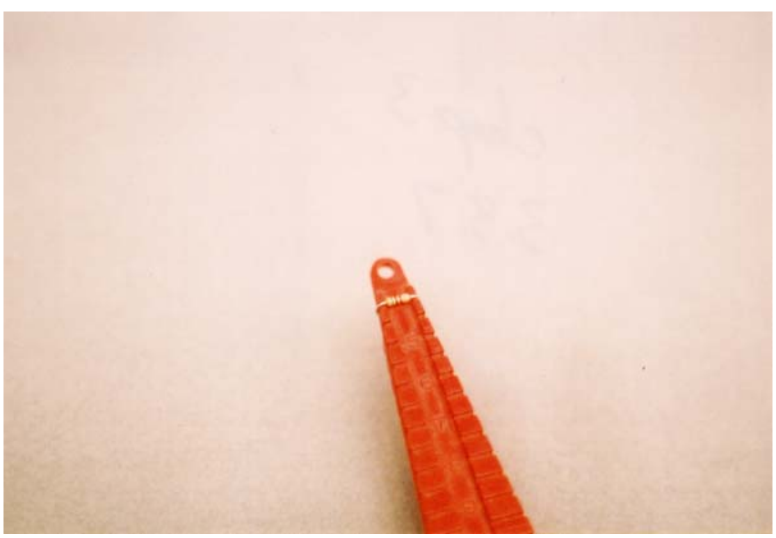
3.3.7. Discrete Components

Place components into the CC/PS PCB according to Diagram 2-???. The most important items are the electrolytic capacitors. If you put them in backwards, the CC/PS will probably let you know by exploding the caps. There are three electrolytic capacitors, C1, C3, and C6. Watch the polarity markings on the caps and the CC/PS diagram.



***Tantalum Capacitor Markings** – The positive lead is the one indicated – not the negative, as in an aluminum electrolytic capacitor.*

Bend resistors to a length of 0.4 inches with a lead bender, available at Radio Shack.



***Lead Bender** – Ensures perfect resistor leads every time.*

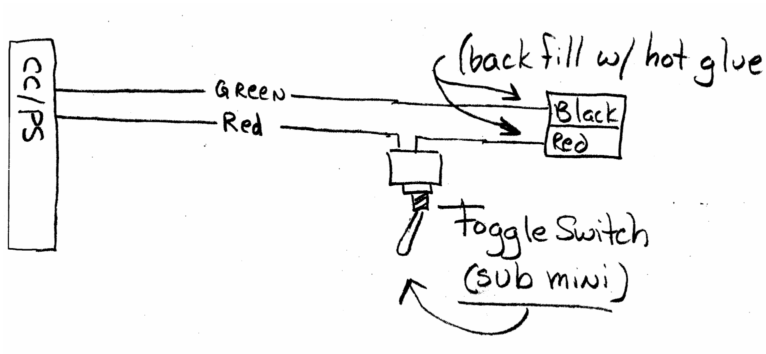
R7 has been replaced with a jumper wire, or a zero ohm resistor. After soldering R7, make sure its leads don't short out on the CC/PS board. Resistors R6 and R14 have been removed from the CC/PS design (they were not accidentally left out of the documentation). U1 and Q1 are in identical looking TO-92 form factors. Read their faces carefully before installing them into the CC/PS. The CC/PS diagram shows their proper orientation. After soldering each component, clip the excess leads.

Component Checklist

- R1 10k
- R2 10k
- R3 1k
- R4 1k
- R5 10k
- R7 0 ohm
- R8 10k trimmer potentiometer
- R9 1k
- R10 10k
- R12 10k
- R13 10k
- R15 1k
- C1 22 uF electrolytic
- C2 0.1 uF
- C3 4.7 uF electrolytic
- C4 0.01 uF
- C5 0.1 uF
- C6 4.7 uF electrolytic
- U1 LM335
- U2 LM2940T-5
- Q1 2N3904

3.3.8. Power Cables

Three cables provide external power to the CC/PS; they are the Main Power, Servo Power, and Auxiliary Power. The cables are identically constructed.



Power Cable *– The toggle switch is inline with the positive power lead (red wire).*

√ Cut six red colored #24 AWG stranded wires to a length of at least 12 inches.
√ Cut three black colored #24 AWG stranded wires to a length of at least 24 inches.
√ Strip ¼" of insulation from one end of each black wire and three of the red wires. Note: this end solders to the PCB.

√ Strip one inch of insulation from the other ends of the wires. Note: this end solders to either a Powerpole® or toggle switch.
√ Solder the ¼" end of pairs of wires to the CC/PS pads marked Main Pwr, Aux Pwr, and Servo Pwr. Note: These pads are located at the top left of the CC/PS and be sure to solder the red wire to the pads marked "+".
√ Slide a short length (at least ½") of heat shrink tubing on the three red wires.
√ Twist the end of each red wire to the center terminal of the SPST or SPDT mini-toggle switches, one wire per toggle switch.
√ Solder the red wires to the toggle switches.
√ Twist one end of the remaining red wires to the outside terminal of the SPST or SPDT mini-toggle switches.
√ Solder the remaining red wires to the toggle switches.
√ Slide a short length of heat shrink tubing over the remaining red wires.
√ Cover both soldered terminals of each switch with heat shrink tubing and shrink it.
√ Double over the ends of the remaining one inch stripped wires.
√ Crimp a Powerpole® terminal to the remaining ends of the red and black wires.
√ Solder the crimped terminal to the wire.
√ Slide the crimped terminal into a Powerpole® housing, being sure to match the color of the Powerpole® housings to its wire.
√ Slide the Powerpole® housings together into a unified connector. Note: There is more involved in this that it initially seems. A standard alignment must be determined so that any battery pack can attach to any power cable. Select a standard for the program, document it, and stick with it.
√ Twist pairs of the wires together to keep the power cables neat and under control.
√ Finish by back-filling the Powerpole®s with hot glue.

3.3.9. Programming/Communication Cables

The BASIC Stamp (and MIM) uses a female DB-9 (D-subminiature) connector and the GPS requires a male DB-9 connector. The BS2p requires four wires connected to its DB-9 connector (the MIM uses three of them) and the GPS requires two wires connected to its DB-9 connector (other wires, like RX and 1 PPS are optional). Make the cables as follows:

√ Cut six stranded wires to a length of 12 inches. Note: Use different colors of wires to differentiate between them. Since each DB-9 needs a ground, there should be at least one black wire per DB-9.
√ Strip back ¼ inch of insulation at both ends of each wire.
√ Solder wires to the pins of the DB-9 connectors as listed below:

- The BS2p cable uses DB-9 (female) pins 2,3,4,5
- The GPS cable uses DB-9 (male) pins 2 and 5

Note: Since pin 5 on a DB-9 connector is ground, make this one a black colored wire.

√ Solder wires to the DB-9 connector pins as indicated in the list above.
√ Slide short lengths of heat shrink tubing over the wires and cover the soldered pins.
√ Shrink the tubing down, covering the exposed solder.
√ On the BS2p DB-9 connector, short together pins 6 and 7 with a piece of resistor lead.

√ Use hot glue and cover all of the backs of the pins of the female DB-9 connectors.

√ Place the male GPS DB-9 connector into a plastic housing.

Note: If the GPS is to connect to a device (like the Kantronics KPC-3+) that allows serial cables to screw to the port, then place locking screws into the DB-9 housing at this point. If the GPS is not to connect to such a device, then leave out the locking screws from the DB-9 housing.

Before closing the housing, cover the interior of the housing and the connector pins of the DB-9 with hot glue. Do this before the glue gets hot enough to melt the plastic housing.
Quickly close the housing and bolt it closed.
Use more glue and seal the opened end in the back of the housing.

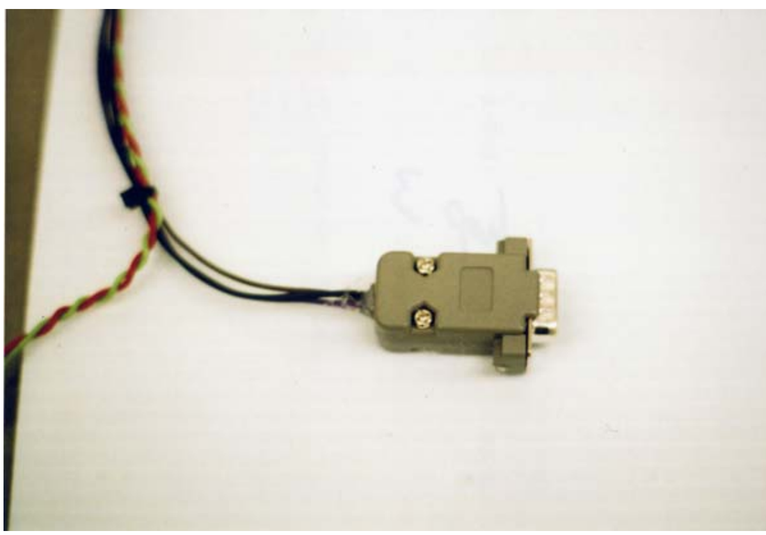
Connect the following pins of the BS2p programming connector to the CC/PS:

- GND to pin 5 of the BS2p DB-9
- ATN to pin 4 of the BS2p DB-9
- RX to pin 3 of the BS2p DB-9
- TX to pin 2 of the BS2p DB-9

Connect the following pins of the GPS connector to the CC/PS:

- GND to pin 5 of the GPS DB-9
- Signal to pin 2 of the GPS DB-9

Twist the programming and communication cables into three neat bundles.



***DB-9 Connector** – Housing for GPS DB-9 connector. Interior volume is filled with hot glue.*

Note: The MIM JMP determines if the MIM is using its comm port for programming or to receive telemetry from the BS2p.

3.3.10. HT Cable

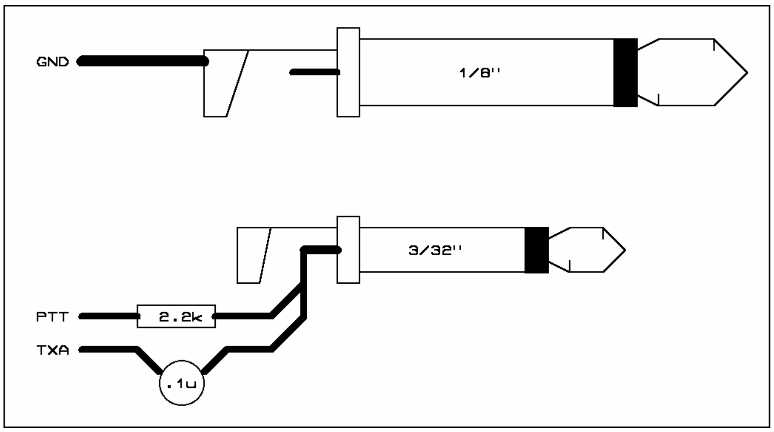
Three wires make up the cable that connects the MIC and SPK of the Alinco DJ-S11 to the MIM Module on the CC/PS. There is a provision for a fourth connection, the Hold Off, which is not recommended. An optional second cable provides external power and switching to the HT.

MIC and SPK

√ Cut three lengths of wire twelve inches long.
√ Strip back ¼ inch of insulation from one end of all three cables.
√ Solder them into the pads labeled Radio on the CC/PS.
√ Solder to the pads marked GND, TXA, and PTT.

The HT cable has the following connections:

- GND to Base of 1/8” phono jack
- TXA to 0.1 uF capacitor to Tip of 3/16” phono jack
- PTT to 2.2k resistor to Tip of 3/16” phono jack



***HT Cables** – Close-up view of phono jacks.*

√ Remove one inch of insulation from the other end of the GND wire.
√ Solder it into the Base of the 1/8” or 3.5mm phono jack.
√ Solder one lead of the capacitor and resistor on the Tip connection of the 3/16” or 2.5mm phono jack. Note: Both the resistor and capacitor are terminating at the same point of the 2.5mm jack, at its tip.
√ Slide a piece of two-inch long heat shrink tubing over the TXA and PTT wires.
√ Remove one inch of insulation from the free ends of the TXA and PTT wires.
√ Twist and solder the TXA wire to the free lead of the capacitor and the PTT wire to the open lead of the resistor.
√ Cover the exposed solder joint with the heat shrink tubing.

HT External Power

√ Cut two wires, both 24” long (use one red and one black colored wire).
√ Remove ½” of insulation from one end of both wires.
√ Solder the red wire to the center connector of DC power plug, a Coax-style DC power plug, 4.0 mm X 1.7mm (with solder tabs).
√ Solder the black wire to the ring of the connector.
√ Slide a length of heat shrink tubing over the positive wire, covering the soldered connection.
√ Squirt a drop of hot glue between the soldered connections.
√ Screw on the plastic cap and fill the interior space with a little bit of hot glue.
√ Strip 1” of insulation for the other ends of the wires.
√ Double over the exposed wire.
√ Crimp Powerpole® connectors on the wires.
√ Slide the crimps into their jackets, using the proper colored housings to indicate positive and ground.
√ Slide the Powerpole® jackets together.
√ Wrap the jackets with a label marked HT.

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

HT Jack Housing

- √ Plug the MIC and SPK jacks into the DJ-S11.
- √ Plug the power connector into the DJ-S11.

Note: Do not make the external power connection a part of the jack housing. The power plug is installed only to indicate the jack housing dimensions. When the power connection is made a part of the jack housing, then the HT can never be run from internal batteries.

- √ Squirt a little hot glue between the jacks, without getting any on the HT.
- √ Put a thin coat of hot glue on one piece of polystyrene.
- √ Press the first sheet of polystyrene onto one face of the glued connectors.
- √ Put a thin coat of hot glue on the second piece of polystyrene.
- √ Flip the HT over to its other side and press the second rectangle of plastic onto the combined connectors.
- √ When the glue in the DJ-S11 plug has cooled, remove the plug from the HT.
- √ Fill the voids in the HT plug with the warm hot glue.
- √ Let the unified connector cool.
- √ Trim the edges of the HT plug with a sharp Exacto knife.
- √ Finish the housing by covering it with heat shrink tubing.

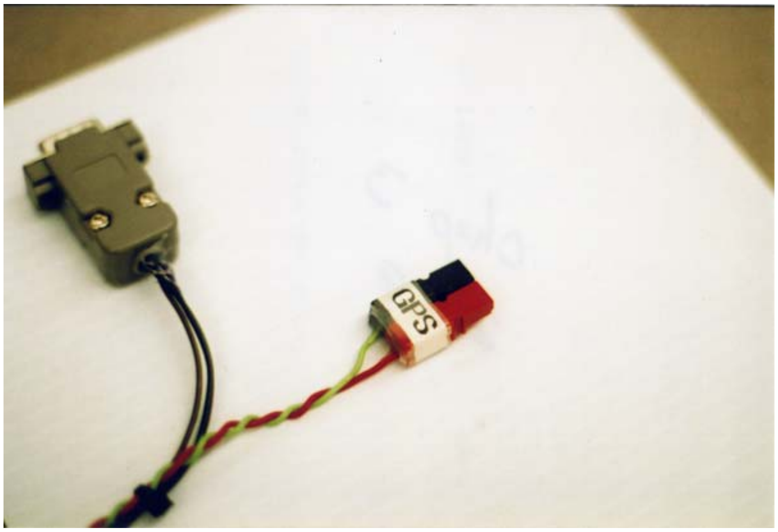
3.3.11. Power Indicator Cable

The two-wire cable of the LED power indicator solders to the CC/PS pads marked D1.

- √ Cut the two lengths of stranded #24 AWG wire twelve inches long. Note: Use two different colors of wire, making the ground wire either black or green.
- √ Strip ½ inch of insulation from one end of each wire and tin the ends.
- √ Trim the leads of the LED to ½" and tin.
- √ Note: The ground wire connects to the LED lead closest to the flat spot on the LED case
- √ Press a wire and LED lead together and then heat them with a solder iron.
- √ Remove the iron after the solder on both the LED lead and wire melts and flows together
- √ Do the same for the other LED lead and wire.
- √ Slide one-inch lengths of heat shrink tubing over the wires, covering the exposed leads of
- √ the LED and shrink the tubing.
- √ Slide a second piece of heat shrink tubing over the covered leads and shrink that down.
- √ The wire soldered to the rounded side of the LED is soldered to the D1 pad marked with
- √ a +.
- √ Solder the wire connected to the flat side of the LED (the black colored wire) to the other side of the D1 pad.

3.3.12. Labeling

Make sticky labels for the Powerpole® connectors, with each label indicating the function of the connector. Use a label maker like the Casio EZ-Label Printer to make professional looking labels. Label the connectors as Main, Servo, and Aux. Tape them around the Powerpole® connectors. Cover the labels with a short length of clear heat shrink tubing to make them more durable. One inch diameter clear heat shrink is large enough to cover the Powerpole® connectors.



***Labeled Powerpole®** – Cover the label with clear heat shrink (1" diameter) to protect the label.*

Using a toothpick, apply small dots of model paint to the CC/PS Expansion Ports. Place a small drop of red paint next to all the columns of pins with +5V, and a small dot of green paint next to all the columns of pins with Ground.

An alternative to painted dots is to use rub-on lettering or colored "sticky" dots. If you use rub-on lettering, cover the letters with a thin drop of clear paint applied with a toothpick.

4.0 Testing and Adjusting the NearSys CC/PS

DO NOT apply power to the CC/PS at this time. Place the CC/PS on a non-metallic surface to prevent short circuits when power is finally applied. You'll need a digital multimeter (DMM) to complete testing. Each test indicates whether it is for the Block One or Block Two CC/PS, or for both. The tests are for opens and shorts, polarity, setting voltage warning, voltage calibration, MIM ADC voltages, MAX186 voltages, SSC II control, ULN2803 control, and GPS.

4.1. Short and Open Circuits

Set the DMM to test continuity and check that the meter operates properly. When you touch the DMM's leads together, the DMM will ring. If not, verify that the DMM is set properly. If it still does not ring, then use a different DMM. When it's time to test pins in IC sockets, push small wires into socket openings. This is not necessary if your test probes have very fine tips. There are ten tests of short and open circuits.

4.1.1. Test One (both)

Connect one test lead of the DMM to the +5V Powerpole® connector. Tap around the ground plane of the CC/PS with the other test lead. There should be no ringing. If there is, you have a short between power and ground that will quickly discharge the battery, possibly causing a fire.

4.1.2. Test Two (both)

Connect one test lead to ground on the expansion port. Use the other lead to tap around the CC/PS on the ground plane and other ground pins. There should be ringing on every tap.

4.1.3. Test Three (both)

Connect one test lead to a CLOCK pin on the expansion port. Use the other lead to connect to the DATA pin on the expansion port. There should be no ringing.

4.1.4. Test Four (both)

Test between pins on the DB-9 connectors. There should be no shorts anywhere. Then test between pin 5 on the DB-9 connectors and the CC/PS ground plane. There should be a ringing on this test.

4.1.5. Test Five (both)

Connect a test lead to the I/O pin in the first expansion port. Use the other lead to press into the BS2p socket. There should be a ringing for each pin that is across from the BS2p pin. There should be no ringing for all other pins. Also check between the input pins on the ULN2803 and BS2p socket. There should be ringing for the connected pins (e.g. BS2p pin 13 and ULN2803 pin 10) but not for other combinations of pins.

4.1.6. Test Six (both)

Connect a test lead to either a DATA or CLOCK pin in the expansion ports. Connect the other test lead to the proper BS2p socket pin (labeled in the CC/PS diagram). There should be a ringing. Test the other pin when done with the first.

4.1.7. Test Seven (both)

Connect a test lead to the power side of the Servo Power connector. Touch the other lead to the middle rows of pins in the servo connectors. There should be a ringing. Tap the second test lead to the bottom row of pins in the servo connectors (ground), there should be no ringing. Switch the first test lead to the ground connector in the servo power connector. There should be a ringing. Afterwards, test that there is continuity between the ground of the power connector and the CC/PS ground plane.

4.1.8. Test Eight (both)

Connect a test lead to the positive side of the Auxiliary Power connector. Check that there is no continuity between the positive power and the ground plane of the CC/PS. Leave the first test lead on the positive Aux Power connector and tap the second lead to ULN2803 pin number 10. There should be a ringing. Next tap the bottom left pin (#9) of the ULN2803 and the ground plane of the CC/PS. You should find continuity.

4.1.9. Test Nine (Block Two only)

Connect a test lead to the GND wire at the bottom of the MIM Module. This pad is located at the top of the MIM (remember, the MIM is upside down) and labeled as GND. Check that there is continuity with the ground plane of the CC/PS. Now connect a test lead to the +5V wire at the bottom of the MIM Module. Check that there is continuity with the +5V row of pins in an expansion port. Verify there is no continuity between the +5V wire of the MIM Module and the ground plane of the CC/PS.

4.1.10. Test Ten (both)

Press one test lead against the base of the +5V wire on the SSC II. There will only be a little bit of exposed wire, so use fine tip probe leads. Confirm continuity between the +5V wire of the SSC II and the +5V row of pins in the expansion port. Verify that there is no continuity with the +5V wire and the ground plane of the SSC II. Now press a test lead into the base of the GND wire of the SSC II and confirm continuity with the ground plane of the CC/PS.

4.2. Proper Voltage and Polarity

At this time, no ICs are to be plugged into their sockets. Make sure the main power switch is turned off before plugging a battery into to Main Voltage. To measure voltages on each chip socket, push thin wires into the empty IC sockets. Set the DMM to the 20-volt DC scale. There are four tests of voltage and polarity.

4.2.1. Test One (both)

Switch on Main Power and observe the SSC II. The SSC II LED lights up green and there is no smoke or sparks.

4.2.2. Test Two (both)

Push wires into the BS2p socket at pins 4 and 21. Connect the black test lead to pin four and the red test lead to pin 21. Plug in the main battery. The DMM should read five Volts, give or take 0.25 Volts. Voltage measurements between pins 4 and 22 should show zero Volts.

4.2.3. Test Three (both)

Push wires into MAX186 socket pin numbers 20 and 14. Connect the black test lead to pin 14 and the red test lead to pin 20. The DMM will read within 0.25 Volts of five Volts.

4.2.4. Test Four (both)

Push wires into ULN2803 socket pin numbers 9 and 10. Connect the black test lead to pin 9 and red test lead to pin 10. Measure and record the voltage of an auxiliary battery. Connect the battery to the auxiliary power connector and the DMM will read the auxiliary voltage.

4.3. Adjusting the Main Bus Voltage Divider (Block Two Only)

Place a wire into the BS2p socket pin number 6. This pin is marked Main V in the CC/PS components diagram. Apply power to the CC/PS and measure the voltage between this wire and the ground plane. The CC/PS voltage regulator provides the necessary five Volts for the board until the battery voltage drops to 5.25 Volts. At a battery voltage of 5.3 Volts and lower, we want the BS2p to see a logic low on its Main V pin. For the BS2p a logic low occurs at 1.4 Volts. Adjust the 10k trimmer (R8) until its voltage drop is 1.4 Volts when the main battery voltage is 5.3 Volts. There are two methods for adjusting the 10k trimmer on the CC/PS. One method involves the use of a variable power supply. The other involves using a battery and doing some math.

4.3.1. Method One

If you have a variable power supply, set it to 5.3 Volts then connect it to the main battery connector. Monitor the voltage between Main V and ground while adjusting the trimmer. Set the trimmer to the one extreme that gives a voltage above 1.4 Volts. Slowly adjust the trimmer back with a jeweler's screwdriver until the voltage drops to 1.4 Volts.

4.3.2. Method Two

The voltage drop of a resistor is a linear function of the resistors in the chain from positive voltage to ground. If you know the current voltage of the battery, then you can calculate the voltage that will appear at a low main bus voltage condition. Measure the voltage of the battery and call this voltage V0. Divide V0 by 5.3 to get a ratio. Multiply this ratio by 1.4 to get the proper current voltage at the Main V pin. Adjust the trimmer until the calculated voltage appears at Main V.

4.4. Voltages to the ADC of the MIM Module

4.4.1. Test One

Apply power to the Main Power connector and set the DMM to the 20 volt scale. For these tests, leave the black test lead connected to the ground plane of the CC/PS. Measure and record the voltages on the MIM Module at its Main V and Temp wires. The Main V wire connects to the main power through a voltage divider and will read approximately half of the main power voltage. Divide the Main V voltage by the main battery voltage. Keep the result as a conversion factor. The Temperature voltage from the LM335 measures approximately 2.90 Volts. The voltage is the temperature of the CC/PS in units of hundreds of kelvins. Room temperature is around 293 kelvins, so the voltage at the MIM Module's Temp wire should measure 2.93 Volts.

4.4.2. Test Two

Measure and record the voltage of a battery attached to Powerpole® connectors. Connect the battery to the Servo power connector then measure and record the voltage at the MIM Module's Servo V wire. Next, connect the same battery to the Auxiliary power connector then measure and record the voltage at the MIM Module's Aux V wire. Divide the battery's voltage by the measured voltage at the MIM Module to determine the proper conversion factor.

4.4.3. Test Three

Calibrating the MIM telemetry output is performed in Test 4.9.

4.5. Voltages on the CC/PS ADC (MAX186) (Both)

Insert the MAX186 into its IC socket.

4.5.1. Test One

Leave the DMM set to the 20-volt, DC scale. Short all the ADC inputs to ground with a wire jumper. One at a time, remove the jumper wire and connect a 1.5-volt battery to the inputs of the MAX186. Connect the black lead of the DMM to the ground plane of the CC/PS PCB or to a ground pin in the expansion port. Use the red DMM probe lead to measure the voltage at each MAX186 input pin by placing the probe in contact with the exposed IC lead.

4.5.2. Test Two

Calibrating the digitized value from the MAX186 is performed in Test 4.9.

4.6. SSC II Test (Both)

Have a servo, servo battery, and main battery at hand to perform this test.

4.6.1. Test One

Switch Main Voltage and Servo Voltage to off on the CC/PS.
Connect a servo horn to a servo and rotate the servo horn to one extreme. Plug the servo into the first SSC II port. Apply servo power before the main power. Observe the servo and verify the servo is rotating to its mid position.

4.6.2. Test Two

Sending commands to the SSC II is performed in Test 4.9.

4.7. ULN2803 Test (Both)

Insert the ULN2803 into its IC socket. Have both a main and auxiliary battery handy.

4.7.1. Test One

For the Block One CC/PS, make a jumper wire that connects +5V from the Expansion Ports to an Input Port of the ULN2803 (the jumper wire is not required to test the ULN2803 in the Block Two CC/PS). Apply both main and auxiliary power to the CC/PS. Set the DMM to the 20-volt DC scale and connect its probes across the ground and power of the first ULN2803 Output Port. Connect one end of the jumper wire to the +5V. There should be no voltage at the Auxiliary Output Port at this time. Now connect the open lead of the jumper to the first Input Port of ULN2803 and observe that auxiliary power is now only available to the first Auxiliary Output Port and none other. Test the remaining ports in the same fashion.

4.7.2. Test Two

Sending commands to the ULN2803 is performed in Test 4.9.

4.8. Reading GPS Sentences (Both)

Insert the BS2p into its IC socket and connect a completed GPS receiver to the CC/PS.

4.8.1. Test One

Power up the CC/PS and GPS receiver, then write and download the following GPS program:

```
'GPS Test
gpschar       var  byte
gpsloop       var  byte
'gps_rx        con 3                'block two cc/ps
'gps_rx        con 7                'block one cc/ps
I4800          con 16884

GPS:
GPGGA:
serin gps_rx,I4800,[wait ("GGA"),spstr 70]
for exploop = 0 to 70
get gpsloop,gpschar
debug gpschar
next
end
```

The debug screen should display the GPGGA sentence starting with the comma after GGA.

4.9. Live Test and Dropped Packets

This is the full up test of the flight computer. Perform this test when an APRS station is available and the owner knows how to save a log. The goal is to program the CC/PS to exercise all its features as if it were going on a mission. Write down the packets that are expected then compared your notes to the log recorded by the APRS station. Expect to see some records dropped. Carry this test out as a part of qualification testing; see Chapter Five, Section Four.

5.0 Programming the NearSys Flight Computers

The following code snippets are broken into functional blocks. Use them to write subroutines for the flight computers. One of the first flight codes you write should be to test telemetry from the flight computer in conjunction with Test 4.9.

5.1. Block One CC/PS

The first step is to program the TNC connected to the flight computer. Consult Chapter Two for information on programming TNCs for near space flights. The code below assumes a KPC-3+ is connected to the CC/PS. If a different TNC is connected, then some of the tests must be performed with debug commands of a flight data recorder (see Chapter Four, Section Five).

5.1.1. BS2p I/O Definitions

```
clock               con  0
adc_ce              con  1
data_io             con  2
tnc_tx              con  3
tnc_rx              con  4
gps_tx              con  5
servo               con  6
gps_rx              con  7

n1200               con  2063           '1200 baud n81 true
n2400               con  1021           '2400 baud n81 true
i4800               con  16884          '4800 baud n81 inverted
i2400               con  17405          '2400 baud n81 inverted
```

5.1.2. GPS

```
alt_curr            var  word     'current gps alt (m)
gpschar             var  byte     'individual character in gps sentence
gpsloop             var  byte     'looping control

gps_rx              con  7
i4800               con  16884    '4800 baud n81 inverted

SPRAM_GPGGA:
serin gps_rx,I4800,10000,NoGPS,[wait ("GGA"),spstr 56]

SPRAM_ALTITUDE:
for gpsloop = 42 to 46
get gpsloop,gpschar
debug gpschar
next

VAR_GPGGA:
serin gps_rx,I4800,10000,BadGPS,[wait ("$GPGGA"),skip 42, dec alt_curr]
debug “Alt:”, dec alt_curr
end
```

5.1.3. TNC

This code assumes a KPC 3+ is connected to the flight computer, and LT buffer four is programmed to accept text and telemeter it.

```
tnc_tx        con 3
I4800         con 18664

serout tnc_tx,I4800,["lt 4 >Testing, 1,2,3", cr]
end
```

5.1.4. MAX186

The following code snippet tells the MAX186 to digitize each of its analog ports and return the value.

```
clock         con    0
adc_ce        con    1
data_io       con    2
exploop       var    nib
adc_code      var    byte
```

```
Exp_Value    var    word

for exploop = 0 to 7                         '8 channels on tv02f
lookup exploop,[$8C,$CC,$9C,$DC,$AC,$EC,$BC,$FC],adc_code
low adc_ce                                   'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]          'shift out instructions
shiftin data_io,clock,2,[Exp_Value\12]       'shift in the data
high adc_ce
pause 10
debug “CH:”, dec exploop, “/”, dec Exp_Value, cr
next
end
```

5.1.5. SSC II

```
servo        con    6
i2400        con    17405                      '2400 baud n81 inverted

serout Servo,i2400,[255,0,0]
```

5.1.6. ULN2803

The ULN2803 is activated by HIGHing the BS2p I/O pin connected to one of its inputs. Make a jumper wire to connect the BS2p and ULN2803.

```
high 12
pause 1000
low 12
```

5.1.7. Main Bus Voltage

The third channel to the MAX186 can be jumpered for Main Power. When done, the following code returns the digitized value of the main bus voltage.

```
clock         con   0
adc_ce        con   1
data_io       con   2
adc_code     var    byte
Exp_Value    var    word
MainV        var    bit

GetMainV:
MainV = 0                                              'good until proven bad
adc_code = $9C
low adc_ce                                             'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]                    'shift out instructions
shiftin data_io,clock,2,[Exp_Value\12]                 'shift in the data
high adc_ce
pause 10
if Exp_Value > 2750 then MainVOkay
MainV = 1                                              'low main voltage
```

5.2. Block Two CC/PS

First step is to program the MIM Module. To program the MIM Module, the MIM JMP jumper (a shorting block) must be set to Pgm. The MIM JMP is located near the center of the CC/PS. Consult the CC/PS diagram to locate it. Once the jumper is set to Pgm then the MIM Module can be programmed through its DB-9 connector. Program the MIM to send all position reports beginning with a string of $GP???. The period, or amount of time selected for position transmissions is irrelevant, since the BS2p forces transmissions from the MIM Module. To take advantage of the digital inputs of the MIM, program the MIM to send telemetry. Finally, as a back up to GPS failure, program the MIM to beacon every minute or two. For the Alinco DJ-S11, leave PTT at 0, or active low. To get mission data into an Igate, select WIDE 3-3 for a path. Refer to the documentation you receive with your MIM Module for more complete information on programming the MIM Module. After programming the MIM Module, reset the MIM JMP to BS2p. If this is not done, then the MIM Module will not hear data from the BS2p.

The last section gives snippets of code needed to operate all features of the CC/PS.

5.2.1. BS2p Definitions

```
CLK           CON    0
ADC_CE        CON    1
DATA_IO       CON    2
ETREX         CON    3
MIM           CON    4
MIM_TX        CON    5
MAIN_V        CON    6
SSC           CON    7
```

5.2.2. GPS

```
I4800         con  16884                       '4800 inverted baud
alt_curr      var  word                        'current gps alt (m)
alt_max       var  word                        'highest alt so far
gpsqual       var  Status_Flag.bit0            '0=poor qual, 1=good quality
gpsreply      var  Status_Flag.bit1            '0=no gps response, 1=gps ok
gpschar       var  byte
gpsloop       var  byte

GPS:
GPGGA:
serin etrex,I4800,10000,NoGPS,[wait ("GGA"),spstr 70]
gpsreply = 1
for exploop = 0 to 70
get gpsloop,gpschar
if gpschar = "*" then ShiftGGA
next
ShiftGGA:
for gpsloop = exploop to 0
get gpsloop,gpschar
put gpsloop+6,gpschar
next
put 0,"$"
put 1,"G"
put 2,"P"
put 3,"G"
put 4,"G"
put 5,"A"
SendGGA:
```

```
for gpsloop = 0 to exploop+6
get gpsloop,gpschar
serout mim,n4800i,[gpschar]
next
gosub KeyMIM                                  'send telemetry

get 33,gpschar
gpsqual = gpschar - 48

gpsloop = 42
alt_curr = 0
GetAlt:
get gpsloop,gpschar
if gpschar = "." then DoneAlt
alt_curr = alt_curr * 10
gpschar = gpschar - 48
alt_curr = alt_curr + gpschar
gpsloop = gpsloop + 1
goto GetAlt
DoneAlt:
get gpsloop+1,gpschar
gpschar = gpschar - 48
serout mim,n4800i,["$GPGLL,,,,,,",cr,dec alt_curr,".",dec gpschar," M*"]
gosub KeyMIM                                  'send telemetry

GPRMC:
serin etrex,N4800I,10000,NoGPS,[wait ("RMC"),spstr 70]
gpsreply = 1
for exploop = 0 to 70
get gpsloop,gpschar
if gpschar = "*" then ShiftRMC
next
ShiftRMC:
for gpsloop = exploop to 0
get gpsloop,gpschar
put gpsloop+6,gpschar
next
put 0,"$"
put 1,"G"
put 2,"P"
put 3,"R"
put 4,"M"
put 5,"C"
SendRMC:
for gpsloop = 0 to exploop+6
get gpsloop,gpschar
serout mim,n4800i,[gpschar]
next
gosub KeyMIM                                  'send telemetry

goto GPSEnd

NoGPS:
gpsreply = 0

GPSEnd:
return

DeadGPS:
for gpsloop = 1 to 10
serout mim,n4800i,["$GPGLL,,,,,,",cr,">Dead GPS*"]
gosub KeyMIM                                  'send telemetry
next
```

```
return

NoSat:
for gpsloop = 1 to 5
serout mim,n4800i,["$GPGLL,,,,,,",cr,">No GPS Lock*"]
gosub KeyMIM                                    'send telemetry
return
```

5.2.3. MIM Module

```
n4800i       con  16884

serout mim,n4800i,["$GPGLL,,,,,,",cr,">Text*"]
gosub KeyMIM                                    'send telemetry

KeyMIM:
pause 1000
high mim_tx
pause 250
low mim_tx
pause 5000
return
```

5.2.4. MAX186

```
exp_value     var  word                         '# of pulses from experiments
                                                'result of adc conversion
exp_high      var  exp_value.highbyte
exp_low       var  exp_value.lowbyte
adc_code      var  byte                         'instructions to adc
exploop       var  byte

ADC:                                            'measure ihu adc
for exploop = 0 to 7                            '3 channels on tv01h
lookup exploop,[$8C,$CC,$9C,$DC,$AC,$EC,$BC,$FC],adc_code
low adc_ce                                      'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]             'shift out instructions
shiftin data_io,clock,2,[exp_value\12]          'shift in the data
high adc_ce
pause 10
put (exploop*2),exp_low
put ((exploop*2)+1),exp_high
next
serout mim,n4800i,["$GPGLL,,,,,,",cr,">EXP-",dec data_rep,","]
for exploop = 0 to 7
get (exploop*2),exp_low
get ((exploop*2)+1),exp_high
serout mim,n4800i,[dec exp_value]
serout mim,n4800i,["/"]
next
serout mim,n4800i,["*"]
gosub KeyMIM                                    'send telemetry
return
```

5.2.5. SSC II

```
n2400i       con 17405                  '2400 baud, inverted

serout SSC,n2400i,[255,0,127]           'rotate servo # 0 to position 127
```

5.2.6. ULN2803

```
high 8                                  'turn on  8
pause 1000                              'wait one second
low 8                                   'turn off  8
```

5.2.7. Main Bus Voltage

```
if MainV = 0 then EndFlight
```

Congratulations, I now pronounce your CC/PS flight computer healthy! Ask about Parallax's educational discount on selected items if you are associated with a school. A project board is not required, as the BS2p is programmed in the CC/PS. While you are at the Parallax website, download the programming software, their BS2p Documentation Guide, and app notes for sample projects. You can learn a lot about designing your experiments by looking at these project descriptions. In the Documentation Guide you'll find all the information you need to know about programming the BS2p.

Go to the Maxim website and ask for a sample of the MAX186, 12 bit, 8 channel Analog to Digital converter. You can purchase the MAX186, but they cost about $20 a piece. Maxim does send out free samples however, so ask for one (you'll probably receive two of them).

Websites for Parts

Parallax has a website at http://www.parallax.com.
Maxim's website is located at http://www.maxim-ic.com

Good to Know – The Great Plains Super Launch (GPSL)

This article is derived from an article I wrote for Mr. Harlan, the publisher of ATV Quarterly.

One reason for the great success at GPSL 2002 is because of the great help and support I had. Without the help of my mother Erma Verhage, Mark Conner (N9XTN), and Ralph Wallio (WØRPK), GPSL 2002 would not have been the success it was. One other thing that helped was the fact there was a history behind GPSL 2002.

Pre-GPSL
Two years ago, in June 2000, I made a trip to Manhattan, Kansas (from Idaho where I teach) to visit my parents. I still had email addresses from my balloon buddies in Kansas and Nebraska, so I proposed we launch a balloon during my visit. We launched our balloon from the Johnson Near Space Center, about ten miles south of the town of Manhattan. This is the same location from which I launched balloons when I was the program manager of KNSP, the Kansas Near Space Program. I had lost my main tracking capsule back in Idaho, so my science capsule hitched a ride with Mark Conner's (N9XTN) tracking capsule. My capsule carried a BASIC Stamp and was programmed to position a 35mm camera and take pictures at fixed intervals. Launch day was covered with dreary overcast skies. Because of the clouds, the photographs looking downwards were pretty much useless. That is, except for one or two that showed Mark's capsule below my capsule and a jet contrail still thousands of feet lower. There were other photographs taken that showed the balloon expanding as it ascended to over 90,000 feet. The chase of this flight went well and chase crews were about ½ mile

away from the capsules as they dropped out of the low cloudbank. I suppose this launch could be considered the first Great Plains Space Launch.

GPSL 2001

In the spring of 2001, when we were considering another balloon launch during my annual visit to my parents, it was decided we should try for a record number of launches that summer. When planning to break a near space record, there's only one source to go to, and that's Ralph Wallio (WØRPK). He informed us that the greatest number of known simultaneous launches was two. So Mark Conner (N9XTN), Bill All (N3KKM), Don Pfister (KAØJLF), and I (KD4STH) began planning for at least three simultaneous launches.

***GPSL 2001** – Launch crews.*

The near space programs involved were the Treasure Valley Near Space Program (TVNSP) from Idaho, the High Altitude Balloon Investigation Testing And Tracking (HABITAT) group, the Near Space Balloon Group (NSBG) from the Kansas City area, and the Nebraska Stratospheric Amateur Radio (NSTAR) group from Nebraska. This time we determined we needed a name for the launches because Kimbra Cutlip of Weatherwise magazine asked to cover the launches. It was Bill All (N3KKM) who came up with the name Great Plains Super Launch, or GPSL, because of the number of balloons we were attempting to launch. GPSL 2001 was a wonderful success; with three balloons being launched and two being immediately recovered (Bill's was recovered a few days later).

***GPSL 2001** – On the launch line, L to R, NSTAR, NSBG, TVNSP.*

HABITAT and NSBG shared a ride on a balloon while NSTAR and TVNSP each took their own ride on a balloon. During its descent, Bill and Don's capsules ran into a problem and stopped sending us packets. Mark's capsule was the first one capsule recovered. The owner and his family of the wheat field that the capsule landed in were fascinated by what had happened. My capsule was recovered second in another cut wheat field.

***GPSL 2001** – Recovery of the author's near spacecraft. L to R, Paul, Dan, Paul, Mark, & Sheri.*

This time however, the landowner didn't care one bit about what we were doing. So we retrieved the capsule and left the field to find Bill. Bill searched for a couple hours in the area we predicted the capsule would land based on its last known altitude and descent. Sometimes we get lucky making this kind of prediction, as when Mark predicted a capsule's recovery location to within less than a mile of its actual landing location. This time however, we were unsuccessful. We met Bill on the road after his search and headed off to lunch, and to have our film processed. Midwestern farmers tend to be a friendly bunch, and when one farmer found a capsule in his field a few days later, he called Bill. Bill had the foresight to leave a phone card and a phone number on his capsule, in case something like this should happen. A few days later Bill made arrangements to pick up his capsule. Ms. Cutlip wrote an excellent article on GPSL 2001. See Weatherwise, November/December 2001, pp. 14 – 23.

GPSL 2002
I wanted GPSL 2002 to be better than GPSL 2001 in every measurement. Since GPSL 2001 saw the launch of three balloons on one day, we planned GPSL 2002 to launch more balloons and occur over more days. We tried for twice as many launches and added an extra day for a symposium. My mother arranged for GPSL 2002 to use the Hemisphere Room at the Kansas State Library (the Hale Library). Ralph maintained the webpage for GPSL 2002 so that everyone could keep up to date on the plans for GPSL. He also kept me on my toes, so I didn't forget anything. Mark started the Yahoo Groups email list and researched things like available motels and rates that guests could use. By the time I left for my summer vacation, everything for GPSL 2002 had been arranged except for food trays.

Officially, GPSL 2002 started on Friday morning, 5 July 2002. Unofficially it began Thursday evening when several of us met for dinner in Manhattan, Kansas. Present at dinner was Bill Brown (WB8ELK), probably the first person to launch a balloon carrying amateur radio gear. Since his flight in 1987, a lot has changed in ham radio. Now we send GPS receivers and TNCs on our balloons to make tracking and recovery easier. But in the early days, it was all done with direction finding. This can be tough when you consider that a balloon may reach altitudes in excess of 90,000 feet and land over 100 miles away.

Friday morning began with several near space programs setting up displays about their programs. The variation in the design and construction of near space capsules is amazing. What these programs are planning and accomplishing is even more amazing. Ralph Wallio (WØRPK) MC'd the symposium. He began with introductions by the 25 attendees of GPSL 2002. Next the near space programs present discussed what they were currently working on. Several videotapes were shown. Some videos were of near space launches; some were of newscasts about launches; while others were actual videos taken from near space. After the morning presentations, we headed over to the Ramada Inn's restaurant, the Gold Fork. They couldn't seat all of us at one table, so we occupied four tables in one corner of the restaurant.

The afternoon presentations were more technical. Presentations covered the range of topics from, Early History, Meteorology, Tracking and Recovery Procedures, Advanced Projects, and Airframes and Avionics. I'm currently putting together proceedings from the GPSL 2002 symposium. So if you'd like more information on the presentations, please email the author. At the close of the presentations, attendees decided the launch time for Saturday morning. The author is accustomed to launching balloons at the break of dawn, before the sun has a chance to create surface winds too high to safely launch balloons. This meant a launch at 6:00 AM, which means we had to arrive at the launch site before 5:00 AM. This was fine with the author (and probably others), but not with the majority of the attendees. So it was decided to arrive at the launch site at 7:00 AM and try to launch by 9:00 AM. Because of winds aloft that were not cooperating with a launch from the traditional Johnson Near Space Center, it had been decided several days earlier to move the launch site out to the Herington Municipal Airport. This required we drive more than an hour from Manhattan to get to the launch site. No doubt that added to the desire to launch later in the morning.

After Friday afternoon's presentations, GPSL 2002 attendees drove to the Sirloin Stockade in Manhattan for dinner. At dinner Bill Brown (WB8ELK) was presented a plaque declaring him the Father of Amateur Radio High Altitude Ballooning. Bill's first flight occurred on his birthday in August 1987. Since his first launch, Bill has launched over 200 balloons carrying some form of amateur radio. And here I thought I was doing pretty well at 33 launches in five and a half years!

Saturday morning couldn't have been much better. There was a little haze in the sky that would limit our ability to see the balloons at high altitudes, but other than that, the morning was perfect. The surface winds were light enough that we were able to safely fill the balloons outdoors. Almost everyone arrived by 7:00 a.m., but we didn't start filling the balloons until much later. Only the Herington Times covered the launch. Other local newspapers and television stations didn't even try to cover the launch. I'm sorry Mr. Harlan wasn't able to make it out to the launch. But unlike other media, Mr. Harlan did make the effort to cover the launch.

The only problem to occur that morning was when Mike Bogard's (KDØFW) balloon burst. His balloon was twenty years old and had begun to bulge oddly during the filling. Eventually the bulge burst with a pop. Bill Brown (WB8ELK) must have been covered in latex, as he was beneath the balloon, holding it by the neck at the time it burst. Fortunately Zack Clobes (WØZC) brought an extra balloon with him. It wasn't until after 9:00 AM that all the balloons were finally filled and sealed. After conferring with the balloon crews, we decided we were all ready for launch. A total of eight weather balloons were carried out to the grassy field near the tarmac. Once safely spread out, we formed a line about 200 feet long.

GPSL 2002 *– Six balloons on the launch line, a record.*

The size of this launch made communications with all the balloon crews difficult. Before launch, every balloon crew manager indicated his readiness to launch by calling out either a GO or NO GO. There was only one NO GO, but it only took a few minutes to correct their lanyard problem.

After a countdown from five, the balloons simultaneously took to the hazy Kansas skies. It was impressive to see all these balloons lift off at once! With the low winds aloft, we were in no hurry to start chasing after the balloons. After getting pictures of the launch crews, we headed out to the Herington Dairy Queen for refreshments and waited there for the first balloon to burst. Zacks' balloon was the first to burst, after having reached an altitude greater than 72,000 feet. Zack used a 600-gram balloon, so it's not surprising his balloon burst first and at the lowest altitude. EOSS's and TVNSP's balloons were 1200 grams each, so these two flights reached altitudes above 87,000 feet before bursting. Ascent times were only about ninety minutes and it took the capsules another hour to land. With APRS on the balloons and Kansas roads arranged in a grid with roads every one mile, the recovery of capsules went very well and fast. The capsule that took the longest to recover was Mike Bogard's (KDØFW) capsule. He didn't fly an APRS tracker; instead Mike flew amateur television (ATV) and a 6m repeater on his balloon. So recovering his balloon required fox hunting skills. Talk about the ultimate foxhunt! By 3:00 PM, all the capsules had been successfully recovered.

After recovery, most balloon crews headed to lunch at the Cracker Barrel restaurant in Junction City, Kansas, located almost one hour north of Herington.

***GPSL 2002** – A well deserved, but late, lunch.*

With over 20 people present, we swamped the restaurant. Stories and photographs were traded during lunch. Everyone agreed this had been a great GPSL and were looking forward to next year's.

GPSL 2003

GPSL 2003 was held in conjunction with the Space Grant's BalloonSat program. Five missions took to the sky, each carrying two BalloonSats.

***GPSL 2003** – Filling five balloons. In forefront, TVNSP's baloon will carry Scrat and Team Ohio's BalloonSats.*

Students from schools across the U.S. met at the Colorado University – Boulder campus to design and build BalloonSats. GPSL 2003 was the first in Colorado and was sponsored by EOSS. Students attached their BalloonSats to one of five stacks, then helped with the prep, launch, chase, and recovery. For the latest information on GPSL, join the GPSL email list on Yahoo Groups.

GPSL 2003 *– About ready to launch one of TVNSP's near spacecraft. This flight will carry Team Alabama's BalloonSats.*

GPSL 2003 *– Five balloons on their way to near space.*

Near Space Humor

Balloon Talk
With Phil and Pop, The Helium Brothers

Phil: Hello and welcome to Nation Public Radio! You're listening to Phil and Pop, the Helium Brothers on Balloon Talk. We're here to discuss near space and your near space problems. If you have a question about your balloon, or anything else, the number to call is 888-Balloon Junk.

Hello, you're on Balloon Talk.

Caller: This is Barbara from Burlington. I only have 600-gram balloons and I need to get a 12-pound capsule above 90,000 feet.
Phil: I'm going to take a guess here.
Pop: I like it already.
Phil: Duct tape two 600-gram balloons together!
Phil: See you Barbara, good luck!

Phil: 888, BALLOON JUNK. That's 888-123-1234, hello, you're on Balloon Talk.
Caller: Hi guys, this is Tim from Tulsa.
Pop: So what's up man?
Caller: I can't get my TNC settings right. I'm always missing packets from the balloon.
Phil: Are you using a KPC-3+ with version 8 EEPROM?
Caller: Yes and no, it's a KPC-3+ with version 6 EEPROM.
Pop: Try duct tape.
Phil: Thanks Tim, see you.

Caller: Hi, I'm a first time caller.
Pop: Okay, so what's going on?
Caller: I ran into trouble when filling a 1200 gram balloon with helium. While we were filling it, my crew noticed there was a hole in it, so we just threw out the balloon and used a new one. One of my balloon crew thought we could have saved the balloon. What should we have done?
Phil: Next time try duct tape.
Pop: I love it!
Phil: Good luck!

Caller: This is Fred from Fresno. After our last near space capsule recovery, we noticed a rip in our recovery system. How can we fix this?
Phil: What kind of recovery system are you using?
Caller: It's a seven foot diameter, ripstop parachute.
Pop: Did you buy it or make it?
Caller: We made it ourselves.
Phil: Then I suggest you use duct tape.
Pop: Man, duct tape fixes everything!

Caller: Hi guys, this is Alan from Atlanta. The BASIC Stamp 2 in my flight computer keeps coming out of its socket when the capsule lands. What am I doing wrong?
Pop: Did you try duct taping the Stamp to the IC socket in your flight computer?
Caller: Ah, no, I hadn't tried that.
Phil: Give that a try.

Caller: I will, thanks guys!
Pop: No problem man!

Pop: Did you notice how easy it is to solve these problems?
Phil: Sure, but our callers don't know this.

Caller: Howdy, I'm Deb, I'm calling from Dallas. I can never get my car started on time in the morning to go on balloon chases.
Pop: Wrong show, try Car Talk!

Caller: My husband always complains about the time I spend chasing near space capsules. What can I do?
Phil: I'll let my brother answer that one.
Pop: Have you tried duct tape?
Phil: Ummm….
Pop: Duct tape will fix everything.
Caller: Okay, I'll give it a try. Thanks!

Pop: Do you know what time it is?
Phil: Time to pay that rental fee on our helium tank?
Pop: No, it's time to play, Stump the Chumps! This is the time in our show when we find out if our advice was insightful….
Phil: Or just criminal!
Phil: Whom do we have on the phone?
Pop: Do you remember a call last year from Paul of Payette asking about getting near space capsules out of power lines?
Phil: Is he the one we recommended bring big wire cutters so he could cut the power lines himself?
Pop: That's the one.
Phil: Before we hear your answer Paul, we need to confirm that we have not talked since your last call.
Caller: No we haven't.
Pop: Or that you weren't influenced by the staff of NPR, by Balloon Talk, or by that 500 cubic feet of helium we sent you.
Caller: Nope
Pop: So did the wire cutters work?
Caller: I don't know. All I remember seeing is a bright flash of light. Now I get an occasional buzzing sound in my ears.
Pop: I wish you the very best!

Phil: Well it's happened again, you've wasted another perfectly good hour listening to Balloon Talk!

[A] Powerpole® is a registered trademark of Anderson Power Products.
[B] Foamies® is a registered trademark of Darice Inc.

CHAPTER FOUR

Near Space Avionics, Part Three
Electronics Supporting the Flight Computer

"Let me get this straight: you can chase a balloon deep into uncharted territory in the middle of Missouri and recover it from thirty feet up in a tree, but you can't find a balloon that lands in your own backyard?"
- Jermone Tonneson (W0JRT),
in reference to an event in the NSBG Balloon Program.

Chapter Objectives

1.0 The Global Positioning System (GPS) Receiver

If you want your $500 near space capsule back, then you must launch a $100 to $150 GPS receiver with it. GPS receivers transmit a series of nationally defined text sentences. Each sentence contains standardized fields of data. You'll learn more about the GPS receiver in this chapter. Typically, the only sentences needed from the GPS receiver during a near space mission are the $GPGGA and $GPRMC sentences. A combination of these two sentences indicates much of the mission status, such as time of day (TOD), altitude, capsule speed, and capsule heading. Most GPS receivers send multiple GPS sentences every second or two. The MIM, Tiny Trak II, and BS2p in the CC/PS are programmed to ignore this stream of data until it is needed.

Before you purchase a GPS receiver and throw it into near space, you must be aware of some limitations.

1.1. Near Space Limitations in GPS Receivers

There are three factors that I'm aware of that are capable of limiting a GPS receiver's use in near space. They include federal government Department of Defense (DoD) limits on GPS receivers, software limitations in GPS receivers, and signal level limitations. Fortunately, several GPS receivers which do not have these limitations are available on the market.

1.1.1. DoD Limitations in GPS Receivers

To prevent GPS receivers from being used to guide terrorist missiles, the Department of Defense and the State Department require that GPS receivers stop transmitting their location in cases where the GPS antenna is at altitudes above 60,000 feet and moving at speeds greater than 999 knots. Notice that this is an AND function: the altitude greater than 60,000 feet AND the speed greater than 999 knots. There are some GPS manufacturers who have chosen to interpret this limitation as an OR function instead. These GPS receivers stop transmitting positional data once they are above 60,000 feet, regardless of the speed. This is a major problem for near space capsules as this altitude is below near space. It is not certain that these receivers will begin transmitting their position once they drop below 60,000 feet. So, it is possible that a receiver that stops giving position data below near space will refuse to give data during recovery, one of the most critical times.

1.1.2. Software Limitations in GPS Receivers

Another factor involves how the GPS is programmed. At least one GPS receiver is programmed with an altitude field that is defined too small. This limits the highest altitude the GPS can calculate and store in memory. This type of GPS will probably still function once the near space capsule descends low enough. While these GPS receivers meet the law as required, they are too severely limited by their programming to be used in a near space capsule.

1.1.3. Signal Level Limitations in GPS Receivers

Some serial devices expect to use true RS232 level signals, as opposed to inverted TTL (transistor-transistor logic) level signals. When TTL shows up in place of RS232, no communications are received, even though serial data is being sent. So what's the difference between TTL and RS232 voltage levels?

Both RS232 and TTL voltage levels are used to send serial data. Serial data just means the data bits are being sent over one wire and received on a second wire, one bit at a time, usually, but not always, in ASCII. A particular voltage represents each bit. When the higher voltage level represents a "1" and the lower voltage level represents a "0", then it is called true logic. Logic levels can be switched, where the higher voltage level represents a binary "0" and the lower voltage level represents a binary "1". This is referred to as inverted logic as opposed to true logic. TTL level signals use five-volts to represent logic 1 and zero-volts to represent logic 0. RS232 is an example of inverted logic. In RS232, a voltage of –12 volts represents logic 1 and +12 volts represents logic 0.

Most of the time in the real world, however, voltage levels never reach their intended highest or lowest levels. Often the voltage swings are lower than the ideal, and may give a weak, or mushy, signal. So in the real world, a binary "1" is represented by a voltage above a defined voltage level and a binary "0" is represented by a voltage below a defined voltage level. In the BASIC Stamp, the dividing point is 1.4 volts. Any voltage above 1.4 volts represents logic 1 and any voltage below 1.4 volts represents logic 0. The resistance, inductance, and capacitance of a cable increases as the length of the cable increases. As a result, the voltage swing of the serial signal becomes weaker.

To overcome voltage limitations of TTL, RS232 was designed with larger voltage swings. Since the serial signal for RS232 begins with a larger voltage swing (-12 volts to +12 volts), there is more room for the voltage swing to weaken. In practice the voltage swings of RS232 seem to be more like -10 to +10 volts. RS232 generally accepts anything below -2 volts as a binary "1" and anything above +2 volts as a binary "0".

Some devices are true RS232 devices. As such, they demand to see a negative going signal to correctly interpret serial communications. If you ever get a communications device and know it is sending it inverted TTL signals but the receiver still does not respond, then the problem is most likely the magnitude of the voltage swing. Use the MAXIM MAX233 IC to convert TTL signals into RS232 signals. The MAX233 inverts the sense of the logic and also increases the voltage swing by using a charge pump. Because of its charge pump, the MAX223 does not require a negative power supply, which simplifies its use. I can't tell you many cracks my head made in my apartment walls trying to figure this out (but it sure felt good to stop banging my head against the wall).

1.2. GPS Recommendations

Taking these limitations into account, there are several GPS receivers I can recommend and some I cannot recommend. I'll explain my reasoning as to my recommendations since GPS specifications change and new receivers are being introduced all the time. Keep these points in mind when looking at a GPS receiver for use in near space.

1.2.1. Not Recommended

The GPS engines that I know do not work are the Garmin GPS20 and the DeLorme Tripmate. The Garmin GPS20 does not implement the DoD limitation properly. The Tripmate apparently has an altitude field that is defined too small. At an altitude of 32,000 meters, it has been seen to stop outputting altitude data.

1.2.2. Recommended

The GPS engines or receivers that I know work are the Garmin GPS25, Garmin Etrex, and the Motorola OnCore VP. I have flown all three on near space capsules in the past. The only problem encountered with the Etrex is that once it shuts off, it will not restart unless you press its power button, a very difficult task at 100,000 feet. One reason the Etrex will shut down is if its battery voltage drops too low. This happens when alkaline cells are used in the Etrex and the internal temperature of the near spacecraft drops too low. However, the Etrex is a very inexpensive GPS receiver and operates for 22 hours on three AA cells. If you decide to use an Etrex, keep the temperature inside the airframe around the GPS receiver warmer than 40 degrees Fahrenheit or use photo lithium cells.

1.3. Specific GPS Receivers

Below are notes on using the Garmin GPS35, the Etrex, and the Motorola OnCore VP.

1.3.1. Garmin GPS35

The GPS I recommend most is one of the Garmin GPS35-LV models, either LVS or LVC. Don't use the GPS35-HVS because of its higher voltage requirement. Also, there's no sense in using the GPS35PC as it has a ten foot cable terminated in a DB-9 connector. Near space applications require shorter cable lengths and need to install their own DB-9. The difference between the LVS and LVC models are:

Model	Voltage	Output Signal
LVS	3.6 – 6.0 V	True RS232
LVC	3.6 – 6.0 V	CMOS

The CMOS output of GPS35-LVC depends on the power voltage. If supplied with 5.0V, the output signal is 0 – 5 V, inverted logic.

The RS232 voltage levels of the LVS can be sent to the BS2p, if a 22k resistor is wired in series with the line. The next section explains how to wire up the cables for the GPS35.

In cases where the GPS continuously sends GPS sentences, like the Etrex or GPS35, put a timeout statement in the SERIN command. This will make sure the BS2p doesn't hang should the GPS crash or the serial communication fail.

```
tnc_tx        con  3
gps_rx        con  7
i4800         con  16884          '4800 baud n81 inverted
GPSStat       var  Status.bit1    '0=good gps       1 = bad gps
alt_curr      var  word           'current gps alt (m)

serin gps_rx,I4800,10000,BadGPS,[wait ("$GPGGA"),skip 42, dec alt_curr]

BadGPS:
GPSStat = 1
serout tnc_tx,I4800,y"/No GPS"]
```

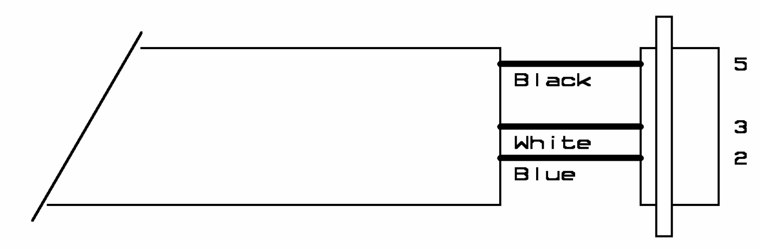
Note: this program assumes the TNC is connected to I/O pin three and the GPS receiver is connected to I/O pin seven. Change the constant statments as needed.

GPS35 Cable
The Garmin GPS35 LVS and LVC cables do not terminate in a DB-9 connector, so one has to be made. I recommend you make your cable in the following way:

Materials

- Female DB-9 connector kit with solder cups
- DB-9 plastic housing kit
- 22k resistor with leads cut to ¼" long (needed for the LVS model, but not the LVC model)
- Two lengths (about six inches) of 22 AWG stranded wire, one red and the other black
- One pair of Powerpole® connectors
- Assorted lengths of heat shrink tubing with large enough diameter to cover the solder cups of the DB-9
- Hot glue
- Label with "GPS" printed on it
- Clear heat shrink tubing large enough to slide over the pair of Powerpole®s

Diagram



GPS35 Cable *– Adding a DB-9 connector to the GPS35 cable.*

Procedure
Strip back two inches of the outer jacket. You'll see about ten wires inside the cable. The wires you need for now are the following:

Blue	RXD1
White	TXD1
Black	GND
Red	Vin

Note that there are other useful lines in the GPS35 cable, like the pulse per second line and the power down line. I do not discuss these lines in this book, but plan to cover them in my advanced projects book.

√ Strip ¼" of insulation from one end of the 22 AWG wires.
√ Strip back ¼" of insulation from the blue and black wires of the GPS35 cable.
√ Slide a short length of heat shrink tubing on the blue and black wires.
√ Solder the blue wire to pin #2 solder cup of the DB-9 connector.
√ Solder both the black GPS35 wire and the 22 AWG wire to pin #5 solder cup of the DB-9 connector.

If using an LVC model:
√ Slide a short length of heat shrink tubing over the end of the white wire.
√ Solder the white wire to pin #3 solder cup of the DB-9 connector.

If using the HVS or LVS models:
√ Slide a length of heat shrink tubing over the white wire.
Note: The heat shrink tubing must have a diameter large enough to cover the resistor.
√ Solder the 22k resistor to pin #3 solder cup of the DB-9 connector.
√ Solder the white wire to the other end of the resistor.

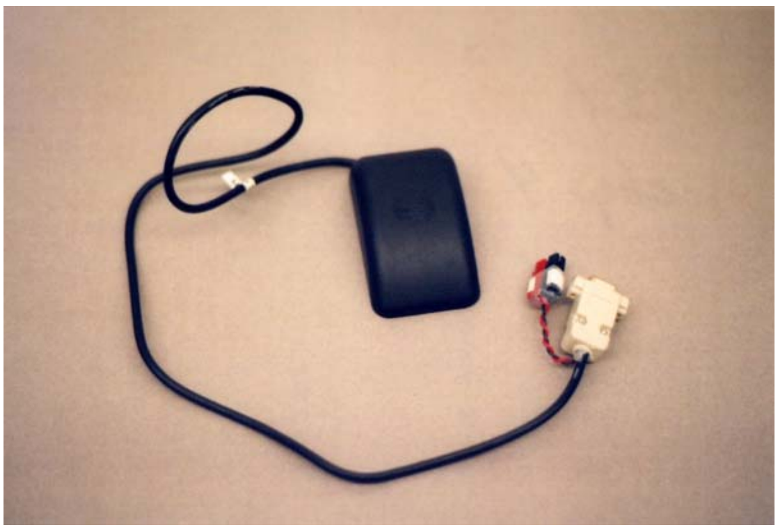
√ Slide a short length of heat shrink tubing over the end of the red wire.
√ Solder the 22 AWG wire to the red GPS35 wire.

The red and black 22 AWG wires exit the DB-9 hood through the back end, where the data cable enters.

√ Slide the heat shrink tubing over all soldered connections and shrink them.
√ Squirt some hot glue over the solder cups of the DB-9.
√ Put a layer of hot glue in the bottom half of the DB-9 hood.
√ Place the DB-9 into the bottom half of the DB-9 hood, being careful not to ooze hot glue all over the place.
√ Squirt some more hot glue over the top of the wires in the hood to fill in gaps.

- √ Put a layer of hot glue in the top half of the DB-9 hood.
- √ Close the top over the bottom half, being careful to wipe up any excess hot glue.
- √ Bolt the halves together.

- √ Strip one inch of insulation from the exposed ends of the red and black 22 AWG wire.
- √ Fold then in half to ½" in length.
- √ Insert the bare wires into the crimps of the Powerpole® connectors and crimp.
- √ Solder the interior of the crimps.
- √ Insert the crimps into their red or black housings, being sure not to mix the housings and
- √ wires.
- √ Backfill the Powerpole® jackets with hot glue.
- √ Slide the Powerpole® jackets together.
- √ Wrap the Powerpole® jackets with the GPS label.
- √ Cover the jackets and label with clear heat shrink tubing and heat it.
- √ Fill in any gap in the back of the jacket with hot glue.



The modified Garmin GPS35 *- Note the receiver terminates in a DB-9 and PowerPole connector.*

The GPS35 and The $PGRMV Sentence
$PGRMV is a Garmin proprietary sentence that reports the three-dimensional velocity of the GPS receiver. The $PGRMV sentence has the following format:

$PGRMV,East,North,Vertical*Check CR LF

Where:
East is the true east velocity of the receiver in meters per second.
North is the true north velocity of the receiver in meters per second.
Vertical is the vertical velocity of the receiver in meters per second.
Check is the check sum of the sentence.
CR LF is the carriage return and line feed at the end of the sentence.

Both the east and north velocities range from –514.4 m/s to 514.4 m/s
The vertical velocity ranges from –999.9 m/s to 9999.9 m/s.

By default, the $PGRMV sentence is not actively reported by the GPS35. To activate the $PGRMV sentence, send the following sentence to the GPS35:

$PGRMO,PGRMV,1,CR LF

Use the following BS2p program to send this command:

```
'****************************
'*   Enable $PGRMV Code     *
'****************************
gps_tx        con  5
gps_rx        con  7
n4800I        con  16884
gpsloop       var  byte
gpschar       var  byte

PGRMV:
debug "Enable RMV", cr
serout gps_tx,N4800I,["$PGRMO,PGRMV,1",cr,10]
pause 5000
debug "Get RMV", cr
serin gps_rx,N4800I,10000,NoRMV,[wait ("RMV"),spstr 20]
for gpsloop = 0 to 20
get gpsloop, gpschar
debug asc? gpschar
pause 500
next
goto Done

NoRMV:
debug "No PGRMV", cr

Done:
end
```

1.3.2. Garmin Etrex

Garmin Etrex *– This handheld GPS receiver makes an inexpensive GPS receiver that is near space capable. However, be sure to use photo lithium batteries to avoid power failure.*

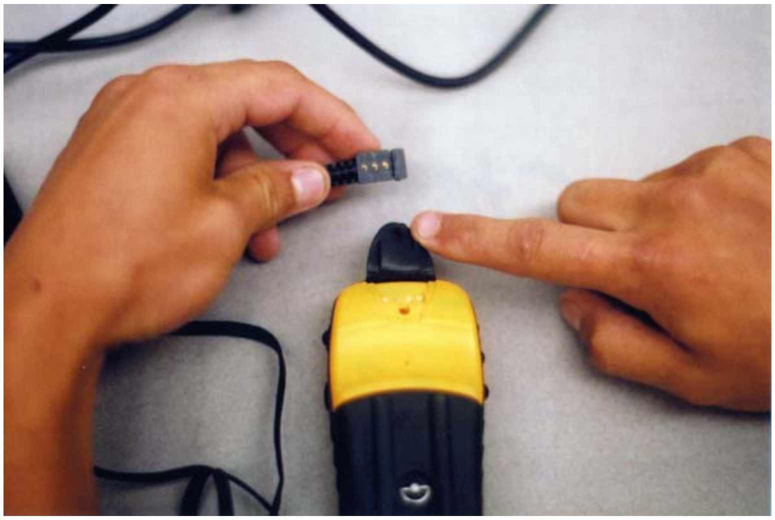
Before using the Etrex, you must configure it to send NMEA data through its port. Follow these steps to enable NMEA output:

- √ Start the Etrex.
- √ Press the PAGE button twice to enter the menu.

- √ Using the DOWN arrow, scroll down to SETUP and press the ENTER button.
- √ Scroll down to INTERFACE and press ENTER.
- √ Press ENTER again to display the options.
- √ Scroll to NMEA and press ENTER.
- √ PAGE out of the SETUP menu.

Reminder: be sure to use photo lithium batteries in the Etrex to prevent the cold temperatures of near space from shutting down the receiver.

Etrex Cable
Definitely go with the Pfranc cable. They're less expensive and plenty good. There's no sense in building an Etrex cable. Although the cable can provide a source of external power to the Etrex, the receiver cannot be switched on without physically pressing its power switch, so do not make this cable.



Etrex Data Cable *– The data cable connects to the plug beneath the rubber boot. The connector slides on for a durable contact.*

Use the same code to read data from the Etrex as you do any other GPS receiver.

1.3.3. Motorola OnCore

Motorola OnCore GPS *– There is no display or antenna.*

The Motorola OnCore VP is just a GPS board; there is no display or antenna. The antenna is purchased separately. A separate antenna has the benefit of letting a near space engineer mount the antenna outside the capsule while leaving the GPS engine inside. The OnCore VP does not have a built-in voltage regulator and therefore requires five volts (within 0.25 volts and with less than a 50 mVpp ripple). The OnCore antenna connects to the board through a SMA looking connector. There is a 2 X 5 pin header for power and data connections to the receiver. The OnCore VP draws 220 mA of current.

Some GPS receivers, like the OnCore, are easily commanded during a mission to send specific sentences. The sample code below instructs the OnCore to send the GPGGA sentence just once:

```
Ext_Comm      con 188                    'baud for TNC/GPS
GPS_In        con 3                      'data from GPS
GPS_Out       con 4                      'data to GPS

GPS_Lock      var Status.bit1            '0=no reply, 1=reply
alt_curr      var word                   'current GPS alt

serout GPS_Out,Ext_Comm,["$PMOTG,GGA,0",CR,10]
serin GPS_In,Ext_Comm,15000,badalt,[wait ("$GPGGA"), skip 45, dec alt_curr]

BadAlt:                                   'GPS did not respond in 10 sec
serout TNC_Out,Ext_Comm,[">NOGPS", cr]
pause 3000                                'tell the world
GPS_Lock = 0                              'no GPS signal
```

Notes About the Program
The command $PMOTG is an instruction to the OnCore VP to send the following sentence at the rate indicated. The format for the command is as follows,

$PMOTG, sentence, rate
where;
sentence = a valid NMEA sentence
rate = frequency the sentence is sent in seconds (0 means send it just once)

So the command, $PMOTG,GGA,0 orders the OnCore to send the GPGGA sentence just once.

The valid sentences for the $PMOTG command are:
GGA
RMC
GLL
GSA
GSV
VTG
ZDA

The $PMOTG command must end with a CR and LF, hence the CR,10 in the SEROUT command.

OnCore Cable
Jumper J1 is the power and data interface to the OnCore VP. The pins have the following respective functions:*

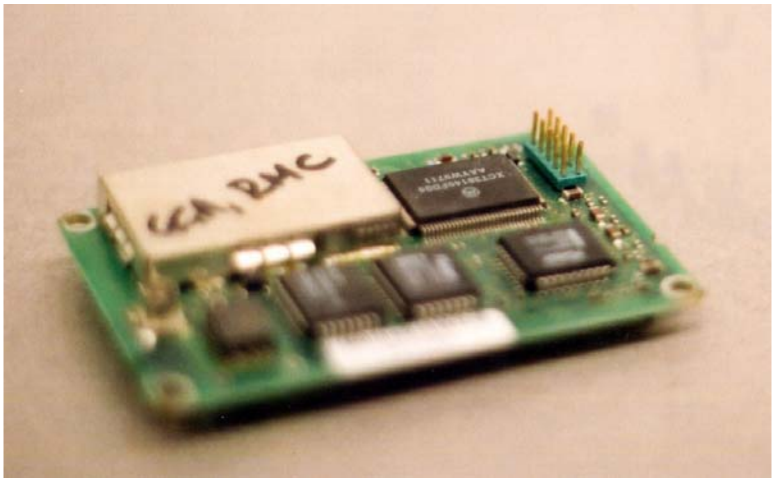
Pin	Signal Name	Description
1	Battery	External Applied Backup
2	5V PWR	+5Vdc Regulated
3	GROUND	Ground (Receiver)
4	VPP	Flash EPROM Programming
5	(Not Used)	
6	ONEPPS	1 Pulse Per Second Output
7	ONEPPS-RTN	1 Pulse Per Second Return
8	TTL-TXD	Transmit 5V Logic
9	TTL-RXD	Receive 5V Logic
10	TTL-RTN	Transmit/Receive Return

* OnCore Users Guide, May 1996, Motorola

J1 is located on the bottom of the OnCore VP and has pinouts as follows:

1	2
3	4
5	6
7	8
9	10

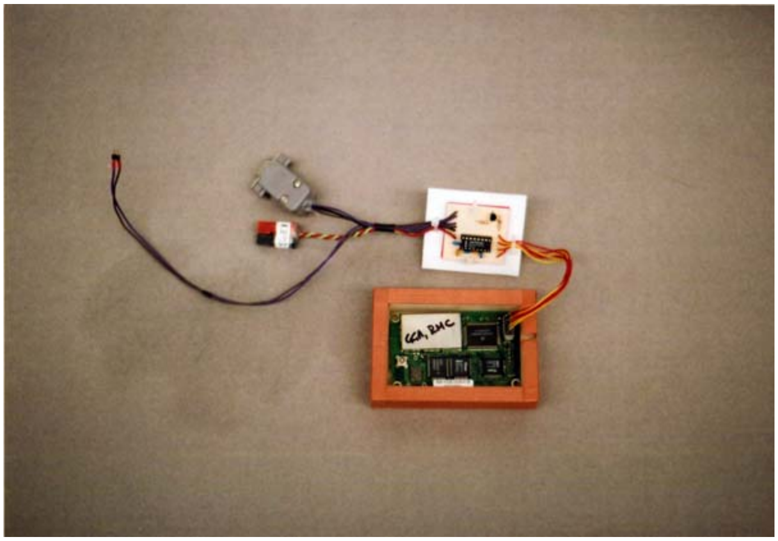
where Pin 1 is the pin closest to the corner of the GPS board.



J1 *- Close-up photo of OnCore pins.*

Of the pins, the ones required are:
2 and 3 for power
8 and 10 for receiving sentences
9 if the flight computer commands the OnCore VP

Making the OnCore VP Cable



Completed OnCore *- The Motorola OnCore GPS board shown after completing and attaching the cables.*

Materials

- 2 by 5 plastic housing for 0.1” between center pins, 0.025” in diameter
  and
- 10 female crimp pins
  or just
- Thin heat shrink tubing to cover #24 AWG stranded wire

- Female DB-9 Connector (with solder cups)
- #24 AWG stranded wire, at least three colors (one red and one black)
- One pair of Powerpole® connectors
- Assorted lengths of heat shrink tubing with large enough diameter to cover the solder cups of the DB-9
- Assorted lengths of heat shrink tubing with large enough diameter to cover the wires making up the cable
- DB-9 plastic housing kit
- Hot glue
- Label with “GPS” printed on it
- Clear heat shrink tubing large enough to slide over the pair of Powerpole®s

Procedure

√ Cut at least four wires to length (from GPS receiver to flight computer).
√ Cut a fifth wire if the flight computer will command the OnCore VP.
√ Strip ¼” of insulation from all ends of the wires, except for the red and black, where you strip 1” from one end of both wires.

Either:

√ Crimp female pins on one end of each wire, and then insert the pins into the 2 X 5 housing in the positions indicated in the table below;

Or:

√ Solder the wires directly to the OnCore pins, and then cover the soldered connection with heat shrink tubing.

Wire	Socket Position
+5V (red)	2
Ground (black)	3
TXD	8
TXD/RXD Return	10
RXD (if used)	9

- √ Strip ¼” of insulation from free ends of all the wires but the red and one black wire (these wires are for OnCore power).
- √ Separate the red and black wires from the rest.
- √ Slide several lengths of heat shrink tubing over the wires to form two wiring harnesses.
- √ Slide the heat shrink tubing over the RXD, TXD, and TXD/RXD wires.
- √ Solder the RXD wire to pin #2 solder cup of the DB-9 connector.
- √ Solder the TXD wire to pin #3 solder cup of the DB-9 connector.
- √ Solder the TXD/RXD Return (ground) wire to pin #5 solder cup of the DB-9 connector.
- √ Slide the heat shrink tubing over all soldered connections and shrink them.
- √ Squirt some hot glue over the solder cups of the DB-9.
- √ Put a layer of hot glue in the bottom half of the DB-9 hood.
- √ Place the DB-9 into the bottom half of the DB-9 hood, being careful not to ooze hot glue
- √ all over the place.
- √ Squirt some more hot glue over the top of the wires in the hood to fill in gaps.
- √ Put a layer of hot glue in the top half of the DB-9 hood.
- √ Close the top over the bottom half, being careful to wipe up any excess hot glue.
- √ Bolt the halves together.

- √ Strip one inch of insulation from the exposed ends of the red and black 22 AWG wire.
- √ Fold then in half to ½” in length.
- √ Insert the bare wires into the crimps of the Powerpole® connectors and crimp.
- √ Solder the interior of the crimps.
- √ Insert the crimps into their red or black housings, being sure not to mix the housings and
- √ wires.
- √ Backfill the pole power jackets with hot glue.
- √ Slide the Powerpole® jackets together.
- √ Wrap the Powerpole® jackets with the GPS label.
- √ Cover the jackets and label with clear heat shrink tubing and heat it.
- √ Fill in any gap in the back of the jacket with hot glue.

2.0 Radios

To transmit telemetry from the TNC, the near spacecraft requires a radio. Because of weight and space limitations, a handheld radio is the best choice. Unless powered from a 12-volt battery, most HT's output no more than a watt of power. Fortunately, transmissions of less than one watt are sufficient for line of sight communications. On the ground line of sight is limited to terrain features and a horizon about three miles away. In near space where there is no terrain or foliage to block a radio transmission, line-of-sight to the horizon is the ultimate limit. In near space, it’s hundreds of miles to the horizon. To keep cost and weight low, use the Alinco DJ-S11 HT as the near spacecraft radio.

2.1. A Tale of Caution: Two-Way Communications with TNCs

Let me tell you a short story about my first near space flight and why I'm currently hesitant to send commands to the near space capsule. My first flight, KNSP 96A, was launched the first Saturday in November 1996. Inside the near space capsule, both of the HT's MIC and SP lines were connected to the TNC. At this point I hadn't planned to communicate with the near space capsule, but wired up the connection for future use. The TNC was placed in transparent (TRANS) mode. In this mode, as opposed to command mode, the TNC sends all data it receives from the CC/PS or GPS receiver. Transmissions from the capsule where formatted as Unproto, so no connection was made with ground stations. All transmissions were sent into the ether for everyone to receive. Just after passing the 30,000-foot mark, a packet station operator in Kansas City saw my near spacecraft, the Isaac Asimov, as a new packet station and attempted connecting to it. The connection placed the TNC into command mode. In command mode, the TNC waits for further instruction and ignores all data sent to it from the GPS or CC/PS. The BS-2IC in the CC/PS had no way of knowing that its data was not being transmitted. The near space capsule was effectively "Lost In Near Space" (this sounds vaguely like a really bad science fiction movie). I can't begin to explain how badly I felt at this time. This was my first near space capsule, my baby, and the baby I had been building for over a year and now it was lost. Fortunately one bright individual* in the KNSP chase crew determined he could connect with the TNC with his laptop. Once the connection was made, the TNC transmitted data for 15 seconds before timing out. As long as the connection was maintained, ground stations received data from the near space capsule. So he kept hitting the ENTER key every ten seconds for the rest of the flight. Because of this unsung hero, KNSP eventually recovered the near space capsule. Believe me, there's no bummer like the bummer of losing your first flight. Ever since then I have been hesitant to connect the center pin of MIC jack to the TNC in fear of a future repeat of this incident.

A little research shows several ways to prevent this occurrence. First, the TNC can be left deaf to the world by not connecting the speaker output to the TNC. The TNC still sends data, but cannot receive any commands. Another way is to prevent connections to the TNC with the NOCOM command. Of course if you do this, you should set up a remote login to your TNC in case you need to reprogram the TNC during a mission.

* I wish I recalled this individual's name.

2.2. The Alinco DJ-S11 Handheld Two-Meter Radio

2.2.1. Theory of Operation

The Alinco DJ-S11 can operate with as little as 4.5 volts and has an output of 340 mW. This is a sufficient amount of power if the antenna is replaced. The antenna that comes with the DJ-S11 may be fine for ground use, but has a poor enough gain that it cannot be used reliably for critical near space telemetry. Replacing the antenna with a simple dipole or J-pole improves its gain, letting its 340 mW do its magic.

2.2.2. Materials

DJ-S11

- Three foot length of RG174/U 50 ohm cable*
- Small wire clamp **
- 3/16" heat shrink tubing

* Purchase this cable from Jameco. Part number is 111472 and its cost is $3.25. Cut a cable in half and you have enough coax to make the HT connection and an antenna.
** The wire clamp is called a 1/8” nylon strap at hardware stores.

Tools

- A small jeweler’s Philips screwdriver
- Fine tipped soldering iron
- Thin solder

2.2.3. Procedure to Replace a DJ-S11 Antenna (with running commentary)

√ Cut the RG174/U cable in half.
One half is used on the HT and the other half becomes part of the antenna.

√ Remove the back cover of the DJ-S11.
There are three screws visible on the back cover of the DJ-S11. There are four additional screws hidden behind the batteries. To remove them, you must first remove any batteries. Beneath the batteries you’ll see the four screws. Remove all seven screws to remove the back cover of the DJ-S11.

√ Remove the folding whip antenna from the back cover.
The folding antenna is mounted to the back cover where it makes a simple mechanical connection to the DJ-S11’s PCB. Remove the antenna by removing the retaining nut with a pair of pliers. This leaves a hole in the back case of the HT, which will be used as an exit point for the coax.

√ Set the back of the cover aside.

√ Locate the male headers on the PCB.
On the HT’s PCB search for a pair of 0.025" males headers, with 0.1" between centers. These two headers are mounted at a right angle to the PCB and located near the top of the radio. These two headers are connected to the antenna pads and are where the new antenna connection will be made.

√ Stick a small piece of tape beneath the headers.
I do this to prevent an accident from damaging the HT. Your mileage will vary.

√ Carefully tin both headers.
Making sure you don’t drop solder onto the PCB.

√ Cut a length of RG-174 (1/8” diameter coax) about eighteen inches long.

√ Strip about two inches of insulation from one end, exposing the braid.
Use a #14 gauge stripper.

√ Spread the braid at the end closest to the insulation, forming a small hole.

√ Push the inner insulation through the opening.

√ Strip back ¾” of inner insulation to expose the center conductor of the coax.
Use a #20 gauge stripper .

√ Tightly twist the braid and center conductor.

√ Tin both the braid and center conductor.

Making the Antenna *- The cut and stripped RG-174 coax.*

√ Cut away the rubber cover over the HT's speaker and MIC jacks.

√ Notch the case where the rubber cover used to be.
Use an Exacto knife and remove a small piece of plastic. Make the hole large enough to let the coax pass through, but no larger than necessary.

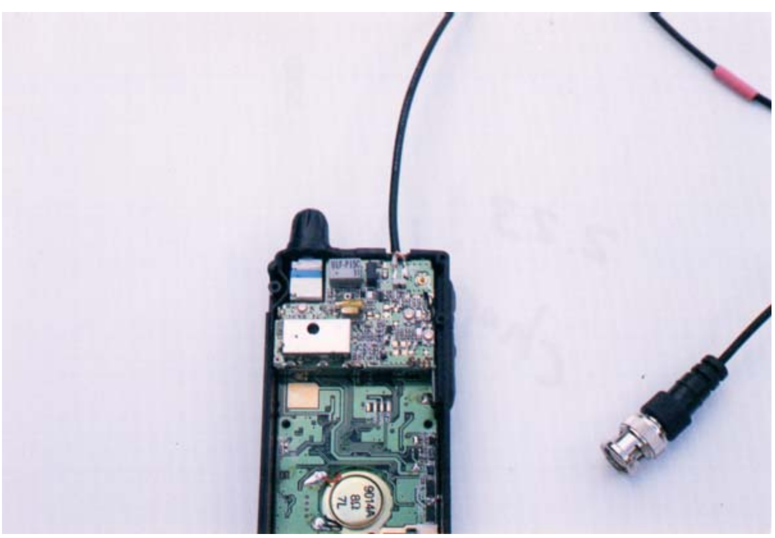
√ Pass the coax through a cable restraint.

√ Loosely bolt the cable restraint to the back cover.
Use the large bolt that comes with the hand strap and bolt the restraint to the threaded hole for the hand strap.

√ Slide on two pieces of heat shrink tubing.
The tubing will increase the diameter of the coax so the cable restraint can tightly clamp onto the coax.

√ Slip the coax through the old antenna opening in the back cover.

√ Place the soldered coax ends up against the male headers on the HT's PCB and carefully solder the coax to the headers.
Make sure no solder bridge is created.



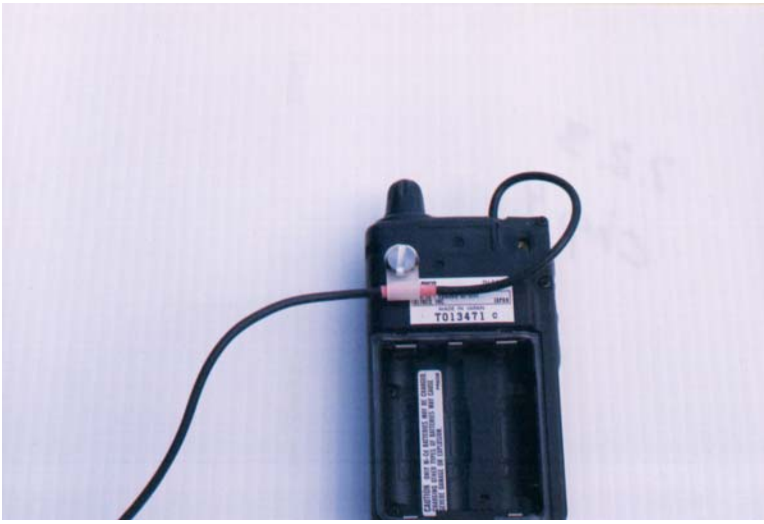
Soldered RG-174 *– The Alinco DJ-S11 (or DJ-S41) after the external antenna coax is soldered on to its two-pin header.*

√ Carefully pull coax out through the back cover as you close the back of the HT.

√ Screw the back cover into place.

Leave some slack in the coax as you thread it through the cable restraint.
- √ Slide the heat shrink tubing into place and shrink it down.
- √ Tighten the cable restraint.

Now the coax is tightly bound and strain relieved.



Fully Modified Alinco DJ-S11 -
Sporting its new antenna.

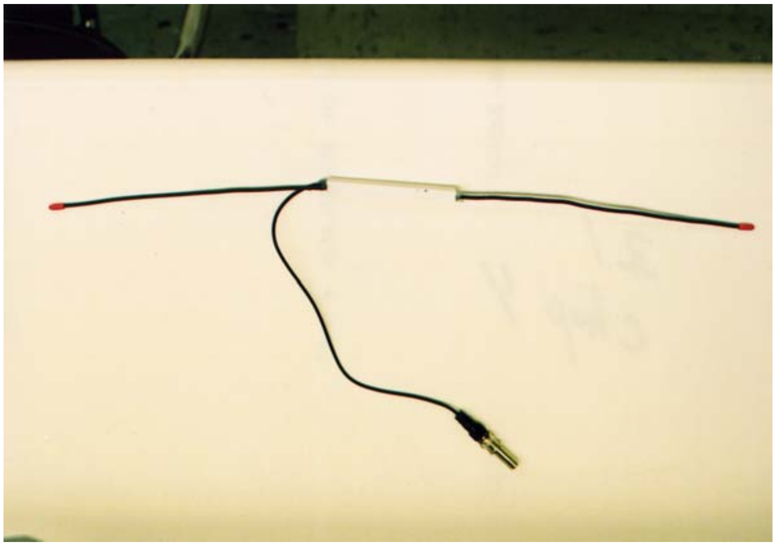
3.0 Antennae

Since everything within 300 miles or more is line of sight in near space, simple dipole antennas are all that are necessary for near space capsules. A simple dipole antenna is excellent for a near spacecraft because of its uniform radiating pattern. This is important because the balloon rotates and there is no control over the direction the antenna points. There's enough gain with mag mount antennas that the chase crews will not need beam antennas, except perhaps for ATV (amateur television) where you need to squeeze out every milliwatt of signal.

A second type of antenna that has been used successfully in near space is the J-Pole. Mark Conner's (NSTAR) capsule uses this antenna quite successfully. The only real risk of a J-pole comes from the chance the near spacecraft may recover on a power line and the antenna lies across two or more power lines. A minor nit pick is that the antenna hangs below the near spacecraft. Any ground photographs taken during a mission include a dangling antenna in them.

Described here are two simple dipole antennae for near spacecraft. The first is a rigid design while the second is uses flexible elements.

3.1. A Dipole Antenna with Rigid Elements



Completed Dipole Antenna with Rigid Elements

Mount rigid dipole antennas to the end of an antenna boom. Directions for making an antenna boom are in Chapter Five, Section Three.

3.1.1. Materials and Tools

The following materials are required to make a dipole antenna:

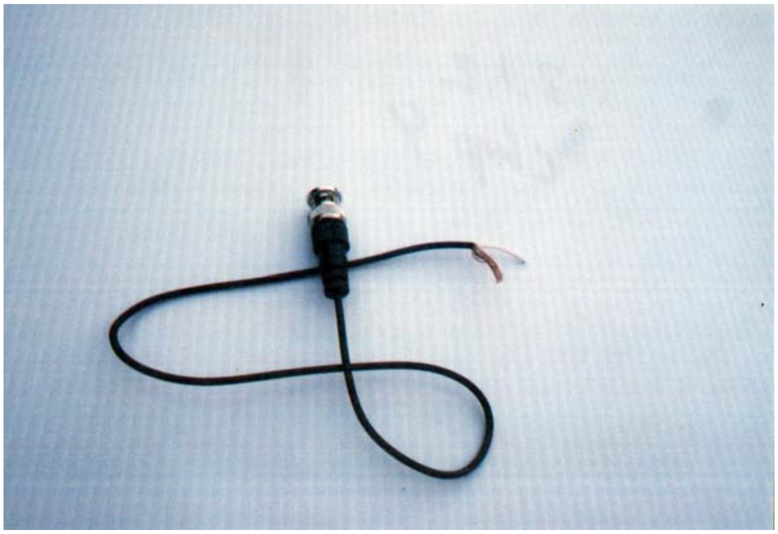
- Two pieces of #12 or #14 AWG insulated solid copper wire
- Half of a coax RG-174/U cable *
- Four inches of hollow 1/2" plastic square tubing**
- A BNC barrel connector
- Nylon zip wire ties
- Heat shrink tubing with diameter large enough to cover the solid wire
- Small diameter bolt thread protectors (select a bright color that closely fits the solid wire.)

* You should have half of this cable lying around, if you have modified the antenna of a DJ-S11. Purchase this cable from Jameco. It is part number 111472 and costs $3.25.
** This material is available at hobby stores.

Collect the following tools:

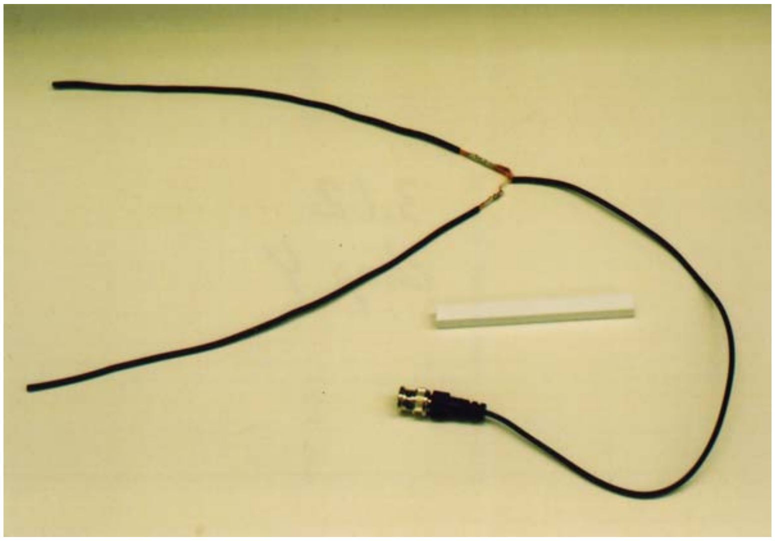
- Wire strippers
- Small pick or pointy Exacto knife
- Soldering iron and solder
- Hot glue and a glue gun

3.1.2. Construction



Stripped RG-174 *- The coax cable with the center conductor pulled through the outer braided jacket.*

- √ Cut two #12 or #14 AWG solid copper wires to a length of at least 20”.
- √ Strip 1” of insulation from one end of each wire.
- √ Cut the coax cable in half if you have not already done so.
- √ Strip back about three inches of outer jacket from the cut end, exposing the inner braid. Use a sharp point and open up the braid near the insulation.
- √ Through this hole in the braid, pass through the inner insulation and conductor.
- √ Strip back the inner insulation by about 2.5 inches.
- √ Open the braid to expose its hollow core.
- √ Insert an end of one of the solid copper wire into the hollow braid.
- √ Twist the braid tightly around the copper wire and solder them together.
- √ Solder the wire to the braid (use a soldering gun as it takes a lot of heat).
- √ Wrap the inner conductor around the second piece of solid wire.
- √ Solder them together. This completes the electrical connection.



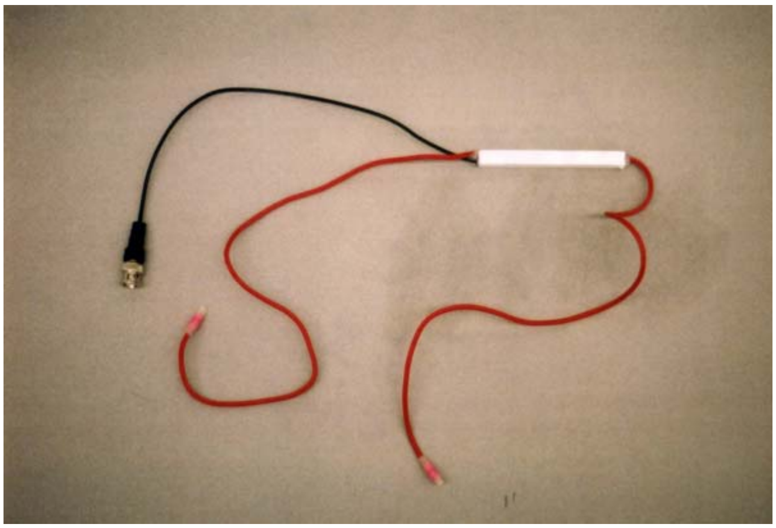
The Soldered Dipole - *The antenna will be placed inside the square plastic tube and hot-glued into place.*

- √ Cut each dipole element to a length of 19.5 inches, measured from their soldered
- √ connection.
- √ Fold the coax cable against the dipole elements in a short zigzag.

- √ Wire tie the coax to the dipole elements
- √ Insert the center of the dipole into the hollow plastic tubing.
- √ Fill the interior space with hot glue.
- √ Shrink enough layers of heat shrink tubing over the exposed ends of the elements to fit the thread protector snugly.
- √ Twist the barrel connector onto the BNC end of the antenna cable.

3.2. Dipoles with Flexible Elements

Dipoles with flexible elements are designed to let one element dangle below and the second to be tied to a link line.



Flexible Dipole Antenna *– A suitable antenna for missions where there is no antenna boom. The bottom element is left to dangle. The top element is tied (loosely) to a link line.*

3.2.1. Materials and Tools

The following materials are required to make a dipole antenna:

- √ Two pieces of 12 AWG stranded (flexible) copper wire*
- √ Half of a coax RG-174/U cable from Jameco
- √ Four inches of hollow 1/2" plastic square tubing
- √ A BNC barrel connector
- √ Nylon zip wire ties
- √ Heat shrink tubing large enough to cover the solid wire
- √ Bolt thread protectors (select a bright color that closely fits the solid wire.)

* A suitable cable is available at hobby shops that cater to RC racing car enthusiasts. The wire is insulated in a silicon jacket and used for power cables.

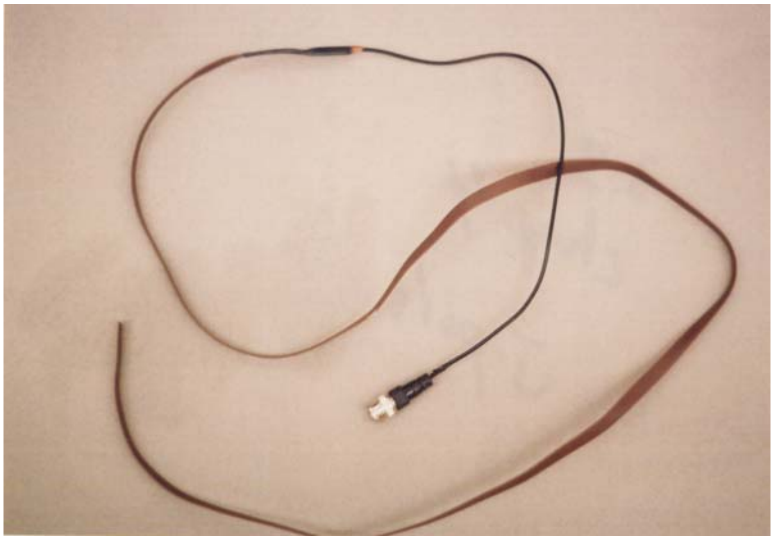
Have the following tools at hand

- Wire strippers
- A small pick or pointy Exacto knife
- Soldering iron and solder
- Hot glue and glue gun

3.2.2. Construction

- √ Cut two # 12 or #14 AWG stranded copper wire to a length of at least 20”.
- √ Strip 1” of insulation from one end of each wire.
- √ Cut the coax cable in half if you have not already done so.
- √ Strip back about three inches of outer jacket from the cut end, exposing the inner braid. Use a sharp point and open up the braid near the insulation.
- √ Through this hole in the braid, pass through the inner insulation and conductor.
- √ Strip back the inner insulation by about 2.5 inches.
- √ Open the braid to expose its hollow core.
- √ Insert an end of one of the stranded copper wire into the hollow braid.
- √ Twist the braid tightly around the copper wire and solder them together.
- √ Solder the wire to the braid (use a soldering gun as it takes a lot of heat).
- √ Wrap the inner conductor around the second piece of stranded wire.
- √ Solder them together. This completes the electrical connection
- √ Cut each dipole element to a length of 19.5 inches, measured from their soldered connection.
- √ Fold the coax cable against the dipole elements in a short zigzag.
- √ Wire tie the coax to the dipole elements.
- √ Insert the center of the dipole into the hollow plastic tubing.
- √ Fill the interior space with hot glue.
- √ Shrink enough layers of heat shrink tubing over the exposed ends of the elements to fit the thread protector snugly.
- √ Twist the barrel connector onto the BNC end of the antenna cable.

3.3. The J-Pole Antenna

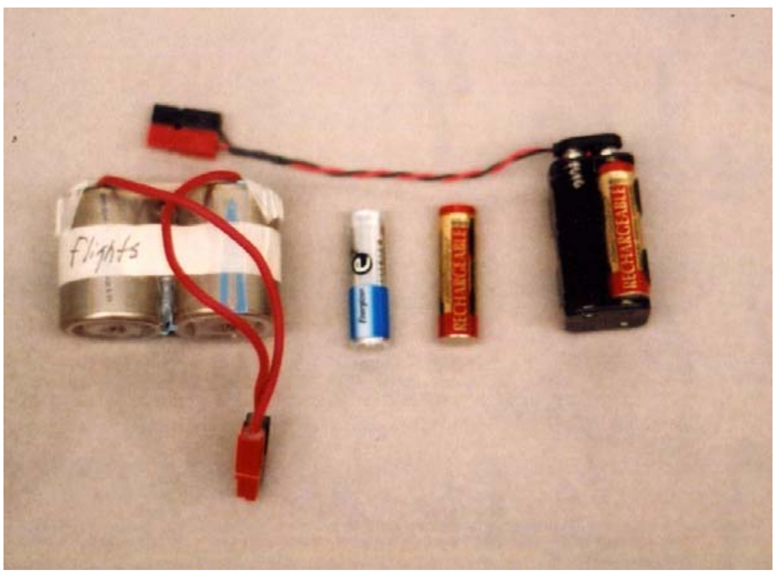


Completed J-Pole Antenna

I recommend using the J-Pole for only tracker flights; if used on science loaded missions, the antenna will intrude on the photographs. A very good website demonstrating how to construct Dr. Carl Jelinek’s roll-up J-Pole antenna from a TV twin lead is http://cvarc.org/jkpolescl.htm.

J-Pole hanging out of capsule

4.0 Near Space Power Systems



***Various Batteries** – L to R – Military surplus lithium, photo lithium, rechargeable NiMH, rechargeable NiMHs in battery pack.*

4.1. Batteries

Most people don't care, but being the professional amateurs that we are, being specific does matter. There's a difference between cells and batteries. A cell is a single unit that chemically produces a voltage potential. A battery is made up of several cells. While "AAA", "AA", "C", and "D" batteries are really cells, a 9V transistor battery is really a battery because it is made up of several cells stacked on top of each other (like Pez candies). Now that I've got that off my chest, let's continue with near spacecraft power systems. Cells have a characteristic voltage that depends on their chemistry. The voltage (a potential or force) produces a current (the flow of charge carriers, usually electrons) when the two terminals of the cell are connected to each other with conducting material. A cell uses energy to create the voltage potential that pushes the electrons that form the current. As the stored chemical energy in the cell is used up, the voltage on the cell terminals decreases. Long before the cell reaches zero volts, it is considered discharged. In fact, if a rechargeable cell is discharged to near zero volts, it has been damaged. Do not use such a cell in a near space application.

The characteristics of a cell that are important for near space are:

- Weight
- Voltage per cell
- Capacity
- Cold sensitivity
- Discharge curve profile
- Primary or secondary cell
- Cost

Note: The ratio of capacity to weight is referred to as the specific energy of the cell.

The near spacecraft is weight constrained. The more weight required for power systems, the less weight available for experiments, or the lower the altitude the stack will reach.

The higher the voltage per cell, then the fewer cells required building a battery pack for the avionics. This also reduces the total weight required for the power system.

The higher the capacity of the cell, the longer the cell can source current, and therefore the fewer the cells needed. Higher capacities allow longer missions (slower ascents which usually imply higher altitudes) and more time for the recovery crew to reach the near spacecraft before it shuts down. Cell capacity depends strongly on the discharge rate of the cell. When a load draws too much of a current the useful capacity of the cell is reduced.

Near space is cold. Really cold. As cells cool, their voltage and capacity drops. Some cell chemistries are more sensitive to the cold than others. The interior temperature of an near spacecraft needs to be characterized before using cells with lower cold tolerances. The most critical time for a power system is during descent when the interior temperature is at its lowest. It's very important the GPS receiver does not stop operating due to reduced battery voltage.

A battery discharge profile is a graph of a cell's voltage over time as the cell is discharged. If cells with a flat discharge curve are used, then battery telemetry reports constant battery voltages until they die. If a battery with a sloped discharge curve is used, then battery telemetry reports a continuous drop in voltage during the mission and gives sufficient warning of battery death.

Primary cells are not rechargeable, while secondary cells are. Primary cells can be discharged to a lower voltage, as you're not worried about damaging them. Secondary cells have a discharge level below which the life expectancy may be degraded.

The cost of batteries is not large compared to the cost of the balloon and helium. For primary cells, the cost of the batteries is a cost added to each flight like the cost of film. For secondary cells, the cost is a one-time cost like the HT or GPS receiver. Rechargeable cells that are not well cared for become an expensive power system, but rechargeable cells could lower the cost of each flight if they can be used enough times.

4.1.1. Cell Chemistries In Detail

Information about batteries in this section was found from several different sources. Primarily, websites of the following manufacturers was used:

Ultralife www.utralifebatteries.com

Duracell	www.duracell.com
Panasonic	www.panasonic.com
Energizer	www.energizer.com

Costs are those at my local Wal-Mart and HobbyTown. Weights are for an "AA" cell form factor. Discharge curves and capacities are determined for a cell that provides enough current to power the CC/PS and GPS receiver. At a voltage of 6.0 V and a current of 125 mA, cells must provide 750 mW for the entire mission. Assuming missions require three hours, plus 30 minutes before launch and an hour after recovery, cells must provide power for a minimum of 4.5 hours to be a viable power source. In addition to having the capacity to operate an near spacecraft, the flight batteries must have a minimum voltage greater than 5.25 volts to keep the voltage regulator operating. Even if the cells in a battery have excess capacity, once their collective voltage drops below the dropout voltage of the LM2940, they can't operate the near spacecraft avionics. Cells having lower operating temperature ranges anywhere near the minimum temperature expected during the descent of the near spacecraft are excluded from critical near spacecraft systems.

Each cell report includes the following statistics:

Cell Statistics	
Weight of cell	in grams
Voltage per cell	in volts
Weight of a 6V system	total weight required creating a 6-volt pack
Capacity	in mAh
Temperature range	in degrees F
Cost	Wal-Mart or hobby store's prices
Discharge curve profile	voltage vs. time for a 750 mW power or 125 mA current drain

Alkalines

Alkaline cells use manganese dioxide chemistry and an alkaline electrolyte. They are superior to the old dry cell.

Alkalines	
Weight of cell	24.4 g
Voltage per cell	1.5 V
Voltage when discharged	0.8 V
Weight of a 6V system	97.6 g
Capacity	780 mAh
Temperature range	-4 to 130 degrees F
Cost	$3.25
Discharge curve profile	The voltage of an alkaline cell drops off immediately after use. There is no leveling off. For a 750 mW requirement, the voltage drops at a roughly constant rate of about 0.083V/hr.

Nicads

Nickel Cadmium cells are secondary cells, that is, they are rechargeable. As long as they are not discharged too far, they are not damaged and can be recharged.

Nicads	
Weight of cell	21 g
Voltage per cell	1.2 V
Voltage when discharged	0.9 V
Weight of a 6V system	105 g
Capacity	700 mAh
Temperature range	-4 to 149 degrees F
Cost	$11.45
Discharge curve profile	The voltage of a NiCd cell quickly drops by about 22% then holds at a near constant level voltage until it's close to fully discharged.

NiMH
Nickel Metal Hydride cells are similar to nickel cadmium cells.

NiMH	
Weight of cell	27 g
Voltage per cell	1.2 V
Voltage when discharged	1.0 V
Weight of a 6V system	135 g
Capacity	1200 mAh
Temperature range	-4 to 122 degrees F
Cost	$22.45
Discharge curve profile	The voltage of a NiMH cell changes near identically to that of a NiCd cell.

Lithiums
Lithiums use lithium-manganese chemistry. The cells described here are equivalent to 2/3 of a "D" cell. These military surplus (part # BA-5598-U) cells come in five to a plastic box, which must be opened carefully to avoid cutting the batteries. Cut the box lid seam at one corner only and pry open. The batteries come wired together; you may leave two attached for use as a pair.

Lithiums	
Weight of cell	98 g
Voltage per cell	3.0 V
Voltage when discharged	1.7 V
Weight of a 6V system	196 g
Capacity	8000 mAh
Temperature range	-40 to 160 degrees F
Cost	less than $1.00
Discharge curve profile	The voltage of a lithium cells drops off at a near constant rate until the cell is discharged.

Note: Surplus batteries need to be tested under a load for 5 to 10 minutes before using them on a mission. The goal is to get them to fail on the workbench, rather than at 100,000 feet (I have had this sort of thing happen). Test them for a draw of 500mA, which exceeds near spacecraft requirements. At 6V, a resistance of 12 ohms is required to create a current of 500mA; at 6V and 500 mA, a total of 3W is generated. So, a power resistor of 12 ohms and 3W is required to load the batteries, but for safety use a 12 ohm, 5W power resistor (Digi-Key part # 12W-5-ND sells for $0.41). To test the battery, connect the power resistor across the battery along with a digital multimeter (DMM) set for DC voltage and watch the voltage for 5 to 10 minutes. It should drop under the load, but not below the 5.3 volt minimum needed to run the voltage regulator I recommend (LM2940T-5). After the load is removed, the voltage should spring back up to what it was originally.

Photo Lithiums
Photo lithium batteries use lithium-iron disulfide chemistry. This reduces their voltage per cell to that of an alkaline cell, letting them be used in equipment designed for alkalines.

Photo Lithiums	
Weight of cell	14.5 g
Voltage per cell	1.5 V
Voltage when discharged	0.8 V
Weight of a 6V system	58 g
Capacity	2900 mAh
Temperature range	-40 to 140 degrees F
Cost	$10.00
Discharge curve profile	The voltage of a photo lithium drops off steeply and never levels out.

4.1.2. The LM2940T-5 Five-Volt Voltage Regulator

This section addresses the issues regarding the LM2940 series of low-dropout voltage regulators, since it is the only voltage regulator used in this book. Take a look at the data sheet in Appendix A as you read through this section. The LM2940T-5 voltage regulator produces a 5.0 (within 5%) volt output as long as its supplied voltage is greater than 5.25 volts. Therefore the greatest amount of battery capacity is used if the battery pack produces 5.3 volts when fully discharged. The greater the voltage supplied to the LM2940, the more energy wasted by the regulator and the lower its efficiency. So another concern becomes, how great is the voltage of the fully charged battery pack? A fully charged battery pack with a lower voltage wastes less energy than a fully charged battery pack with a higher voltage.

For example:

CHARGED BATTERY PACK APPROACH				
Chemistry	**Discharged Voltage**	**Under Voltage**	**Full Charge Voltage**	**Over Voltage**
Alkaline	3.2	1.00	6.0	0.75
NiCd	4.5	0.75	6.0	0.75
NiMH	5.0	0.25	6.0	0.75
Lithium	3.4	1.85	6.0	0.75
Photo lithium	3.2	2.05	6.0	0.75

DISCHARGED BATTERY PACK APPROACH				
Chemistry	**Discharged Voltage**	**Under Voltage**	**Full Charge Voltage**	**Over Voltage**
Alkaline	5.6	0.3	10.5	5.25
NiCd	5.4	0.1	7.2	1.95

NiMH	6.0	0.7	7.2	1.95
Lithium	5.1	-0.1	9.0	3.75
Photo lithium	5.6	0.3	10.5	5.25

Efficiency
Data supplied by Ralph Wallio (W0RPK) indicates the following efficiencies for the LM2940T-5 for a supplied current of 186 mA:

Input	Efficiency
7.5V	63.8%
7.0V	68.3%
6.5V	72.8%
6.0V	78.6%
5.5V	85.5%

When supplied with the lowest possible voltage, the LM2940 operates at its highest efficiency. So as the flight battery discharges, the voltage regulator generates less waste heat. If you use the minimum number of cells to operate the avionics, then the avionics never get the full capacity of the cells. If you use enough cells to get their full capacity, the voltage regulator initially doesn't operate at very high efficiency, wasting the battery capacity.

4.1.3. Some Recommendations

The best cell chemistry to use depends on your greatest concern. Ideally, the cell chemistry selected has a flat discharge curve for the majority of the time and a full charge not higher than 6.0V. At the same time its voltage begins to gently drop near the end of its charge, giving a warning that they are about to die. The ideal cell is inexpensive and light weight. They will have a high capacity, so they provide power for extended recoveries. However, no cell chemistry provides its ideal total capacity at the currents needed to operate a near spacecraft. Below are two examples illustrating this.

Mark Conner's (N9XTN) near spacecraft draws a current of 400 mA (this includes the TNC, GPS, and radio). When operated from 4000mAh NiMH, it operates for eight hours before failing. Mark gets 3200 mAh out of a 4000mAh flight battery, or 80% of their rated capacity.

My (KD4STH) near spacecraft draws a current of 160 mA (this includes the GPS and CC/PS). When operated from 2900 mAh photo lithiums, it operates for 12 hours before failing. I get 1900 mAh out of a 2900 mAh flight battery, or 65.5% of their rated capacity.

The reason for the greater percentage of rated capacity in the NiMH cells is that their discharge curve is flatter than the discharge curve of the photo lithiums. NiMH and NiCd cells self-discharge at a rate of 1% of their total charge daily. Lithium cells self–discharge at such a low a rate that they can be stored for up to ten years before use. Lithium cells are lighter in weight and have the larger specific energy. For a three to four hour flight, most cells will provide sufficient power, as long as they are not affected by the cold of near space.

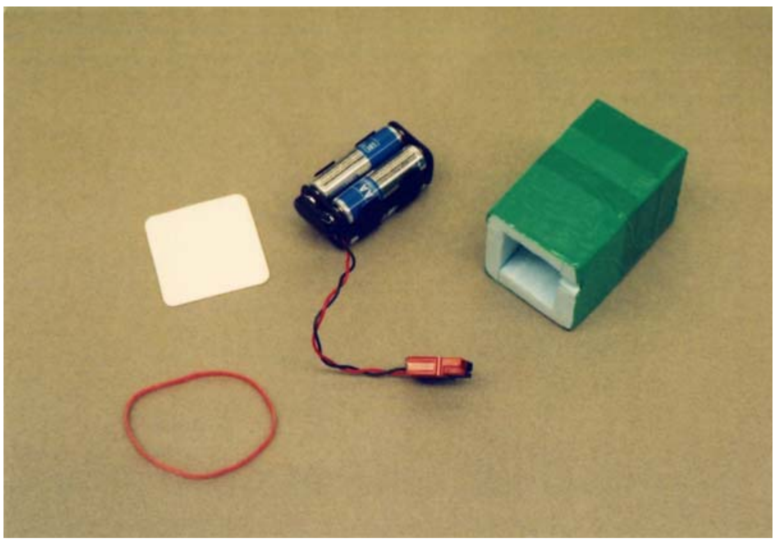
If your primary concern is to have a guaranteed, fully charged flight battery, then using fresh, non-rechargeable cells is your best option. If the airframe interior stays warm enough (no lower than about 40 degrees F), then alkalines are the least expensive route. Photo lithiums are second best as far as cost. If using non-rechargeable cells, do not open their package until the morning of the mission. This ensures they do not accidentally discharge before the launch. Charging rechargeable cells just before launch warms them up and delays their cooling during the flight.

If your primary concern is to have cells that operate regardless of the temperature, then using lithiums is your only option. Photo lithiums are the least expensive and most available option.

If cost is your primary concern, then using a rechargeable cell is your best option. NiMH is a much better chemistry than NiCd, for both rated capacity and lack of memory effect. While the low capacity of NiCds doesn't prevent their use, the risk of a memory effect is enough to recommend against using NiCds. Be sure to top off the NiMH cells the night before a launch.

An near spacecraft can be stored at the launch site the night before a launch. However, the flight battery should be stored indoors where it stays warmer. Leaving them out all night where they chill lowers their capacity before the launch.

4.2. Building Warm Boxes



A battery box *- The battery pack fits tightly inside the taped Styrofoam box and is sealed with a lid of polystyrene plastic and a rubber band.*

The warm box is a Styrofoam box containing temperature sensitive items like the flight cells. The warm box helps keep cells warm during the mission, keeps them within their cell holder during the flight, and prevents cells from shorting out if they make contact with metal. Locate warm boxes near the toasty warm GPS receiver*. This way the battery is stored in a warm location and can easily be loaded into the airframe just before launch.

* The GPS receiver is toasty warm compared to the decidedly chilly –60 degree temperatures outside the near spacecraft.

4.2.1. Materials

- ¾" or ½" Styrofoam sheet
- Hot glue
- One 4 "AA" cell holder
- A nine-volt battery snap
- One pair of Powerpole® connectors
- Uline tape

4.2.2. Construction

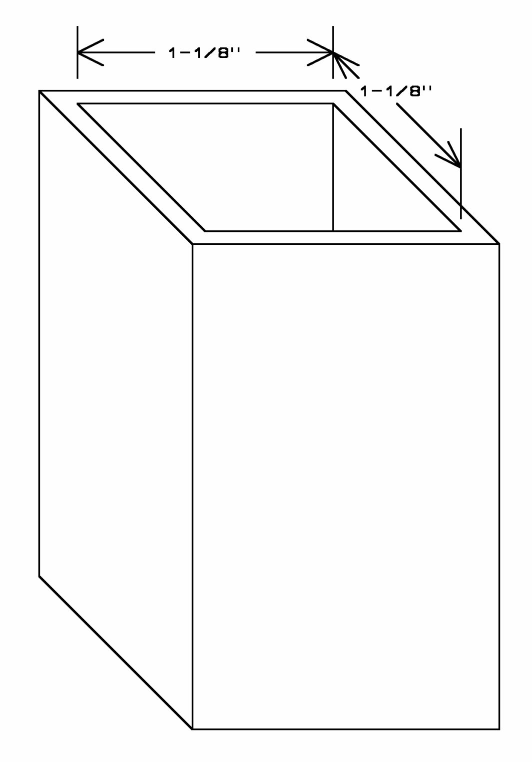
Electrical

- √ Strip 1” of insulation from the bare ends of the nine-volt battery snap.
- √ Double over the bare ends and crimp with Powerpole® crimps.
- √ Insert crimps into the proper colored housings.
- √ Backfill the Powerpole® housings with hot glue.
- √ Slide housings together.

Mechanical

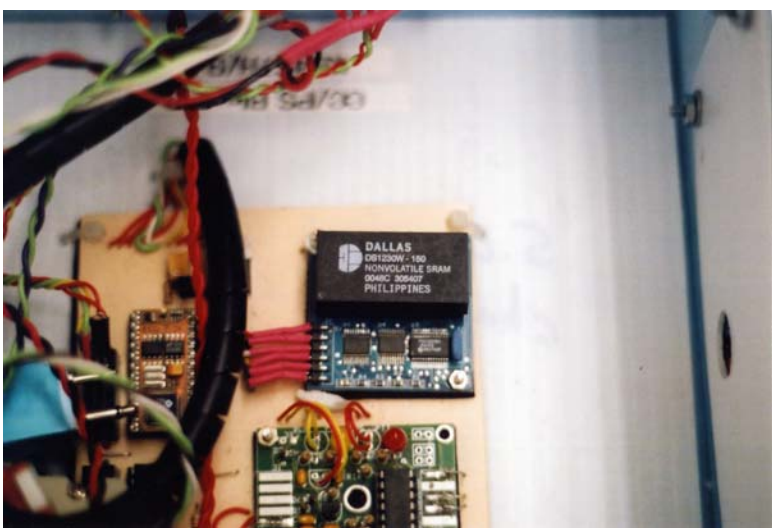
These directions are specifically for the flight cells, but can be modified for HTs and other temperature-sensitive devices.

- √ Snap nine-volt battery snap onto the 4 “AA” cell holder.
- √ Load a set of cells into a 4 “AA” cell holder.
- √ Measure the dimension of the cell holder and cells.
- √ Cut four sides and a bottom from Styrofoam to size so that a tight fitting box can be built
- √ to house the cell holder and cells. Note: Trim the Styrofoam a little larger than necessary as the box is trimmed to the proper size after construction.
- √ Glue the Styrofoam sides into a box form with hot glue. Note: Built the warm box around the battery holder to get to a tight fit.
- √ Flatten the bottom of the warm box with a sharp Exacto knife or Exacto saw.
- √ Glue the base to the warm box.
- √ Smooth the cut edges and sides with a sander.
- √ Place the battery holder back into the warm box and trim the warm box to be flush with
- √ the top of the battery holder.
- √ Cut any necessary notches into the top of the warm box to pass the battery cable.
- √ Cover the warm box in Uline tape (this just makes it look better).
- √ Cut another piece of Styrofoam to cover the top of the warm box. Note: Often I used a 0.04” thick sheet of polystyrene in place of foam.
- √ Cover the top in Uline tape.
- √ Optional: Make a label for the warm box indicating what item is inside.
- √ After the battery holder (or other temperature-sensitive device) is installed inside the warm box, rubber band the cover over the top



AA Cell Battery Box *– These are inside dimensions. The outside dimensions depend on the thickness of the Styrofoam, which can be sanded down.*

5.0 Data Flight Recorder



Flight Data Recorder *(FDR) – The completed FDR shown inside the near space capsule.*

Transmitting data (telemetry) to ground stations allows ground crews to "see" the data collected during the mission. This telemetry must be recorded in a log file during the flight, so ground crews must begin logging APRS telemetry before lift-off. This is so important that it should be in the mission's checklist. Invariably, some packets are not recorded and therefore logs are never complete. Even if all the telemetry is recorded, it's a major pain to clean up a 50 kB log after a mission by removing the 75% of other people's communications (junk, after you've been cleaning logs for two hours). So instead of transmitting science data to ground stations, record it onboard the near spacecraft instead. Now science data is recorded in the format you design, making it easier to load into a spreadsheet. And best of all, the data is just your data, not the position reports of every vehicle in the Recovery Crew.

5.1. Theory of Operation

The company Solutions Cubed makes a great device for logging data. The RAM Pack B is a microcontroller module designed to accept inputted data and store it on a RAM chip.
At the start of a mission, the flight computer puts the RAM Pack B into FIFO mode. FIFO (first in, first out) mode allows the flight computer to send data to the RAM Pack B without having to keep track of the current address. Once the RAM Pack B is in FIFO mode, the flight computer sends it telemetry data sequentially one byte at a time. After the mission, a program to read the data from the RAM Pack B is downloaded into the flight computer. An adapter cable plugs into the P3 of the near spacecraft and the data is read into an open file under the control of a terminal program. The file is saved as a text file. Minor modifications are made to the text before the file is imported into a spreadsheet for further processing. This process takes a fraction of the time required to clean up an APRS log. It really is a slick process.

5.1.1. Materials

For the Data Logger:

- DS1230W – 150 32kX8 nonvolatile RAM (NVRAM)*
- A RAM Pack B from Solutions Cubed (come with 8kX8 RAM)
- Six #24 AWG stranded wires. Use different colors, with at least one red and black.
- 12 pieces of 1/8" heat shrink tubing, cut 3/8" long
- One or two thin nylon wire ties or
- One or two pieces of 3/8" diameter heat shrink tubing, cut ½" long
- Depending how you made your I/O ports, either
- Double row male header, cut five pins long (10 pins total)
  Or
- Crimp pins and plastic housings

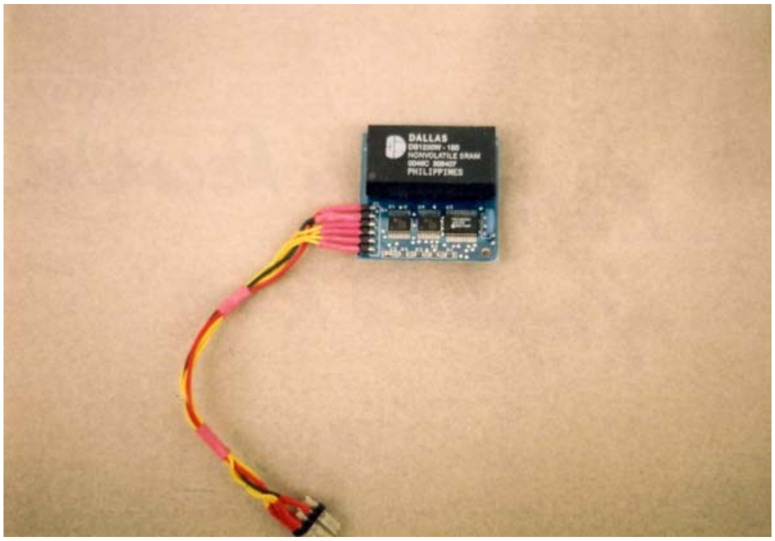
For the Download Cable:

- 9-Position Male, D-Subminiature Connector RS# 276-1537C
- 9-Position Female, D-Subminiature Connector RS# 276-1538C
- Two #24 AWG stranded wire (black and white)
- 1/8" heat shrink tubing
- D-Subminiature Connector Hood RS# 276-1539D
- Hot Glue
- Three Resistor leads
- Two Labels marked Downloading
- Clear heat shrink tubing to fit assembled hood

*Available from Dallas Semiconductor. Order it as a free sample.

5.1.2. Procedure

Switching RAM Chips



Flight Data Recorder with Replaced RAM *- The RAM Pack B with a NVRAM makes the ideal data recorder. A lot of science data can be recorded in 32 Kbytes.*

The RAM Pack B arrives with an 8kX8 bytes volatile RAM. Note that the X8 refers to the fact that each byte is eight bits wide, which is the standard for the BASIC Stamp. Unfortunately the standard RAM does not meet our needs. First, we need a NVRAM (non-volatile RAM) so that data isn't lost when main power is shut down. Second, 8 kB of RAM is too limited for a near space mission. It's better to have too much memory than too little.

The RAM chip is switched out for a NVRAM, following the advice of the RAM Pack manual. To get the replacement chip, obtain a DS1230W – 150 nonvolatile RAM from Dallas Semiconductor. Carefully remove the old chip and insert the new one in its place. You may need to use a lead straightener on the NVRAM chip first.

Cabling RAM Pack B

The RAM Pack B comes with a six pin male header. The pins functions are:

Pin Name	Function
MODE	Switches between FIFO and addressable modes
READ/WRITE	Determines if the nodule should read or write data
FM	Data is sent to the module on this pin
TM	Data is sent from the module on this pin
GND	Signal and power ground
Vcc	+5V

To interface the module, wires are soldered to the RAM Pack's I/O pins. The other ends of these wires are soldered to a connector for the flight computer's I/O port.

√ Strip ¼" of insulation from both ends of all six wires.
√ Quickly tin the headers on the RAM Pack and the short ends of the double row male
√ headers.
√ Put two pieces of heat shrink tubing on each wire.
√ Keep the heat shrink tubing near the center of the wires.
√ Solder one end of each wire to the RAMPack header, the red connects to the Vcc pin and the black connects to the GND pin. The other colors are your choice.
√ If you're using heat shrink tubing for bundling the cable, slide it on now.

Depending how you made your I/O ports, either:

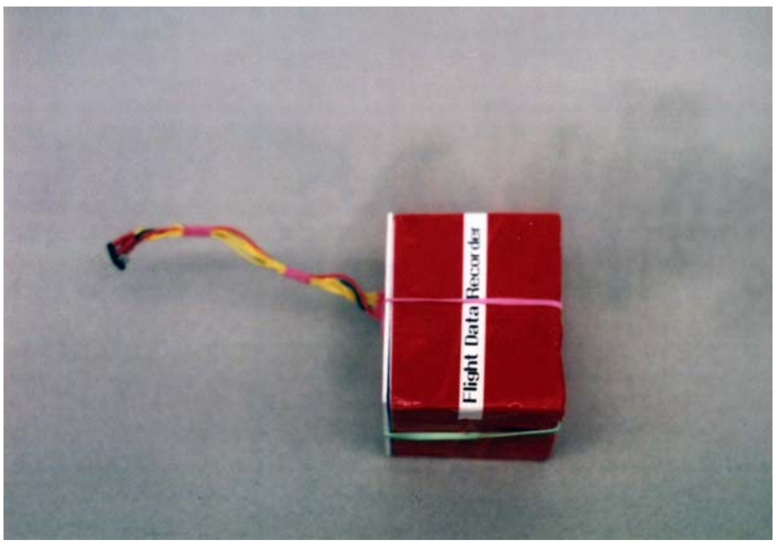
- √ Solder the FM and TM wires to the I/O pins of the double row male headers.
- √ Solder the Mode wire to the CLK pin of the double male header.
- √ Solder the Read/Write wire to the DATA pin of the double row male header.
- √ Slide the heat shrink tubes over the soldered connections and shrink them down.

Or:

- √ Crimp a header pin on the FM and TM wires and slide them into sockets for the I/O pins of the I/O port.
- √ Crimp a header pin on the Mode wire and slide into a socket for the CLK pin of the I/O port.
- √ Crimp a header pin on the Read/Write wire and slide into a socket for the DATA pin of the I/O port.

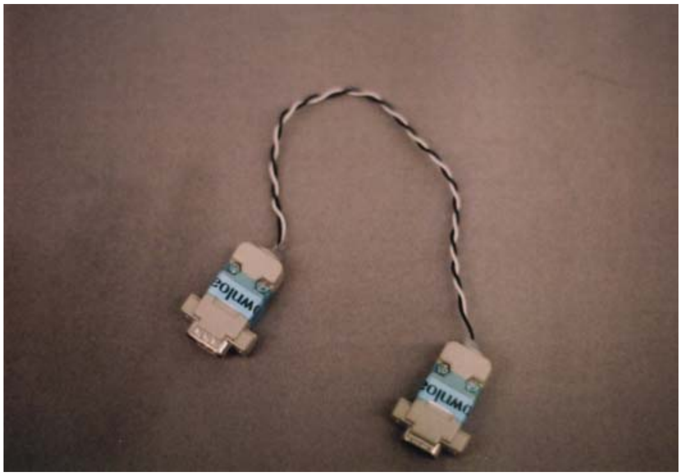
- √ Shrink the bundling heat shrink tubing, tie on the nylon ties to bundle the cable.

I recommend making a warm box for the RAMPack at this point. Cover it with red Uline tape and label it as Flight Data Recorder, so it will stand out inside the near spacecraft.



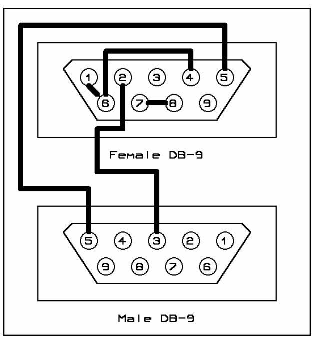
Flight Data Recorder *- The enclosed flight data recorder (black box). Make it a bright color so it stands out in the debris field left by your near spacecraft!!*

Making Download Cable



Download Cable

After each mission, data onboard the near spacecraft is recovered from the flight data recorder. First the flight data read program is downloaded into the BASIC Stamp. Then a download cable connects the flight computer (through the program jack) to a PC running the Windows Terminal program.



Schematic of Download Cable *– Note: Pins 1, 4, & 6 of the female DB-9 are connected together.*

- √ Cut ½” lengths of heat shrink tubing and slide onto wires, keeping them in the center and away from the heat of the soldering iron.
- √ Cut ½” lengths of clear heat shrink tubing.
- √ Slide on large clear heat shrink bands over all wires.
- √ Make the following solder connections:
  Black wire to pin 5 on both connectors.
  White wire to pin 2 on female connector and pin 3 on male connector.
  On female, use resistor leads to connect the following pins:
  7 to 8, solder both ends of wire.
  1….6, solder only pin 6.
  1…4, solder only pin 4.
  Solder pin 1.
- √ Check carefully that no short circuits were created.
- √ Slide heat shrink tubing over wires in the solder cups and shrink.
- √ Cover ends in hot glue.
- √ Squirt in a layer of hot glue into base of hood.
- √ Place connector in (won’t need the attaching screws.)
- √ Finish gluing and close top.
- √ Bolt hood together.

√ Back-fill the opening.
√ Twist wires in cable.

5.1.3. Software

The following three program listings are required to use the RAM Pack B as a Flight Data Recorder (FDR, the near space black box). The first program is loaded into the flight computer before a mission and overwrites data before a mission. The second program is a part of the flight code. First it prepares the RAM Pack for FIFO mode so that data can be stored. Then the program stores important flight (GPS altitude, time, and velocities) and science data (particular to the mission) to the RAM Pack during this mission. The last program is downloaded to the flight computer to read the data in the RAM Pack and send it to an opened file under the terminal program. There's no reason each of these routines can't be stored in their own program slots and run at the appropriate times. I developed this software from the App Notes that Solutions Cubed sent with the RAM Pack B.

Clearing out the RAM Pack B before a Mission

The following program clears out memory in the RAM Pack B. Every memory location is overwritten with a ***#.*** When downloading the data from the data flight recorder, RAM Read program looks for a ***#*** to determine the end of the flight data.

```
'************************
'*     Setup RAMPack    *
'* Write # In FIFO Mode *
'************************
mode          con  13
rw            con  14
fm            con  15
tm            con  15
addr          var  word
n1200         con  2063    '1200 baud n81

input 15
output 14

debug "Setting Up RAM Pack", cr
SetRAMP:
high fm
high rw
high mode                  'not in fifo mode
pause 3000
serout fm,n1200,[$55,$04]  'set baud rate for fifo
pause 1000
serout fm,n1200,[$55,$03]  'use expanded memory
pause 100

debug "Overwriting RAM Pack", cr
low rw                     'put into fifo write mode
low mode                   'put into fifo mode
for addr = 0 to 32767
serout fm,n1200,["#"]      'overwrite all memory locations
next

debug "Finished Overwriting RAM Pack", cr
end
```

Storing Data during a Mission

A data record to be stored in the Flight Data Recorder is built up in the BS2p's SPRAM. At the end of a mission cycle, the data record is read from SPRAM and loaded into the Flight Data Recorder. In the BS2p the SPRAM is 128 bytes in size. During a mission, GPS sentences are stored in the first 65 bytes of SPRAM. Since the last byte of SPRAM can't be used, there are only 62 bytes free for a data record. I recommend storing a data record into SPRAM, starting with the last available byte and working forward. After an entire data record is created and stored, the data record is read into the Flight Data Recorder (FDR). Afterwards the cycle begins all over again, and a new data record is created.

The following BS2p routines prepare records in SPRAM and load them into the FDR.

The first routine puts the RAM Pack B into FIFO mode. This routine is performed at the start up of the capsule.

```
'****************************
'*      Set Up RAMPack      *
'****************************
RAMPack:
high fm
high rw
high mode                    'not in fifo mode
pause 3000
serout fm,n1200,[$55,$04]    'set baud rate for fifo
pause 1000
serout fm,n1200,[$55,$03]    'use expanded ram
pause 100
low rw                       'put into fifo write mode
low mode                     'put into fifo mode
return
```

The first record to be loaded into SPRAM for eventual downloading into the RAM Pack B is the data rep, or the number of the data record to be stored.

```
'****************************
'*  Put DataRep Into SPRAM  *
'****************************
SaveDataRep:
Workspace = DataRep
Digitbyte = WorkSpace/100
Digitbyte = Digitbyte + $30
put 125,Digitbyte
Digitbyte = Digitbyte - $30
WorkSpace = WorkSpace - (Digitbyte*100)
DigitByte = WorkSpace/10
Digitbyte = Digitbyte + $30
put 124,Digitbyte
Digitbyte = Digitbyte - $30
DigitByte = WorkSpace - (DigitByte * 10)
Digitbyte = Digitbyte + $30
put 123,DigitByte
put 122,","
return
```

GPS data is then loaded into SPRAM with this routine.

```
'****************************
'*    Get GPGGA Sentence    *
'****************************
GPGGA:
```

```
serin gps_rx,I4800,10000,NoGPS,[wait ("GGA"),spstr 56]

UTCgga:
for gpsloop = 3 to 6
get gpsloop,gpschar
'SPRAMAddr = 122 - gpsloop
SPRAMAddr = 124 - gpsloop
put SPRAMAddr,gpschar
next
put 117,","                  'SPRAMAddr = 117


ALTITUDE:
for gpsloop = 42 to 46
get gpsloop,gpschar
SPRAMAddr = 158 - gpsloop
put SPRAMAddr,gpschar
next
put 111,","                  'SPRAMAddr = 111

'****************************
'*    Get PGRMV Sentence    *
'****************************
PGRMV:
for gpsloop = 1 to 20
put gpsloop,"X"
next

serin gps_rx,I4800,10000,NoGPS,[wait ("RMV"),spstr 20]

RMV:
for gpsloop = 1 to 20              '$pgrmv varies in length
get gpsloop,gpschar
if gpschar = "*" then EndRMV
SPRAMAddr = 111 - gpsloop
put SPRAMAddr,gpschar
next
EndRMV:
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,","                  'SPRAMAddr = end of pgrmv
goto EndGPS
```

Every time science data is collected, it is stored into SPRAM with the following routine. In this routine, the value of the data to be stored is saved in the variable, Exp_Value. The number of digits in the data is stored in the variable n

```
n = 4
WorkSpace = Exp_Value
gosub SaveData
```

The routine to save the data uses the following code.

```
'****************************
'*  Convert Data Into Bytes *
'****************************
SaveData:

if n < 5 then N4
N5:
digitbyte = workspace/10000
workspace = workspace - (digitbyte*10000)
```

```
digitbyte = digitbyte + $30
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,digitbyte
n = 4

N4:
if n < 4 then N3
digitbyte = workspace/1000
workspace = workspace - (digitbyte*1000)
digitbyte = digitbyte + $30
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,digitbyte
n = 3

N3:
if n < 3 then N2
digitbyte = workspace/100
workspace = workspace - (digitbyte*100)
digitbyte = digitbyte + $30
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,digitbyte
n = 2

N2:
if n = 1 then N1
digitbyte = workspace/10
workspace = workspace - (digitbyte*10)
digitbyte = digitbyte + $30
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,digitbyte

N1:
digitbyte = workspace + $30
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,digitbyte
SPRAMAddr = SPRAMAddr - 1
put SPRAMAddr,","
return
```

At the end of a flight cycle, the following routine is called to copy the data record currently in SPRAM to the FDR.

```
'****************************
'*   Send Data To RAM Pack  *
'****************************
TellRAMP:
SPRAMAddr = 125
LoopRAMP:
get SPRAMAddr,digitbyte
serout fm,n1200,[digitbyte]
SPRAMAddr = SPRAMAddr - 1
if SPRAMAddr < 20 then EndTellRAMP
if digitbyte = "*" then EndTellRAMP
goto LoopRAMP
EndTellRAMP:
return
```

Notice that for the data rep and GPS data, the BS2p keeps track of the SPRAM address currently open. These routines are fixed and never change from mission to mission. However, the experiments flown on each mission does change. So the SaveData routine takes full advantage of the FIFO capabilities of the RAM Pack B.

Downloading Data after a Mission

After recovery, download the following program into the flight computer and then switch off the capsule.

```
'**********************
'* Read RAM Pack Data *
'**********************

value    var byte
addr     var word
highaddr var addr.highbyte
lowaddr  var addr.lowbyte
n1200    con 2063
b1200i   con 18447
mode     con 13
rw       con 14
fm       con 15
tm       con 15

Begin:
input 15
output 14
pause 5000

high fm                            'read in non-fifo mode
high mode                          'get out of fifo mode
pause 2
high rw                            'not in write fifo mode

'serout fm,n1200,[$55,$04]
'pause 100
serout fm,n1200,[$55,$03]
pause 100
serout fm,n1200,[$55,$05,$00,$00]  'reset pointer
serout 16,b1200i,["start", cr,10]
'debug "Start", cr
pause 2000
GetData:
if Addr = 32767 then EOF
serout fm,n1200,[$55,$01,highaddr,lowaddr]
serin tm,n1200,[value]
serout 16,b1200i,[value]
'debug value
Addr = Addr + 1
if value = "*" then EOR
if value = "#" then EOF
goto GetData
EOR:
serout 16,b1200i,[cr,10]
'debug CR
goto GetData

EOF:
high mode
end
```

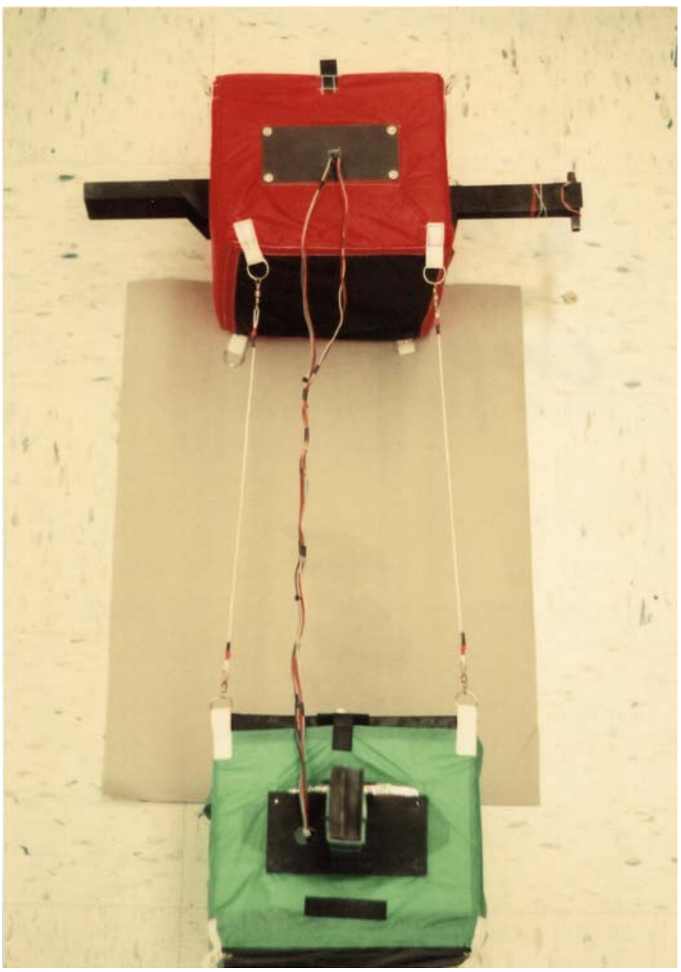
After connecting the capsule to the PC with the downloading cable, start the Windows terminal program (HyperTerminal) and give it the following settings:

N81
1200 baud

Save these settings and create an icon for the HyperTerminal.

Start HyperTerminal and open a download file. Next power up the capsule and watch the data get sent to the HyperTerminal. After the data is downloaded, close the download file, save the file under a meaningful name (one related to the flight designation), and close HyperTerminal. Start Notepad and open the download file. Edit any fields requiring changes. There are three changes I recommend. The first is to fix the altitude field for very low altitudes. The second is to add commas in the time field to separate hours, minutes, and seconds, and the third is to add commas in the latitude and longitude fields to separate degrees from minutes. After saving the modified file it is ready to import the data log into a spreadsheet as a comma delimited file.

6.0 Module Umbilical



Module Umbilical *– The umbilical cable typically consists of cables for servos and data.*

To meet the simple weight requirements of FAR 101, there may be missions when experiments controlled by the flight computer are mounted to the other module. When this is necessary, an umbilical must connect the flight computer on the first module to the experiments on the second module. The umbilical typically consists of cables for servos and data.

Materials

- #24 AWG stranded wire
- Male headers, 0.1” between centers
- Crimp pins
- Crimp housings
- Crimper
- Several diameters of thin heat shrink tubing
- Hot glue

Procedure

This procedure describes the construction of cables that make up an umbilical. A cable is constructed for each experiment mounted to a module not containing the flight computer. Make a couple sets of cables and set them aside for later use. By far, most cables are either two- or three-wire cables. Two wire cables are used for power or signals and three wire cables are used on servo connections.

Cables

√ Cut two or three lengths of #24 AWG wire to a length of four feet. * Note: Make the wire colors red for power, black for ground, and white for signal.
√ Cut several one-inch long pieces of thin heat shrink tubing with a diameter large enough to slide over all the wires in the cable.
√ Slide the tubing evenly over the wires, but several inches from the end, and shrink them to keep the wires in a neat bundle.
√ Strip ¼” of insulation from the ends of the wires on one end of the cable.
√ Crimp pins on the wires and solder.
√ Cut a crimp housing wide enough for the wires in the cable and trim the cut edges.
√ Insert the crimped wires into the housing. Note: Watch the order of the wires in the cable.
√ Cut a length of 0.1” male headers three pins wide.
√ Slide one-inch lengths of thin heat shrink tubing over the open ends of the wires.
√ Strip ¼” of insulation from each of the wires in the open ends of the three wires.
√ Twist and tin the ends of the exposed wires.
√ Tin the short side of the pins in the male header.
√ Solder the wires to the headers. Note: Watch the correct placement of the wires in the cable.
√ Slide the heat shrink tubing over the soldered connections and shrink.
√ Apply a small amount of hot glue between the pins on the male header.
√ Slide a two-inch length of heat shrink tubing over the open ends of the wires.
√ Position and shrink the tubing so that the long end of the pins are exposed but the soldered short end of the pins is not.

* Depending on the length of the link lines, the lengths of the wires will change. Each wire must connect one end to the flight computer and the other end near the umbilical opening of the second module. My experience is that four feet is long enough to do this. In all cases, make sure the cables are long enough that the link lines are under tension, and the cables are not.

Alternative Cables

An alternative to the above procedures is to make an umbilical from ribbon cables. I cannot stand working with ribbon cable because of the fineness of the wires in it. Perhaps you will have better luck that me.

6.1. Directions for Use

6.1.1. Materials Needed to Incorporate an Umbilical

- Duct tape
- Twister seals
- Masking tape

6.1.2. Procedure

Preplanning

√ Determine which modules are to contain the flight computer and experiments.
√ Determine an orientation for the modules, that is, determine which faces of the modules line up with each other.
√ Note: Take into account the position of experiments and Quad panels with openings to pass cables through.

In the Primary Module

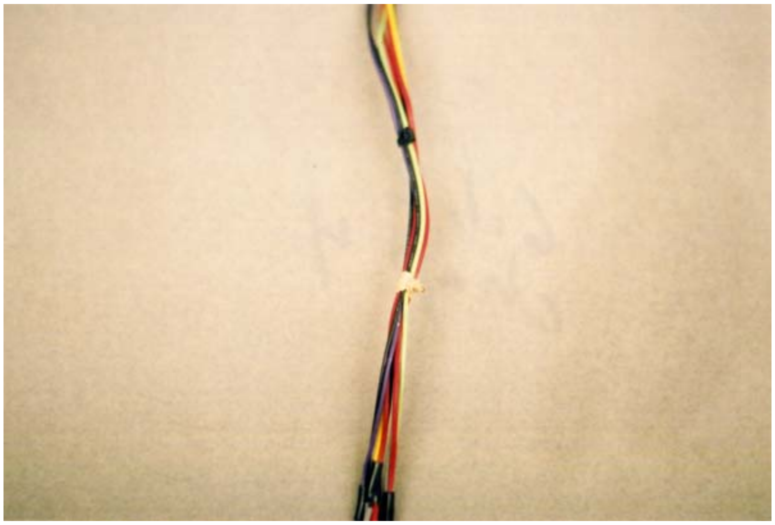
√ Connect the necessary cables to the flight computer.
√ Extend the cables through the opening in the proper Quad panel. Note: Select a Quad panel where the cable(s) will not interfere with the mission, like get in the way of a camera.
√ Label the function of each cable with a small piece of masking tape near the open end of the cable.
√ Consolidate the cables into a single umbilical with twister seals. Note: Apply twister seals about every six inches, with each twister seal bundling every cable into a single umbilical.

In The Secondary Module

√ Label the free end of each experiment cable with a piece of masking tape.
√ Extend all cables from experiments in the secondary module through an opening in the proper Quad panel.
√ Combine the cables into a single umbilical with a twister seal after the cable exits the airframe.

During Capsule Closeout (at the launch site)

√ Link the modules of the capsule together with link lines.
√ Connect like-labeled cables in the umbilical together.
√ Separate modules to verify that the umbilical is long enough.
√ Remove masking tape labels.
√ Apply a small strip of duct tape around each connected cable housing.
√ Twist tie the umbilical together around the connections.



The taped umbilical cable.

Good to Know

The Global Positioning System

Got GPS? *Once the near spacecraft is recovered, everyone brings out their GPS receiver.*

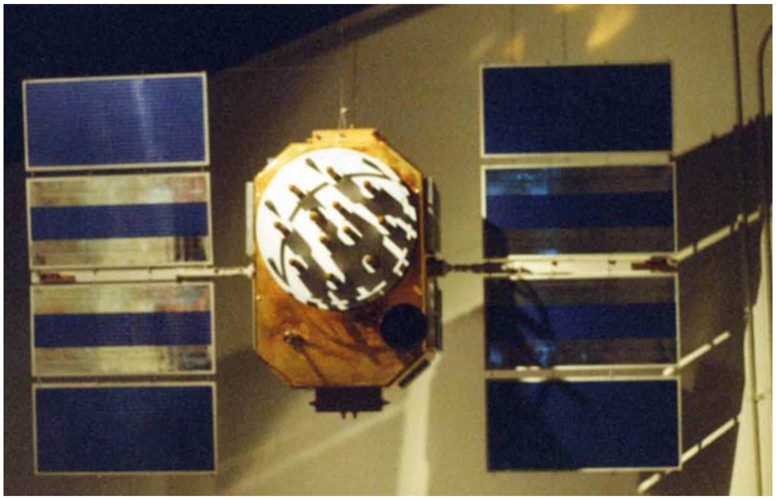
How the GPS Works

One of the most important components on board the near space capsule is the GPS receiver. Without it, it is difficult to both locate the capsule and analyze the returned science. While you can achieve successful results without understanding the GPS receiver, you will be even more successful with an understanding of it.

There are three parts (called segments) making up the GPS system: a space segment made up of satellites, a control segment made up of ground stations that monitor and update the satellites, and a user segment made up of all the GPS receivers currently in use. We are users of the third segment and depend on the proper functioning and the accuracy of the space control and ground segments.

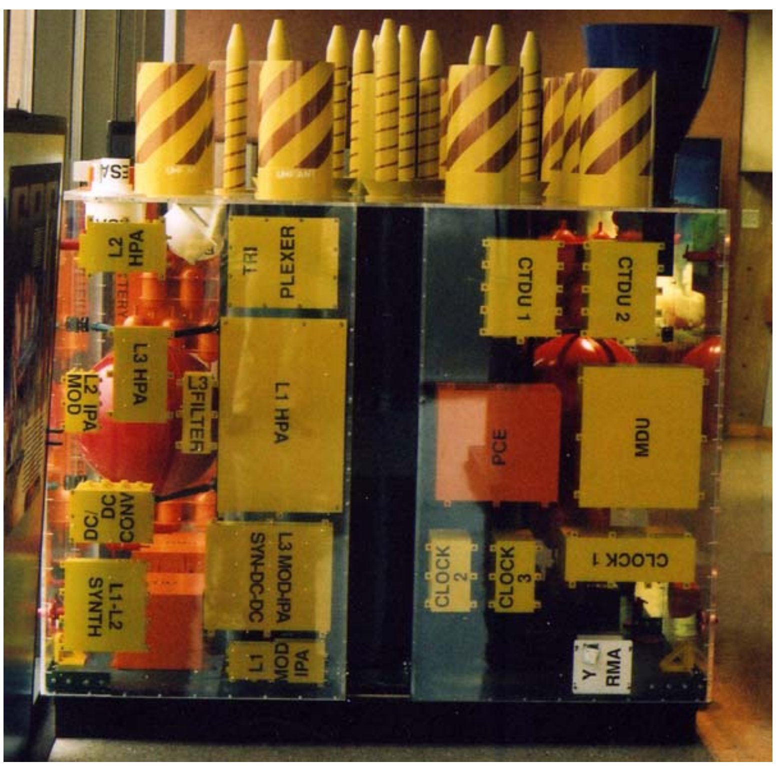
The Space Segment

The NAVSTAR (NAVigation, Satellite Timing And Ranging) satellites are a constellation of 24 satellites orbiting the Earth in twelve-hour orbits at an altitude of 13,000 statute miles.



Cool Satellite – *A Navstar satellite on display in a museum. This is the space element of the GPS system.*

Four satellites evenly occupy each of the six orbits of the constellation. Each orbit is inclined 55 degrees to Earth's equator and equally spaced out. In this way, there is always more than the minimum of four visible satellites needed by a GPS receiver to determine an accurate position.



Interior of Transparent GPS Satellite – *Almost 6 feet tall. From the Space History Museum in Alamogordo, New Mexico.*

Each satellite contains a synchronized atomic clock and transmits data to both the user and the ground control segments. The user segment receives two separate channels, L1 and L2, of navigation data.

L1 (1575.42 MHz)

The L1 channel broadcasts C/A Code, P Code, and NAV messages.

L2 (1227.60 MHz)
The L2 channel broadcasts P Code (no C/A Code) and NAV messages.

C/A Code
(Course/Acquisition Code) consists of a short series of pseudorandom bits. C/A Code does not provide the accuracy that P Code does and is the only code that civilian GPS receivers receive. Being pseudorandom, the C/A code for each NAVSTAR is unique. A unique pseudorandom code from each satellite is necessary for identification, as all NAVSTAR satellites transmit on the same frequency using CDMA (Code Division, Multiple Access). The unique pseudorandom code prevents NAVSTARs from jamming one another so a GPS receiver can determine which NAVSTARs are heard. C/A Code is amazingly accurate. With Selective Availability (SA) turned off, your GPS receiver determines a position within less than 100 feet most of the time. Watch the amount a stationary GPS position jumps around to see this accuracy. If someday you suddenly notice a drop in accuracy, then there is probably trouble some place in the world.
The alternative to using pseudorandom codes on the same frequency is to do what Glonass (the Russian version of GPS) does. Satellites in the Glonass system transmit on one of 25 separate frequencies, instead of all sharing the same frequency. This use of separate frequencies by FDMA (Frequency Division Multiple Access) adds to the complexity of the Glonass User Segment.

P Code
P Code is Precise Code and consists of a very long series of pseudorandom bits that is modulated at a higher frequency than C/A Code. The P Code is encrypted, making it available to only military GPS receivers.

NAV Messages
NAV Messages are broadcast over both channels (by modulating the C/A and P Codes at 50 bits per second) and contains the following information:

System Time (from atomic clocks)
Corrections to the clock
Data on how the ionosphere delays L1 and L2 channels from the NAVSTAR
Satellite ephemeris (describes the orbits of the NAVSTARs)
NAVSTAR health (who’s working and who’s not)

The Control Segment
The Control Segment maintains the health and accuracy of the NAVSTAR constellation. Several monitoring stations spread over the world and under the centralized control of the Master Control Station in Colorado Springs, Colorado makes up the Control Segment. In addition to transmitting L1 and L2 channels to the User Segment, each NAVSTAR satellite also transmits its clock time and ephemeris to monitoring stations in the Control Segment. The Master Control Station computes corrections for each satellite and has those corrections sent back up to each NAVSTAR. Updates are necessary as atomic clocks and satellite orbits drift. Some health and status reports of NAVSTARs can be heard over the WWV radio station, the Atomic Clock broadcaster in Boulder, Colorado.

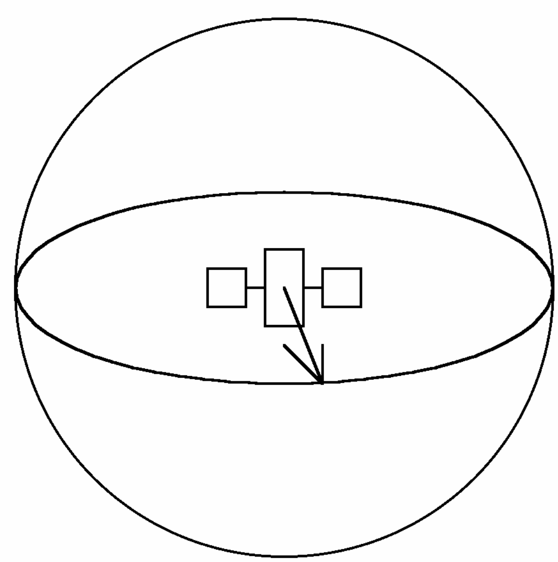
The User Segment
Once our GPS receiver identifies the C/A Code for each satellite it can hear, it retrieves the following information from the NAV data:
System Time
Clock Corrections

Propagation Delays
Satellite (Vehicle) Ephemeris
Satellite Health

Determining a three-dimensional fix requires the GPS receiver to lock onto four satellites. Locking on a satellite means the GPS receiver claims it has identified a satellite (by its C/A Code) and understands the satellite's transmissions. The two factors impacting a receiver's ability to lock in a satellite are how close the satellite is to the horizon and the obstacles on the ground blocking its transmissions. While in near space there are no obstacles blocking satellite transmissions, a low satellite is still a problem. The antenna of a GPS receiver is designed to give very good coverage over most of the sky, with antenna gain dropping off only near the horizon (recall that the horizon is depressed in near space, giving the near spacecraft a larger sky to see NAVSTARs).

A good way to visualize how a GPS receiver determines its position is to picture what kinds of positions can be determined with one, two, three, and four satellites. But first, remember that light travels at a known and (ideally) fixed speed. The further the GPS receiver is from a NAVSTAR satellite, the greater the difference between the GPS receiver's clock time and the satellite's clock time.

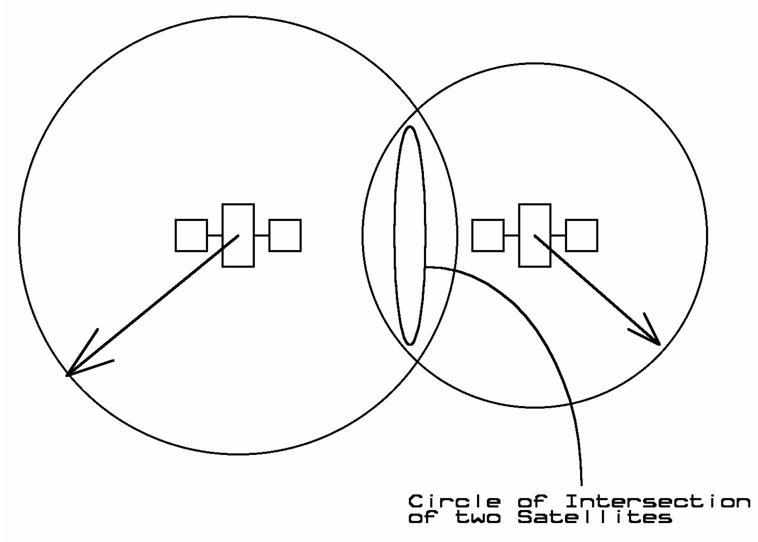
One Satellite Case



One satellite diagram *– If you know your distance from one satellite, then you are located somewhere on the surface of this sphere.*

Assuming the GPS receiver's clock time is accurate, when a GPS receiver knows its distance from a single satellite, then the GPS receiver knows it is located somewhere on a sphere with a radius of that known distance, centered on the satellite. Note however that a GPS receiver does not know the precise time with only one NAVSTAR: it requires several NAVSTARs to determine the time accurately. So the one satellite solution is just a thought experiment.

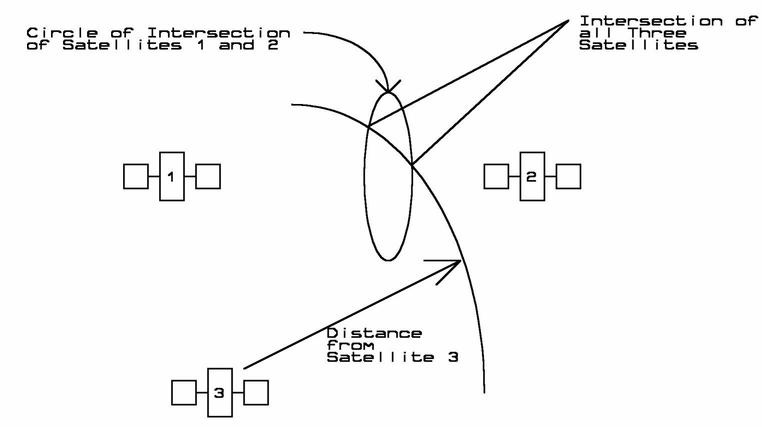
Two Satellite Case



Two Satellite Diagram *– If you know your distance from two satellites, then you are located somewhere on the circle of the intersection of the two spheres.*

Since the intersection of two spheres creates a circle, knowing its distance from two satellites lets the GPS receiver determine its position along a ring in space.

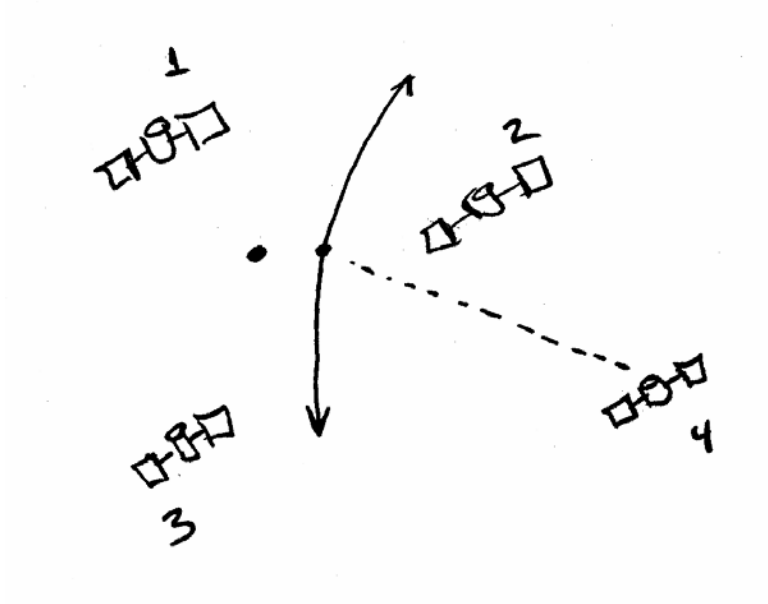
Three Satellite Case



Three Satellite Diagram *– If you know your distance from three satellites, then you are located at one of two points formed by the intersection of the last example's circle and the sphere from Satellite #3.*

The intersection between a circle (determined by the two satellite case) and a third, new sphere (determined by the third satellite), is two points. Ideally then, when three satellite distances are known, the GPS receiver can determine two possible positions where it could be located. One of the positions will make sense and other one won't (for instance, the Earth would block signals from a GPS receiver located at the second position). Ideally a GPS receiver should be able to determine its altitude in this case. Because of the GPS receiver's uncertainty about the time (brought on by things like propagation delays through the ionosphere) a GPS receiver does not attempt to determine the altitude of the receiver (the GPS only gives a 2-D fix).

Four Satellite Case



Four Satellite Diagram *– When you know your distance from a fourth satellite, one of the points from the three satellite case can be thrown out. In actual use, the distance from a single NAVSTAR cannot be determined without the help of signals from other NAVSTARs.*

With an additional satellite, only one of the two points determined from the first three-satellite case intersects with the sphere around the fourth satellite. In addition, the extra satellite signal lets the GPS receiver determine the system time more accurately, leading to more accurate positions and an altitude determination. Note that the altitude is the least accurately determined position generated by a GPS receiver.

The NMEA Standard and the Two Most Important GPS Sentences for Near Space

GPS receivers output data following standards designed by the National Marine Electronics Association (NMEA). The particular specification followed is designated NMEA-0183. The NMEA-0183 specifications require GPS receivers to transmit data as RS232 (inverted logic) serial at 4800 baud N81. NMEA-0183 has designated several standard sentences, of which the two most important sentences for near space work are the GGA and RMC sentences. Here's an example of these two sentences:

$GPGGA,153919.00,4332.2076,N,11608.6666,W,1,08,1.1,13497.1,M,18.3,M,,*78
$GPRMC,153924.00,A,4332.2317,N,11608.6330,W,24.4, 46.3,231099,16.1,E*7E

Every NMEA-0183 sentence from a GPS receiver begins with $GP. The $ indicates the beginning of a sentence and GP indicates the sentence comes from a GPS receiver. The rest of the first field of each example identifies the type of sentence; in this example, either GGA or RMC.

The next field in both the GGA and RMC sentences is the time is in hours, minutes, and seconds in UTC, which is Coordinated Universal Time determined by the atomic clock and broadcast by WWV in Fort Collins, Colorado. UTC is synchronized with GMT, or Greenwich Mean Time, also called Zulu time, in London, England. A GPS displays a blank field here if it doesn't have a position fix. Indeed the GPS receiver cannot know the time accurately unless it has a position fix. If you see two commas after the sentence type, then the GPS is determining a position at the time the sentence was generated.

In both sentences, the fields following the time in UTC are the latitude in degrees and decimal minutes followed by the longitude in degrees and decimal minutes. A comma separates the latitude and longitude. There is no separation between the degrees and minutes in both the latitude and longitude, but there is a decimal separating the whole minutes from the fractional minutes.

The other fields in these sentences are formatted as follows:

The GPGGA Sentence
$GPGGA, Time in UTC, Latitude North, Longitude West, GPS Quality Indicator, Number of Satellites, DOHP, Altitude in Meters, Geoidal Separation in Meters, Age of Differential Data, Differential Reference Station ID, Checksum.
The terminology in this sentence is explained below.

Where:
$GPGGA is the sentence type.
The time is in hours, minutes, and seconds
Latitude is in degrees and decimal minutes.
Longitude is in degrees and decimal minutes.
GPS Quality Indicator is 0 if the GPS hasn't calculated a position solution, 1 if the GPS has calculated a position solution, and 2 if the GPS is using differential data in its position solution.
The Number of Satellites indicates the number of satellites the GPS has a lock on.
DOHP is the Dilution of Horizontal Position, an indicator of the accuracy of the GPS receiver's position calculation. The closer to 1.0, the better.
Altitude is the GPS antenna's height above an ideally shaped Earth.
Geoidal Separation indicates a mathematical correction to the Earth's shape.
Differential data is left blank unless a differential receiver is sending data to the GPS receiver.
Checksum is a mathematically calculated hexadecimal number describing the total text of the sentence. It is used to detect data errors.

The GPRMC Sentence
$GPRMC, Time in UTC, Latitude North, Longitude West, Speed in Knots, Heading in Degrees, True North, The Date, Magnetic Variation, Checksum

Where:
$GPRMC is the sentence type.
The time is in hours, minutes, and seconds as determined by the Universal Time Clock.
Latitude is in degrees and decimal minutes.
Longitude is in degrees and decimal minutes.
Speed is given in nautical miles per hour (1 knot is equal to 1.2 mph).
The heading is the direction of travel and is not related to the direction the GPS is pointed.
Magnetic Variation is the difference between true north and magnetic north.
Checksum is a mathematically calculated hexadecimal number describing the total text of the sentence. It is used to detect data errors.

Sources for this report:
OnCore User's Guide Version 7.0, Motorola
http://www.trimble.com
JPL's satellite website, http://Leonardo.jpl.nasa.gov/msl/QuickLooks/

Near Space Humor

Eleven Places You Don't Want Your Near Space Capsule To Recover

1. In the exercise yard of the state penitentiary.
2. In front of the White House.
3. On top of the containment building of your local nuclear power plant.
4. On the property of an anti-government militia during their Saturday practices.
5. In the middle of the state's largest lake.
6. In an open railcar of an express train on its way to the other side of the country.
7. In automobile junkyard guarded by the biggest, meanest dog you've ever seen.
8. On the runway of a major airport.
9. In the bottom of the Grand Canyon.
10. On the top of the state’s tallest mountain in the middle of winter.
11. On the north rim of the Grand Canyon, while you’re on the South Rim.

Appendix A – LM2940 Datasheet

National Semiconductor

January 2003

LM2940/LM2940C 1A Low Dropout Regulator

General Description

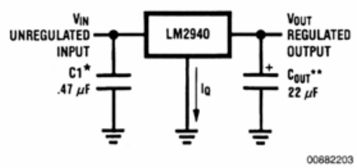
The LM2940/LM2940C positive voltage regulator features the ability to source 1A of output current with a dropout voltage of typically 0.5V and a maximum of 1V over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included which reduces the ground current when the differential between the input voltage and the output voltage exceeds approximately 3V. The quiescent current with 1A of output current and an input-output differential of 5V is therefore only 30 mA. Higher quiescent currents only exist when the regulator is in the dropout mode ($V_{IN} - V_{OUT} \leq 3V$).

Designed also for vehicular applications, the LM2940/LM2940C and all regulated circuitry are protected from reverse battery installations or 2-battery jumps. During line transients, such as load dump when the input voltage can momentarily exceed the specified maximum operating voltage, the regulator will automatically shut down to protect both the internal circuits and the load. The LM2940/LM2940C cannot be harmed by temporary mirror-image insertion. Familiar regulator features such as short circuit and thermal overload protection are also provided.

Features

- Dropout voltage typically 0.5V @I_O = 1A
- Output current in excess of 1A
- Output voltage trimmed before assembly
- Reverse battery protection
- Internal short circuit current limit
- Mirror image insertion protection
- P^+ Product Enhancement tested

Typical Application



*Required if regulator is located far from power supply filter.

**C_{OUT} must be at least 22 µF to maintain stability. May be increased without bound to maintain regulation during transients. Locate as close as possible to the regulator. This capacitor must be rated over the same operating temperature range as the regulator and the ESR is critical; see curve.

Ordering Information

Temperature Range	Output Voltage 5.0	8.0	9.0	10	12	15	Package
0°C ≤ T_J ≤ 125°C	LM2940CT-5.0		LM2940CT-9.0		LM2940CT-12	LM2940CT-15	TO-220
	LM2940CS-5.0		LM2940CS-9.0		LM2940CS-12	LM2940CS-15	TO-263
−40°C ≤ T_J ≤ 125°C	LM2940LD-5.0	LM2940LD-8.0	LM2940LD-9.0	LM2940LD-10	LM2940LD-12	LM2940LD-15	LLP 1k Units Tape and Reel
	LM2940LDX-5.0	LM2940LDX-8.0	LM2940LDX-9.0	LM2940LDX-10	LM2940LDX-12	LM2940LDX-15	LLP 4.5k Units Tape and Reel
−40°C ≤ T_J ≤ 125°C	LM2940T-5.0	LM2940T-8.0	LM2940T-9.0	LM2940T-10	LM2940T-12		TO-220
	LM2940S-5.0	LM2940S-8.0	LM2940S-9.0	LM2940S-10	LM2940S-12		TO-263
−40°C ≤ T_J ≤ 85°C	LM2940IMP-5.0	LM2940IMP-8.0	LM2940IMP-9.0	LM2940IMP-10	LM2940IMP-12	LM2940IMP-15	SOT-223
	LM2940IMPX-5.0	LM2940IMPX-8.0	LM2940IMPX-9.0	LM2940IMPX-10	LM2940IMPX-12	LM2940IMPX-15	SOT-223 in Tape and Reel
SOT-223 Package Marking	L53B	L54B	L0EB	L55B	L56B	L70B	

The physical size of the SOT-223 is too small to contain the full device part number. The package markings indicated are what will appear on the actual device.

 DS008822 www.national.com

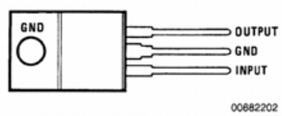
Ordering Information (Continued)

Temperature Range	Output Voltage				Package
	5.0	8.0	12	15	
−55˚C ≤ T_J ≤ 125˚C	LM2940J-5.0/883 5962-8958701EA	LM2940J-8.0/883 5962-9088301QEA	LM2940J-12/883 5962-9088401QEA	LM2940J-15/883 5962-9088501QEA	J16A
	LM2940WG5.0/883 5962-8958701XA				WG16A

For information on military temperature range products, please go to the Mil/Aero Web Site at http://www.national.com/appinfo/milaero/index.html.

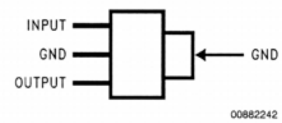
Connection Diagrams

(TO-220) Plastic Package



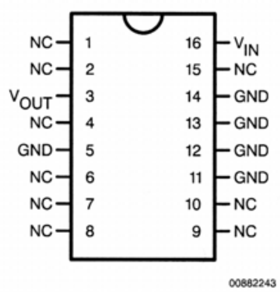
Front View
Order Number LM2940CT-5.0, LM2940CT-9.0, LM2940CT-12, LM2940CT-15, LM2940T-5.0, LM2940T-8.0, LM2940T-9.0, LM2940T-10 or LM2940T-12
See NS Package Number TO3B

3-Lead SOT-223



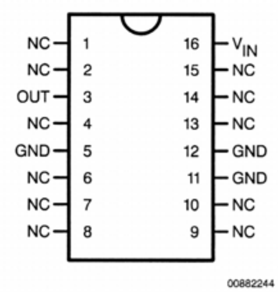
Front View
Order Part Number LM2940IMP-5.0, LM2940IMP-8.0, LM2940IMP-9.0, LM2940IMP-10, LM2940IMP-12 or LM2940IMP-15
See NS Package Number MP04A

16-Lead Dual-in-Line Package (J)



Top View
Order Number LM2940J-5.0/883 (5962-8958701EA), LM2940J-8.0/883 (5962-9088301QEA), LM2940J-12/883 (5962-9088401QEA), LM2940J-15/883 (5962-9088501QEA)
See NS Package Number J16A

16-Lead Ceramic Surface-Mount Package (WG)



Top View
Order Number LM2940WG5.0/883 (5962-8958701XA)
See NS Package Number WG16A

CHAPTER FIVE

Wrap Up And Near Space Qualifying

"The good thing about standards
is there are so many to choose from."
-Mark Caviezel and others

Chapter Objectives

1.0 Avionics Pallet

You can't just throw the Flight Computer along with the flight battery, radio, GPS, and TNC into a Styrofoam box and launch it. All avionics must be mounted securely inside the near space capsule so they are incapable of sliding around, bumping a switch, or pulling on a wire. Since avionics may need to be reorganized, do not permanently mount the avionics to the bottom of the near space capsule. Instead, mount the avionics to an avionics pallet and insert the pallet into the near spacecraft. A lightweight and easy to machine avionics pallet can be made from Coroplast[A] and Styrofoam[B]. For simple beacons and trackers, a single sheet of Coroplast is sufficient. When the avionics pallet incorporates multiple layers of electronics, use Styrofoam to add a third dimension to the pallet.

1.1. The Simple Avionics Pallet

This pallet is designed for mounting the individual PCBs for trackers, beacons, or experiments to a durable, lightweight surface that prevents traces from being shorted out.

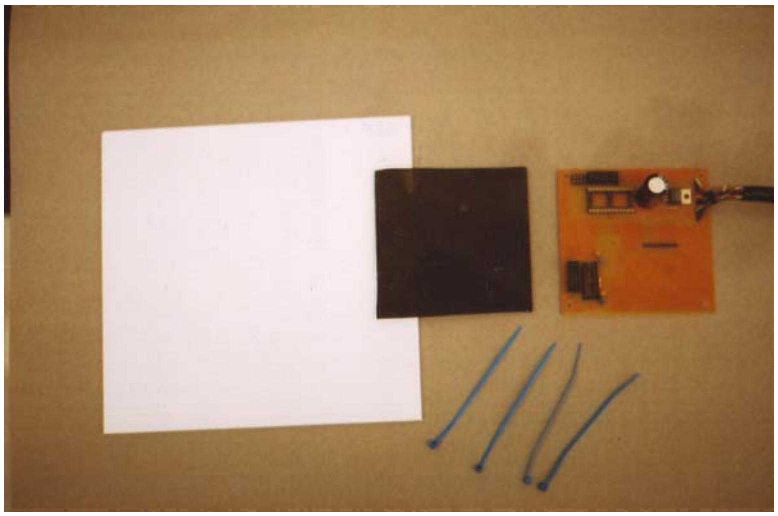
1.1.1. Parts List

- Coroplast Sheet
- Foamed Neoprene Sheet[C]
- Nylon Wire Ties (Zip ties)

1.1.2. Procedure

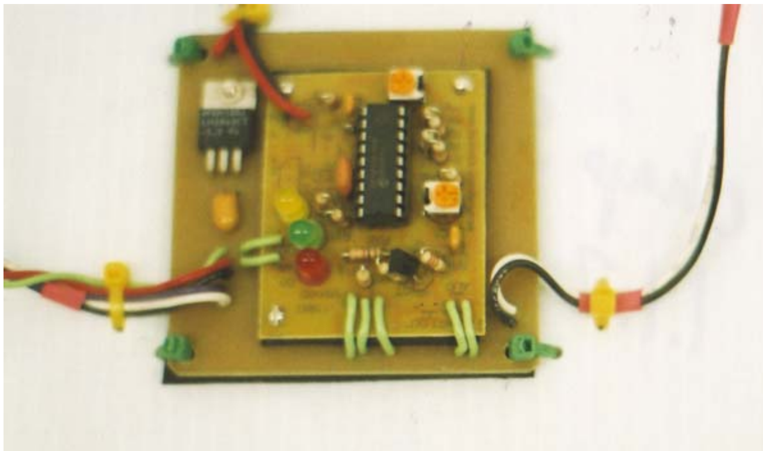
The simple avionics pallet can mount a near space radio beacon to the back of an HT, or an entire flight computer into a near spacecraft. The construction method is identical, only the scale of the project changes. The neoprene foam cushions the PCB and fills gaps between the PCB and the Coroplast pallet. Nylon wire ties secure the PCB and neoprene to a sheet of Coroplast. This arrangement protects the underside of the PCB from shorts while still making it possible to get at the traces to fix a problem.

Note: If the pallet is used to secure a near space beacon to an HT, then cut the Coroplast to fit the back of the HT and mount both the pallet and HT inside of a warm box. The warm box is primarily used to protect the HT buttons from being pushed during a mission. In this design, the beacon pallet can be rubber banded to the back of the HT. See Chapter Four, Section 4.2 for directions on making warm boxes.



Parts for an avionics pallet - *Coroplast, neoprene foam, PCB, and nylon wire ties.*

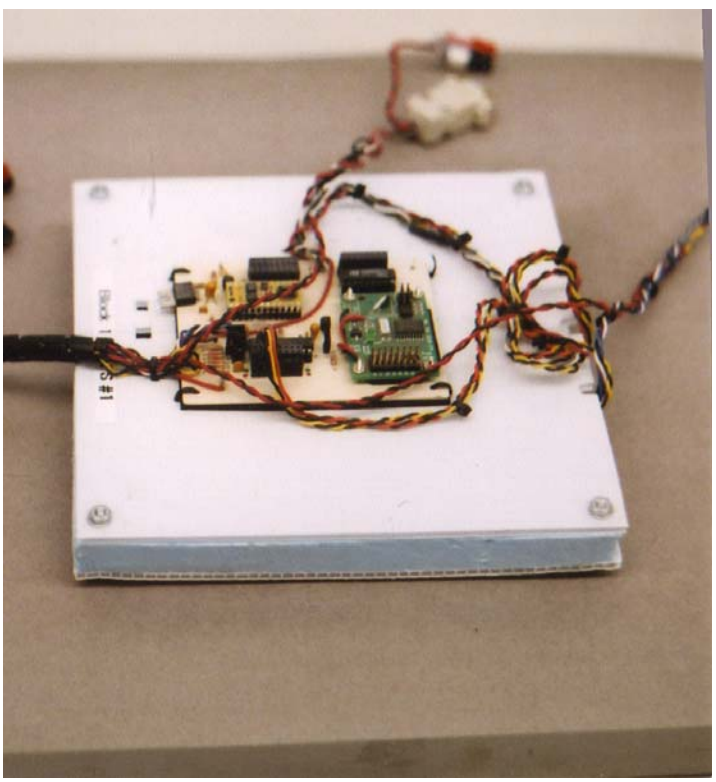
- √ Cut a sheet of Coroplast to fit the airframe.
- √ Lay the foamed neoprene sheet under the PCB.
- √ Mark the size of the PCB and locations of its mounting holes.
- √ Carefully cut and punch holes into the neoprene.
- √ Lay the PCB on top of the Coroplast and mark the location of the mounting holes.
- √ Carefully punch the holes into the Coroplast (the sharp end of a file works well).
- √ Measure ½" away from the Coroplast holes and make a second set of holes that are outside the edges of the PCB.
- √ Lay the PCB and neoprene on top of the Coroplast.
- √ Use nylon wire ties to tie the PCB down to the Coroplast. Orient the zip ties so that their heads are above the Coroplast, and not beneath it.
- √ Lay the cables on the Coroplast and mark the location of holes for nylon wire tie strain reliefs on the Coroplast.
- √ Carefully punch holes in the Coroplast and tie the cables down to the Coroplast as a strain relief.



***PBC on Coroplast** – Zip ties hold the PCB to the Coroplast.*

1.2. The Advanced Avionics Pallet

When adding a larger board to the pallet, it may be advantageous to make the pallet in two layers. A large PCB, like a KPC 3+ TNC, is mounted to the bottom layer and a smaller PCB, like a flight computer, is mounted to the top layer. Make sure the bottom mounted item is a device seldom needing access. Keep frequently accessed boards on the top surface of the pallet.



***Advanced Avionics Pallet** - The completed two-layer avionics pallet.*

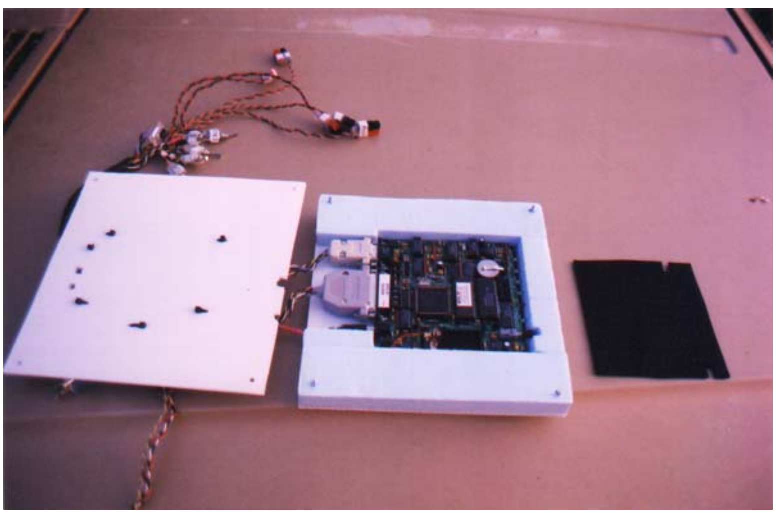
1.2.1. Parts List

Same as a simple Avionics Pallet, plus:

- #6-32 mounting hardware (nuts, bolts, washers)
- Blue or Pink Styrofoam
- Hot glue

1.2.2. Procedure

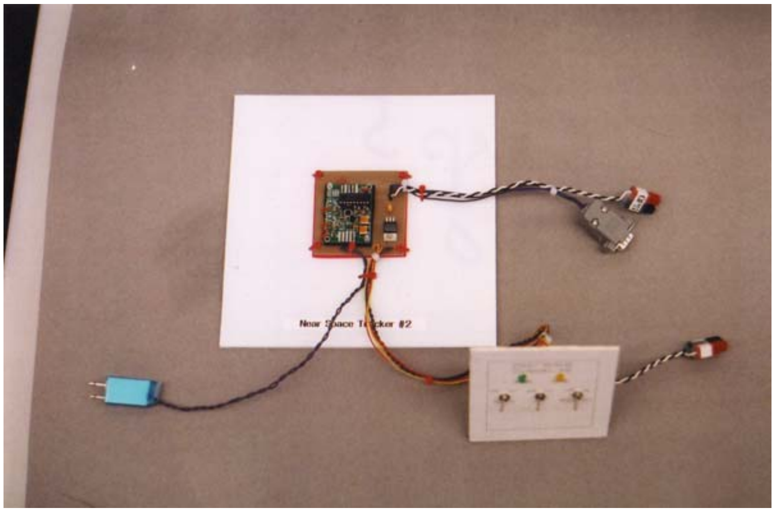
√ Begin by determining which boards will be mounted to the top and bottom layers of the avionics pallet. Be sure to place boards that need infrequent access on the bottom layer.
√ Position and orient boards for the bottom layer.
√ Cut Styrofoam to form a wall around the border of the bottom layer. Note: make the border thick enough that #6 mounting hardware can pass through it and high enough to raise the top layer above the board.
√ Use hot glue to adhere the Styrofoam wall to the bottom layer of Coroplast.
√ Place the top Coroplast layer on top of the bottom layer and drill holes for the #6 bolts.
√ Bolt the top of the pallet to the bottom to test the fit (use washers under the bolt head and nut).
√ Separate the two layers if they fit properly.



***Completed pallet** - The two layer avionics pallet, opened.*

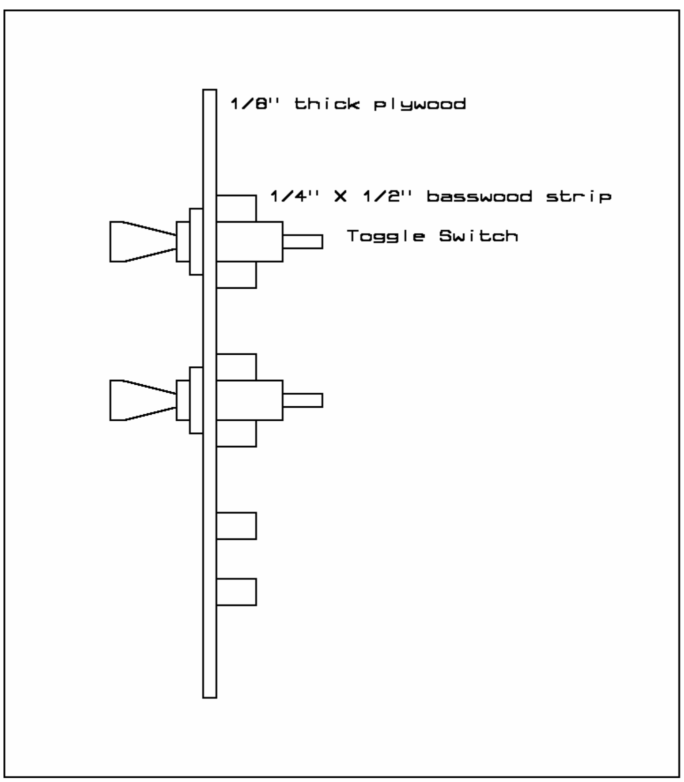
√ Lay foamed neoprene sheet under the bottom PCB.
√ Mark the size of the PCB and locations of its mounting holes.
√ Carefully cut and punch holes into the neoprene.
√ Lay the bottom PCB on top of the bottom Coroplast and mark the location of the mounting holes.
√ Carefully punch the holes into the bottom Coroplast (the sharp end of a file works well).
√ Measure ½" away from the bottom Coroplast holes and make a second set of holes that are outside the edges of the PCB.
√ Lay the PCB and neoprene on top of the bottom Coroplast.
√ Use nylon wire ties to tie the PCB down to the bottom Coroplast.
√ Orient the zip ties so that their heads are above the bottom Coroplast, and not beneath it.
√ Lay the cables on the bottom Coroplast and mark the location of holes for nylon wire tie strain reliefs on the Coroplast.
√ Cut channels into the Styrofoam wall to pass the bottom PCB cables through.
√ Repeat the same process for the top PCB(s) and the top Coroplast.

2.0 Control Panel



Completed control panel *– shown with avionics pallet.*

The airframe's Control Panel (which is mounted to the P3 port of the airframe) provides central access to all programming and power functions of the avionics pallet. Each avionics pallet has its own Control Panel and they move as a unit from airframe to airframe. The Control Panel is mounted to the inside surface of the airframe and a polystyrene frame is mounted to the outside, sandwiching the airframe foam between them. The polystyrene frame acts a washer, keeping the airframe foam from being crushed by the nut and washer of the #6 hardware.



Control panel *– Side view.*

[side diagram of control panel]

2.1. Materials

- 1/8” or 1/16” plywood
- 30-mil thick polystyrene
- Paper Label *
- ¼” square basswood dowel
- Spiral wire wrap
- Two toggle switches (used as spacers when assembling the Control Panel)
- #6 mounting hardware (nuts, bolts, and washers)
- #1 mounting hardware (nuts, bolts, and washers) to fit DB-9 connector
- Model Paint and Sticky Colored Dots **
- White glue
- Wood glue
- Hot glue
- Clear paint (dull coat)

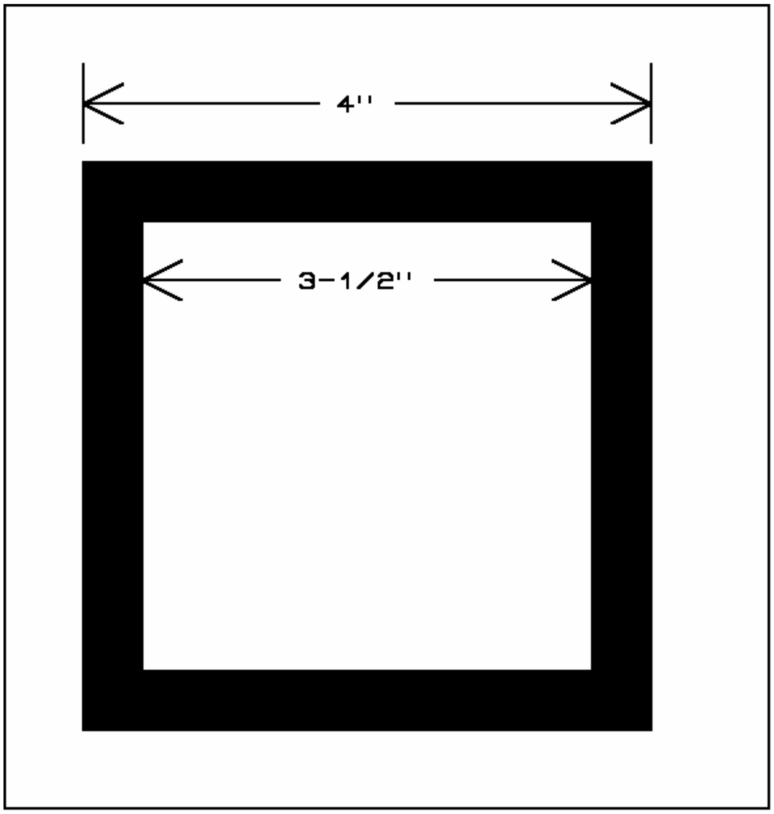
* Print a label with a word processor. Organize switch functions, programming headers, and power-on LEDs and then surround the text in the appropriate size box. A set of sample labels is included in the appendix. When designing the paper label, make the ON and OFF directions consistent for all Control Panels and clearly label the ON and OFF directions. There’s almost nothing worse than going to launch only to find the batteries were discharged the night before because someone left the NEAR SPACECRAFT on all night. See Appendix D for examples of Control Panel faces.

** This is optional. The paint is applied to the top ¼” rail of the Control Panel and the sticky dots are applied to one side of the toggle switches. Make the paint and sticky dots the same color. If used, by aligning the paint and dots, the toggle switches are aligned properly in their rails to match the ON and OFF directions indicated on the Control Panel.

2.1.1. Procedure

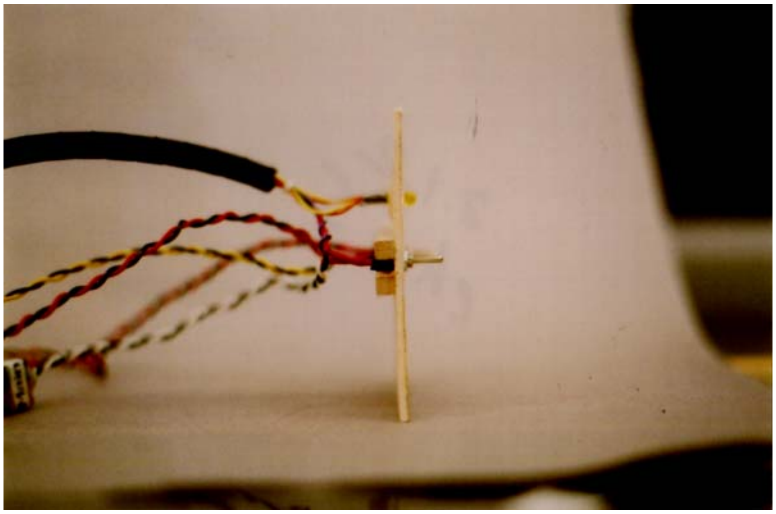
√ Cut a piece of 1/8" or 1/16” plywood to cover the P3 Port with enough border to attach the plate with four #6 bolts (1/2” border all the way around).

√ Cut a square out of the polystyrene to dimensions that match the Control Panel.



Polystyrene face *– This is optional, but highly suggested.*

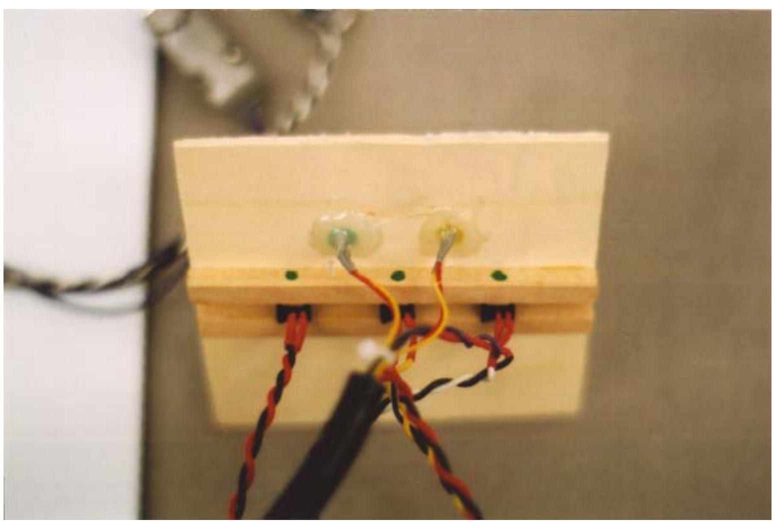
√ Cut the center out of the polystyrene to match the P3 Port opening.
√ Make the appropriate paper label for the plywood (see Appendix D).
√ Spray label with clear paint and let paint dry.
√ Glue paper label over 1/8" or 1/16" plywood.
√ Cut holes for power switches, power-on LED, DB-9 connector (if needed).
√ Overlap Control Panel and polystyrene frame and drill holes for #6 bolts in corners of the Control Panel.
√ Mount and align two toggle switches to the panel as spacers.
√ Form two rails on the back of the Control Panel by gluing two wooden strips to back of the Control Panel, clamping body of toggle switches between the strips. The rails keep the switches from spinning when you tighten up their mounting nuts.
√ Repeat the previous step for all rows of switches on the Control Panel.



***Back view of control panel** - Note the toggle switches are "trapped" between the bars, which keeps the switches from rotating.*

Optional steps, but recommended:

- √ Paint a dot of model paint at the top of the top rail of the Control Panel.
- √ Flip toggle switches into the ON position.
- √ Orient toggle switches so their handles match the ON position labeled on the Control Panel.
- √ Place a sticky dot on the topside of each toggle switch going into the Control Panel. The dots help to ensure the toggle switches are all aligned as indicated on the Control Panel.



***Note the alignment dots -** As long as the dots on the switches are aligned with the dots on the control panel, all the switches shut on and off in the same direction.*

- √ Attach toggle switches and power-on LED indicator to the back of the Control Panel.
- √ Use hot glue to mount power-on LED indicator securely to the Control Panel.

Optional: Instead of hot gluing LEDs to the Control Panel, use an LED with a face that threads into the Control Panel.

Placing the DB-9 connector (if used):

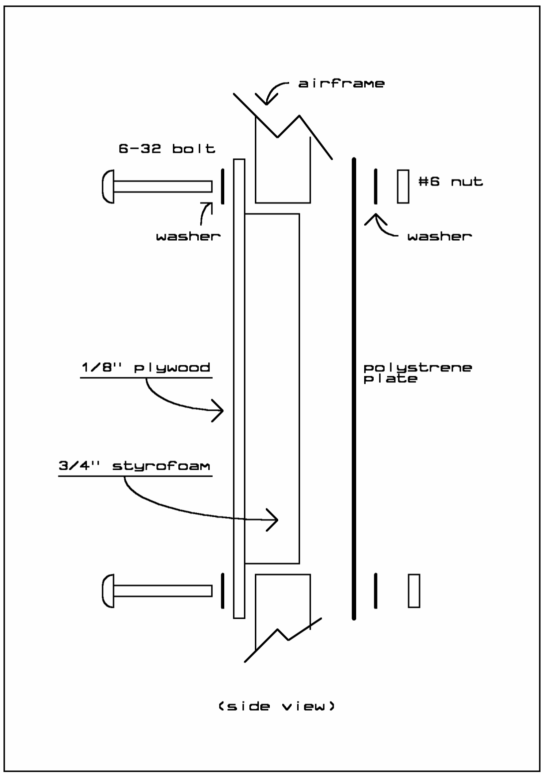
- √ Place DB-9 connector into the opening of the Control Panel and mark location of #1 mounting hardware.
- √ Drill small holes to bolt the DB-9 connector to the Control Panel.
- √ Mount DB-9 to the Control Panel.

Cut spiral wrap to length and wrap around the cables between the pallet and the Control Panel.

3.0 Quad Panels and Booms

3.1. Quad Panels

Quad panels cover the open quad ports of the airframe. Experiments or antenna booms are mounted to them. Together with a NearSys CC/PS, they form a modular near space system that can be moved from launch to launch, or module to module. Quad panels are mounted to the exterior of the airframe with #6 bolts, washers, and nuts. A polystyrene plate is mounted to the inside surface to act as a washer. The airframe side is sandwiched between the panel and plate.



Side View of a Quad Panel Mounting *- Panels fit into the port opening and are bolted into place through the corners of the quad panels. An interior plate sandwiches the airframe.*

3.1.1. Materials

- 1/8” or 1/16” plywood*
- ¾” thick Styrofoam**
- Epoxy
- Latex gloves
- Heavy weight, like a cast iron baking pan
- #6-32 by 1¼” mounting hardware (nuts, bolts, washers)
- 30-mil polystyrene

*Use thicker plywood when the quad carries heavier weights or longer booms. In most cases, a 1/16” plywood panel works well.

** You should have kept the Styrofoam panels you cut out of the airframe when you were constructing it.

3.1.2. Procedure

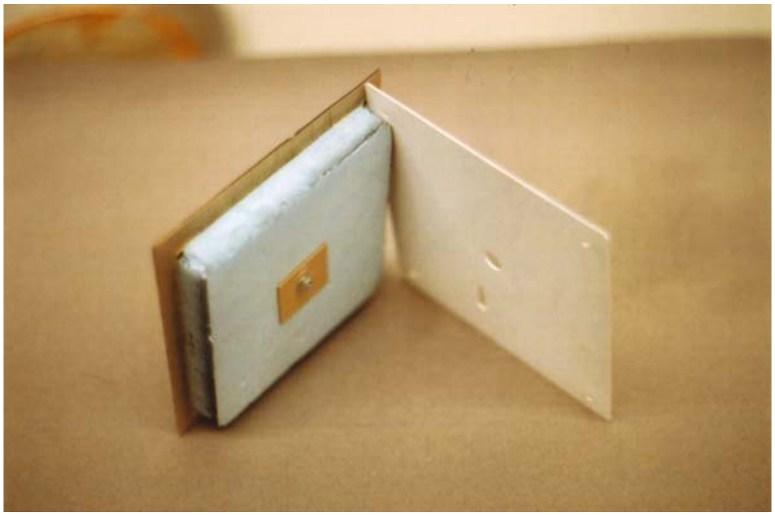
These directions assume the airframe is designed as illustrated in Chapter One, Airframes.

Note on cutting Styrofoam:
Use a long-bladed Exacto knife and a straight edge. It's time to replace the dull blade when your Styrofoam begins to chip, rather than cut cleanly.

- √ Cut out a new Styrofoam panel or trim the one that was removed from the airframe during its construction. Cut or trim the panel to a dimension of 5-1/8" on a side.
- √ Verify the Styrofoam panel easily slides in and out of the open quad port of the airframe.
- √ Cut the plywood into a square with sides 6" long.
- √ Lay the plywood panel smooth-face down, as you are going to epoxy on its rough face.
- √ Put on a pair of latex gloves.
- √ Mix up epoxy and apply to one face of the Styrofoam panel.
- √ Center the Styrofoam over the plywood and epoxy the two together.
- √ Apply masking tape between the Styrofoam and plywood to keep the Styrofoam from sliding.
- √ Add weight on top and let sit for one hour.

- √ Remove weight and tape.
- √ Test fit panel in airframe.
- √ Drill out 1/8" diameter holes through the plywood and in the corners of the Styrofoam.
- √ Test fit panel again, this time using #6 hardware to bolt the panel into the port.

- √ Cut 30-mil polystyrene plastic into a square with six inch long sides.
- √ Align the polystyrene to the panel and mark the location of the corner bolt holes.
- √ Drill out the bolt holes in the polystyrene (an Exacto knife works well).
- √ Test fit the Quad panel again, this time with the internal polystyrene plate.



A quad panel and plastic interior plate.

Usually a boom or other experiment is mounted to the Quad Panel. Often these require other openings through the Quad Panel for cables to pass through. The same size hole must be made in the plastic plate and in the same location. It would be a good idea to give this some thought and determine a single location and size for these pass-through holes. This allows any polystyrene plate to be used with any Quad Panel. If the location and size of pass-through holes is not standardized, then a new polystyrene plate must be made for each new Quad Panel (even with the adoption of a standard, there will be instances when a Quad Panel needs a specific plate). Do not drill the pass-through if the Quad Panel is to have a boom; instead wait until after the boom is epoxied to the Quad Panel.

A CD holder and booms are examples of items added to a Quad Panel.

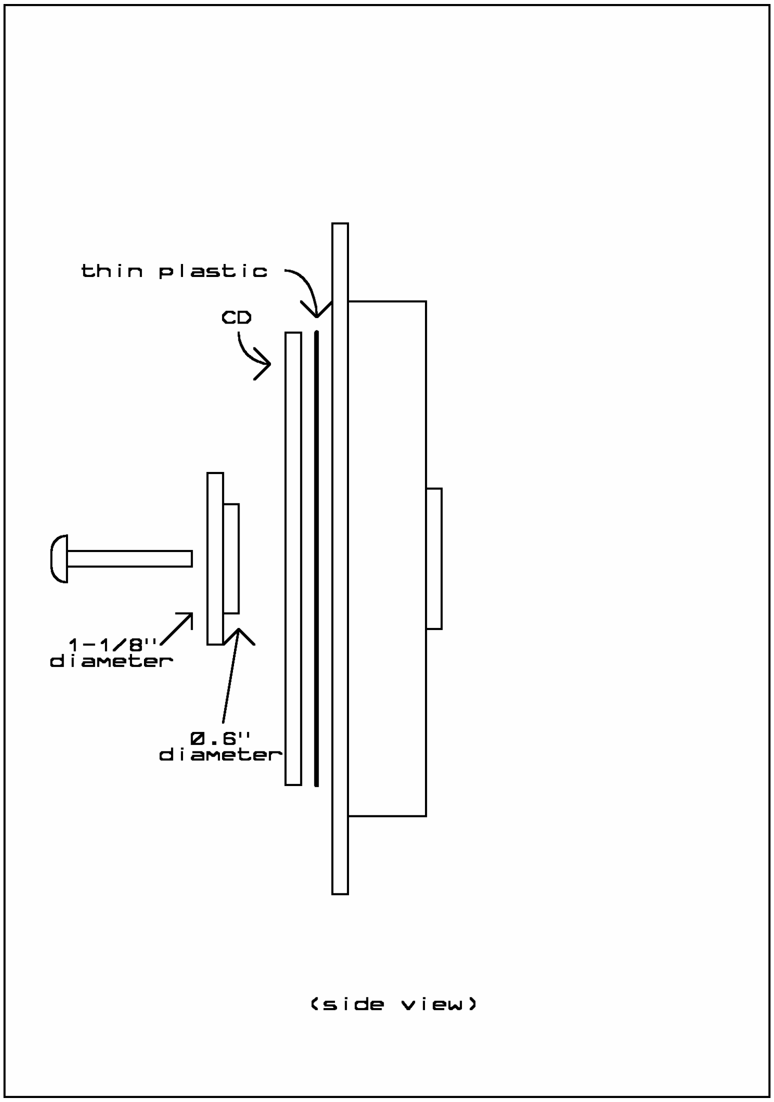
3.2. CD Holder

CD-ROM holder - *Anyone remember Voyager I and II's gold record?*

Remember Voyager 1 and 2? How about Carl Sagan's gold phonograph record? Amateur near space explorers can do a similar thing with CDs. A CD with text and images in web format carried on a near space flight is a wonderful way to commemorate an event or program. The directions below explain how to safely mount a CD to a Quad Port in a fashion that makes it visible on the near spacecraft.

3.2.1. Materials

- Completed Quad Panel
- 1/16" plywood
- 1/8" plywood
- #6 mounting hardware (nut bolt, and two washers)
- Epoxy
- Very thin plastic sheet



***CD Holder** – Side view of pieces making up the CD holder.*

3.2.2. Procedure

√ Paint the Quad Port.
√ Cut a circle 0.6" in diameter from 1/16" plywood.
√ Test fit disk to center hole of CD.
√ Cut a circle 1-1/8" in diameter from 1/8" plywood.*
√ Cut a circle 4-3/4" in diameter from a sheet of thin, smooth-faced plastic. **
√ Find and drill an oversized 1/8" diameter hole in the centers of the 0.6" and 1-1/8" disks.
√ Epoxy disks together, using a bolt and nut to clamp the disks together until epoxy sets, which creates the center clamp.
√ Find center of Quad Port and drill an oversized 1/8" hole.
√ Punch a 1/8" hole in the center of 4-3/4" plastic disk.
√ Paint center clamp if necessary.

√ Attach a CD to the modified Quad Port as follows:
√ Place 4-3/4" disk on data side of CD.
√ Lay and center CD on Quad Port, data side down.

√ Insert center clamp into CD center, sandwiching CD between Quad Port and center clamp.

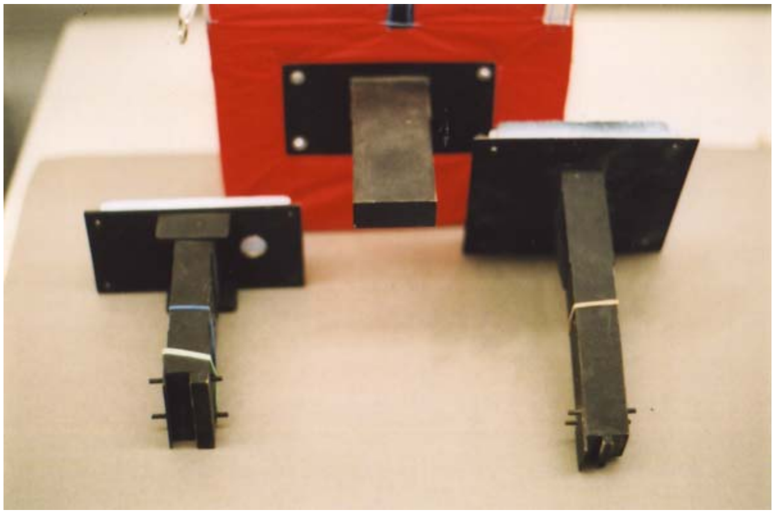
The 4-3/4" disk protects the data surface of the CD from abrasion and exposure to UV in near space. CDs sent into near space in this fashion were unaffected by their trip.

Note: A stack of CDs can be launched into near space if the center clamp is made deeper.

* A plastic or metal disk is also appropriate.
** The diameter of a CD.

3.3. Booms

Booms keep antennas and other experiments away from the airframe. There are basically two types of booms, those that are wider that they are tall and those that are taller than they are wide. Wider booms are useful for mounting stationary experiments while taller booms are useful for scan platforms and antenna booms.



Booms *– Several types of booms.*

3.3.1. Materials

- ¾" or 1" thick Styrofoam
- 1/32" thick plywood
- 1/8" thick plywood
- Epoxy
- Latex gloves
- Masking tape and clamps

3.3.2. Procedure

Cut a piece of Styrofoam to the desired length.

As an example, I usually make antenna booms six to eight inches long and 1.5" deep, and experiment booms six inches long and three inches wide (my booms have a core of ¾" thick Styrofoam).

- √ Lay the largest side of the boom on a sheet of 1/32" plywood and draw two outlines of the boom.
- √ Add a 1/8" border to the outline and cut the plywood with a knife of scissors.*
- √ Mark the rough side of each plywood piece with pencil (this side is epoxied)
- √ Put on a pair of latex gloves.
- √ Mix up epoxy and glue the plywood to two opposite sides of the boom.
- √ Use strips of tape and clamps to press the plywood to the boom until the epoxy sets

- √ After the epoxy sets, remove the clamp and tape.
- √ Sand the Styrofoam and plywood to size on a sanding belt.
- √ Epoxy two more pieces to the bare sides of the boom by repeating the above steps.
- √ After the epoxy sets, sand the plywood faces to meet properly at their edges.

- √ Epoxy 1/8" thick plywood to one end of the boom (do not epoxy plywood to the other end of the boom).
- √ After the epoxy sets, sand the plywood face to meet properly at its edges

- √ Cut "triangles" of 1/8" thick plywood to form braces for the boom
- √ Test fit the boom and braces
- √ Epoxy the open end of the boom to a Quad Panel; make sure the boom is perpendicular to the Quad Panel.
- √ Use masking tape and a clamp to secure the boom and brace as the epoxy sets.
- √ Drill out the pass-through after the epoxy sets.

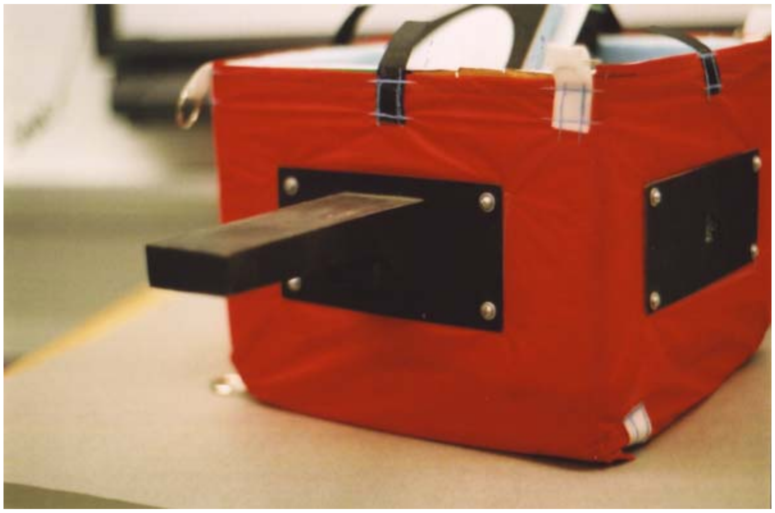
* Do not use your best scissors for this.

3.4. Modifications to Booms

The following three modifications illustrate how antennas, servos, and long extensions are added to booms.

3.4.1. Modifications for Experiment Mounting Booms

Wide booms are useful for mounting experiments outside the airframe. The experiment is either bolted or rubber banded to the boom. The following design is for a generic experiment boom, suitable for a wide variety of experiments.



***Experiment Boom** - A wide boom makes a convenient location to mount experiments. Secure experiments with bolts or rubber bands.*

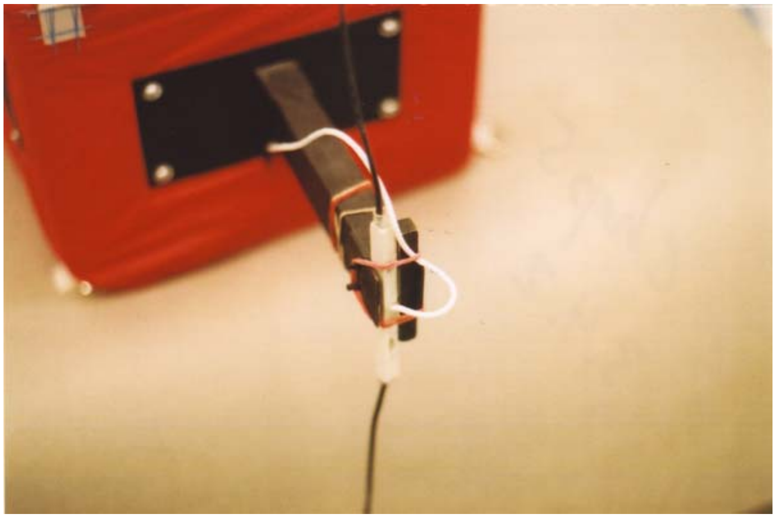
Materials
- 1/8" plywood
- Two Popsicle sticks
- Epoxy
- #6 mounting hardware (nuts, bolts, and washers)

Procedure
- √ Cut a doubler for the boom from 1/8" plywood, making its dimensions equal to the bottom surface of the boom.
- √ Mark the 1/8" on its rough side, the side that will be epoxied to the boom.
- √ Epoxy the double to the bottom of the boom and clamp until the epoxy sets.
- √ Drill a set of two 1/8" holes the length of the boom, centered on the boom.
- √ Cut two Popsicle sticks to one inch longer than the width of the boom.
- √ Epoxy the sticks to the underside of the boom, between mounting holes.
- √ Paint the boom.

Future experiments are either bolted to the holes in the boom, or are rubber banded to the boom with the Popsicle sticks. Rubber bands start at the Popsicle sticks, around the experiment, then to the Popsicle stick on the other side of the boom.

3.4.2. Modification for an Antenna Boom

The following steps complete a boom for a dipole antenna (as described in Chapter Four, Section Three).

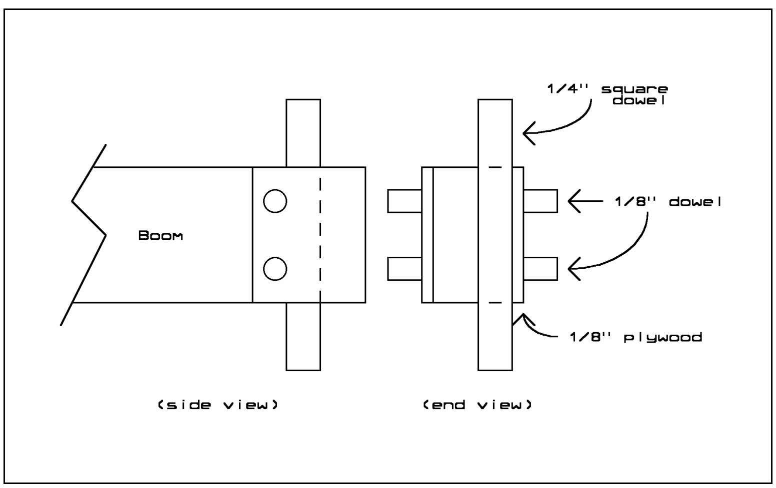


Business end of an antenna boom - *An antenna is lightweight enough to be secured with a rubber band.*

Materials

- 1/8" plywood
- 1/8" dowel
- ¼" square dowel

Procedure



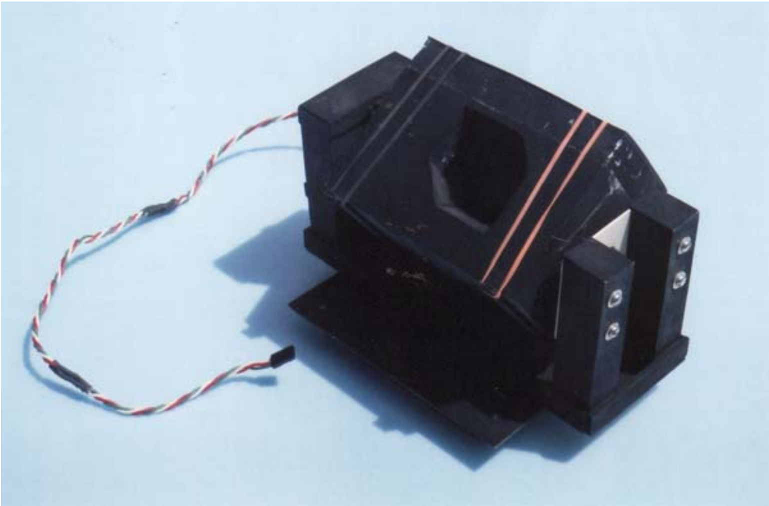
Mechanical drawing of antenna boom - *The dowels glued into the boom secure the ends of the rubber bands (use two for redundancy) holding the antenna in place.*

√ Cut two pieces of 1/8" thick plywood to form an extension to one side of the end of the boom (example dimensions would be ¾" by 2").
√ Epoxy and clamp the plywood panels to the sides of the boom, extending ¼" beyond the end of the boom, and then let the epoxy set.
√ Cut the square dowel to length (the height of the boom).
√ Place an antenna body against the plywood face as a spacer and trim the square dowel to fit.
√ Epoxy the length of square dowel onto the end of the boom.
√ Tape the square dowel into position until the epoxy sets.
√ Test fit antenna body and trim if necessary.
√ Drill two holes through end of antenna boom, through the 1/8" plywood sides.
√ Cut two lengths of dowel ½" longer than the boom width.
√ Center the dowels into the holes and epoxy the dowels into place.
√ Trim up and sand any sharp edges or burrs.

√ Paint boom and Quad Panel.

To use the boom, press the antenna body into the open slot at the end of the boom. Stretch rubber bands from one dowel end to around the antenna body to the other dowel end. Use two rubber bands, one for each pair of dowels. An extra rubber band acts as a backup, should one rubber band break.

3.4.3. Adding Servos to a Boom (Making a Scan Platform)

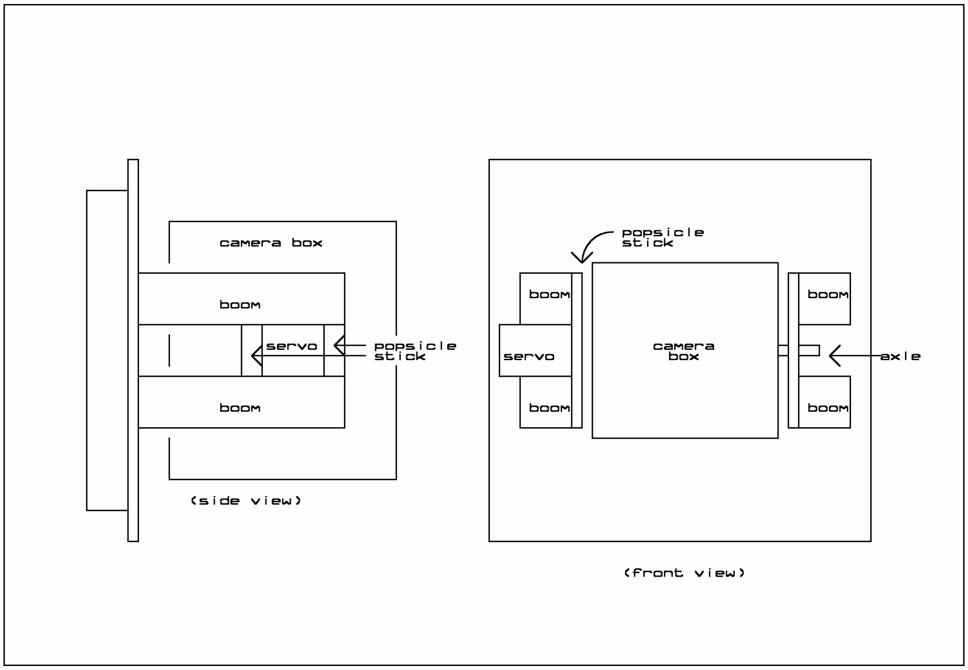


The scan platform *- This one is for a camera box.*

The following modification illustrates how a servo is mounted between two booms. This is a good method for creating the driven end of a single axis scan platform for items like cameras. The scan platform outlined in this section has two sides, the servo boom and the axle boom. A device rotated by the scan platform is mounted between the two sides. When making a scan platform for a camera box, the directions below assume the camera box has already been constructed. The directions work for devices other than camera boxes.

Materials

- ¾” Styrofoam
- 1/32” plywood
- ¼” thick balsa strip (used as a temporary spacer)
- 1/8” plywood
- #4-40 mounting hardware
- Popsicle sticks
- Epoxy
- Servo (For example, Parallax Standard Servo Stock# 900-00005)

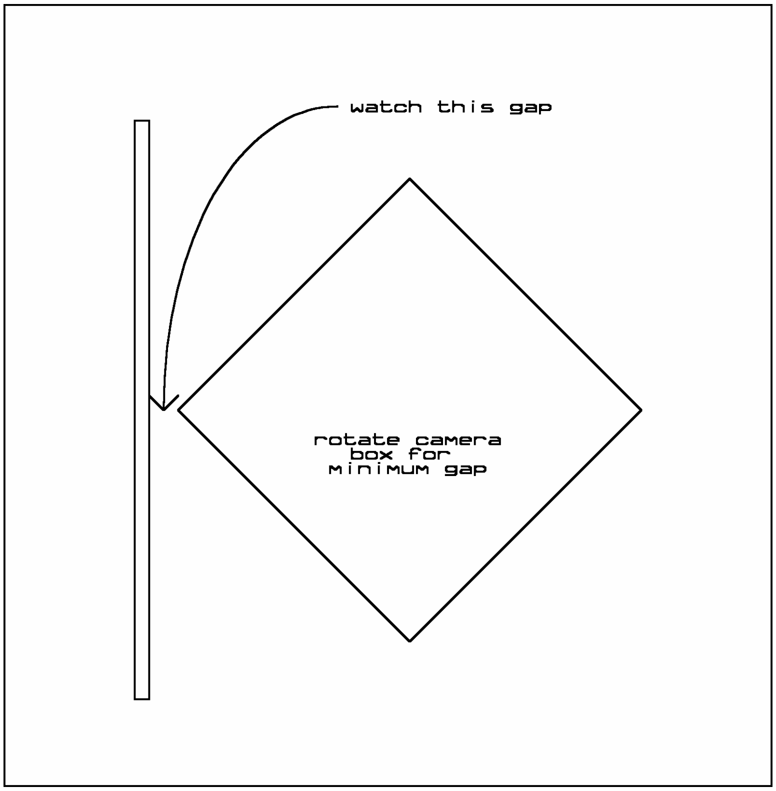


Mechanical Drawing of Scan Platform - *I have used this design many times for rotating camera boxes.*

Procedure

Determining the Length of the Booms

- √ Have the camera box and hatch on hand.
- √ Rubber band the hatch to the top of the camera box.
- √ Press the camera box axle into a servo.
- √ Lay the ¼" spacer on the table.
- √ Set the corner of the camera box on the spacer.
- √ Rotate the servo to be perpendicular to the table and with its longest end pointing down.
- √ Measure the distance from the tabletop to the highest end of the servo.
  This is the length of the booms.



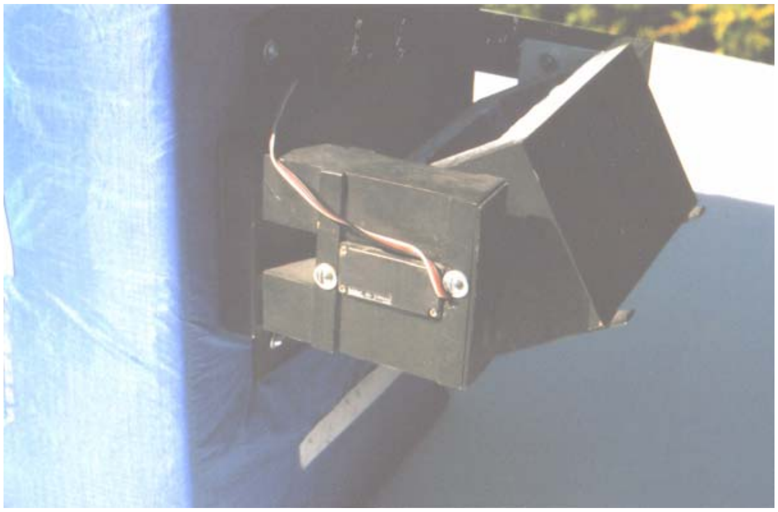
Clearance issue with rotating experiments *- Make booms of scan platforms long enough for the experiment to clear.*

Making Boom Pairs

- √ Cut four ¾” strips of ¾” thick Styrofoam to a length in excess of the measured boom length. Note: The booms will be cut to the proper length later.
- √ Laminate 1/32” strips of plywood over the Styrofoam.
- √ Trim and sand sides of booms as they are laminated.
- √ Use a T-Square to draw a flat base around one end of each boom.
- √ Sand the base flat according to the T-Square lines. Note: The other ends will be trimmed after completing the scan platform.

Completing the Scan Platform

- √ Use two booms at this time; the other two are used in the next step.
- √ Tape or rubber band two booms to both sides of a servo.
- √ Square up the bottoms of the booms to be perpendicular to their lengths.
- √ Cut two Popsicle sticks to length, so they extend across the booms and servo.
- √ Slide the servo away from the booms slightly, so that the Popsicle sticks slide beneath the servo-mounting tabs
- √ Epoxy the Popsicle sticks into place so that they and the booms form a box around the servo.
- √ Clamp the Popsicle sticks to the booms as the epoxy sets.
- √ Carefully sand the tops of the booms to be flush with the top side of the Popsicle stick.
- √ Cut a 1/8” thick sheet of plywood to cover the exposed ends of the Styrofoam and edge of the Popsicle stick.
- √ Epoxy the plywood into place.
- √ Drill one hole in each Popsicle stick that matches a hole in the servo-mounting tab.
- √ Epoxy the boom bases to the Quad Panel.



The servo side of a scan platform - *The servo is bolted to popsicle sticks that have been epoxied to the scan platform booms.*

Optional Base

- √ Cut a rectangle of 1/8" plywood to form a support base for the boom. Note: Cut the plywood strip inch high and long enough to span the booms.
- √ Epoxy the base to the bottom of the booms.

3.4.4. Adding an Axle to a Boom

The following modification illustrates how to mount an axle between two booms. This is a good method for creating the passive axle end of single axis scan platforms for items like cameras. The reference to the outside of the booms means the side of the booms that are facing the outside edge of the Quad Panel.

Axle side of scan platform - *Note the bolts holding the plastic plate in place.*

Materials

- The remaining two booms from the previous step
- Rectangular spacer to temporarily hold the booms apart. Note: A one inch thick spacer works for the ¼" diameter axle (dowel) for camera scan platforms.
- 1/8" plywood
- ¼" dowel
- Several Nylon washers that fit the ¼" diameter dowel

- #6-32 mounting hardware
- Epoxy

Procedure

- √ Assemble the previously constructed booms.
- √ Have a completed camera box on hand.*
- √ Insert the camera box onto the scan platform's driven axle.
- √ Place booms and camera box on a flat surface, like a table.
- √ Square the camera box in relation to the table surface.
- √ Measure the height to the center of the ¼" axle in the camera box. This is the axle height.
- √ Set booms and camera box aside.
- √ Rubber band the two remaining booms to the spacer.
- √ Square up the bottom of the booms to make them perpendicular to the boom length.
- √ Measure from the bottom of the booms to the axle height.
- √ Use a T-Square to mark the axle height across the booms.
- √ Mark ½" higher and lower than the axle height. These marks represent the edges of the cross piece.
- √ Use the T-Square to draw perpendicular marks across the booms to outline the position of the cross piece.
- √ Make the cross piece by cutting 1/8" thick plywood to size, so it extends across the booms and is one inch high.
- √ Cut two pieces of 1/8" thick plywood as doublers for the outside surface of the booms, making each doubler one inch high and as wide as a boom.
- √ Epoxy the doublers to the outside surface of the booms, over the cross piece outline.
- √ Find the center of the cross piece and drill an over-large ¼" hole for the axle.
- √ Rubber band or clamp the booms back onto their spacer.
- √ Square up the ends of the booms to make the booms perpendicular to their base.
- √ Clamp the cross piece of plywood across the booms, centered on the height of the axle. Note: The cross piece is mounted to the inside surface of the booms.
- √ Drill two holes in each boom, passing through the doublers and cross piece.
- √ Bolt the cross piece to the booms.
- √ Carefully sand the top edges of the booms to the edge of the cross piece.
- √ Bolt the cross piece to the booms to hold them rigid.
- √ Slide a few ¼" nylon washers on to the ¼" axle of the camera box.
- √ Slide the free boom onto the camera box, up against the washers.
- √ Epoxy the booms to the Quad Panel.

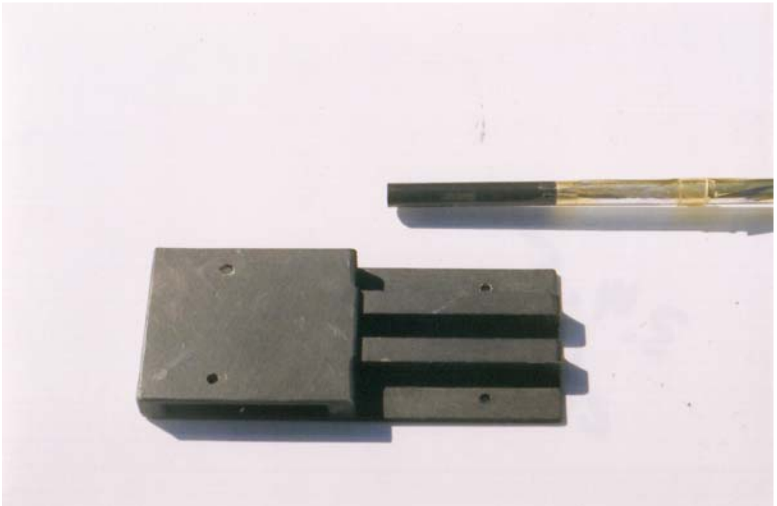
Optional Base

- √ Cut a rectangle of 1/8" plywood to form a support base for the boom.
- √ Epoxy the base to the bottom of the booms.

* The camera box must have a ¼" axle epoxied to it already.

3.4.5. Adding Long Boom Extensions (Extension Fitting)

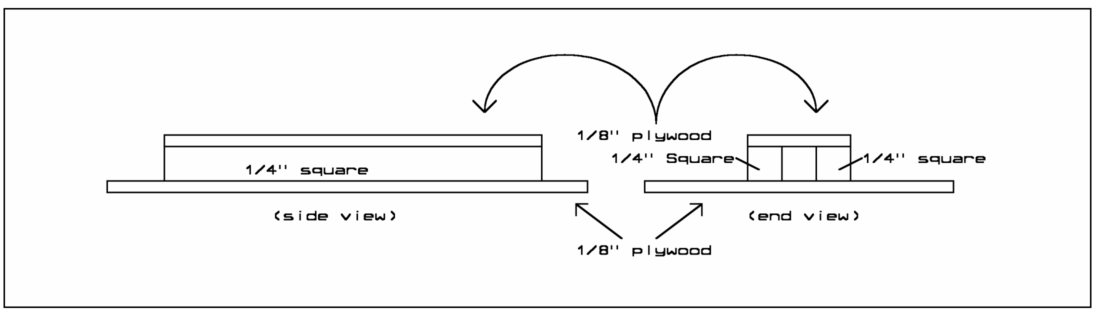
The extension fitting is bolted to a wide experiment boom and the fiberglass rod extension slides into a channel of the fitting.



Extension Boom

Materials

- 1/8” plywood
- ¼” square rod
- Epoxy
- #6 mounting hardware (nuts, bolts, and washers)
- ¼” fiberglass dowel (the type used in kite spars)



Mechanical drawing of extension boom - *Friction holds the boom in place.*

Procedure

√ Cut a piece of 1/8” plywood to fit the width of the boom and a length of 4.5”.
√ Cut a second piece of 1/8” plywood the same width and a length of 3”.
√ Draw a line down the center of the 3” length of plywood.
√ Cut four 3” lengths of ¼” square rods.
√ Epoxy two of the square dowels centered and to the outside edges of the 4.5” length of plywood and clamp until the epoxy sets.
√ Place the fiberglass rod along the center of the 4.5” plywood as a spacer and epoxy the remaining two square rods against the sides of the fiberglass rod.
√ Remove the fiberglass spacer and clamp the square rods in place.
√ Remove the clamps and test fit the fiberglass rod; it should slide in the center channel formed by the inner two square rods.
√ Apply epoxy to the tops of the square rods and clamp the 3” length of plywood on top.
√ Drill 1/8” holes into the 4.5” plywood (bottom of extension fitting) to match four holes in the experiment boom.

√ Test fit the extension fitting by bolting it to the experiment boom and sliding the fiberglass rod into the center channel.
√ Paint the extension fitting.

3.4.6. Notes on Using Extension Booms

- Lightweight experiments are preferable for the ends of long booms.
- Hot glue adheres Coroplast housing to fiberglass booms.
- Do not let cables or wires dangle from the booms; tie the wires down to the boom for the length of the boom.
- Use wire zip ties or short lengths of heat shrink tubing to tie wires to booms.
- Do not permanently glue fiberglass booms to extension fittings; the extension boom must be free to pull out before breaking the experiment boom.
- Leave a few inches of slack wire at the base of the boom and extension fitting to prevent wires from breaking or binding if the boom extension pulls out.

4.0 Qualification Testing

A new near spacecraft must be tested before its first launch. The cost of the flight and hardware is too great to risk sending a capsule that may fail thirty minutes into a three-hour flight. The goal of Qualification Testing (QT) is twofold:

- Ensure the capsule is reliable for a near space flight.
- Determine the nominal flight values and symptoms of failures.

In the first case you are attempting to make sure the capsule will not fail during a typical flight (ensuring flight reliability), and in the second case you are determining the symptoms of an impending failure in flight (useful in failure analysis). To meet these two goals of QT I have designed three sets of tests. The first set of tests ensures the capsule is functioning properly and determines nominal values for avionics. The second set of tests ensures events during a flight will not lead to an in-flight failure. The third set of tests determines the symptoms of failure

4.1. Capsule Function, Nominal Values, and Calibration

The five tests in this section check that the capsule powers up properly, determines a nominal value for current, calibrates the flight battery voltages, calibrates interior temperatures and determines the extent of self-heating inside the capsule, and determines the nominal percentage of dropped packets. I strongly encourage these tests be performed, especially if this is your first near spacecraft.

4.1.1. Proper Power Up and Function

The first test determines that the avionics do not contain a short or open and that the BS2p in the flight computer is programmable in-circuit. Basically you cannot proceed to the next tests unless the first test is successful.

Procedure
Install a fully charged flight battery and power up the near space capsule. There should be no smoke, fire, or sparks emitted by the near space capsule. If testing the CC/PS, download a sample program and verify that the program downloaded properly and that debug data is being received.

4.1.2. Current Draw

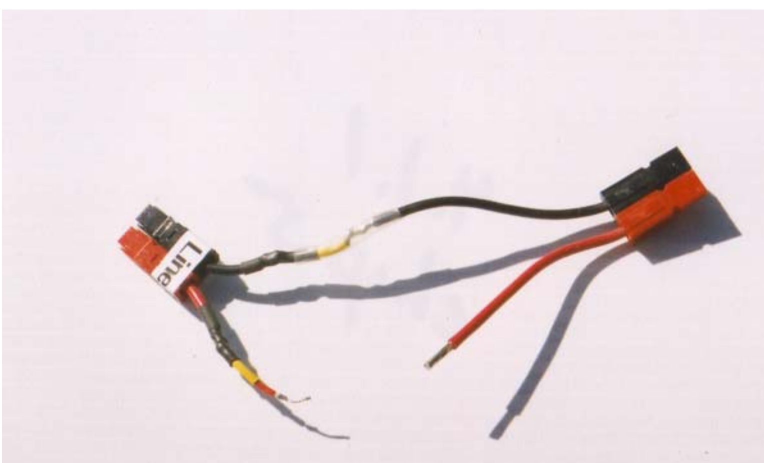
A baseline or nominal value for avionics current draw needs to be determined and recorded. To do so, construct a current cable for measuring the current with a DMM (set for DC current). In future configurations of the capsule, a new current measurement is compared to the nominal value to detect errors in configuration or to ensure the main power is capable of operating the capsule for the expected duration of the mission.

Materials

- Four Powerpole^{D} connectors
- #22 gauge wire in red and black
- "Current Cable" label
- 1-1/2" diameter clear heat shrink tubing, cut ½" long
- Hot glue

Construction

√ Cut one piece of each color of wire, each about six inches long.
√ Strip ½" of insulation from both ends of both wires.
√ Crimp Powerpole crimps on the ends of the wires.
√ Solder the wires to the crimps.
√ Insert the crimps into the Powerpole housings; match the color of the housing to the wire.
√ Slide the housings together.
√ Back fill the housings with hot glue.
√ Apply the labels to the housings.
√ Heat shrink clear tubing around the labels.
√ Cut the red wire in half.
√ Strip ½" of insulation from the wires and tin the wires.



Current measuring cable - *This power cable can be temporarily split apart, enabling you to measure current flow.*

Procedure

√ Connect this current cable between the avionics and battery.
√ Set the DMM to measure current (200 mA scale).
√ Connect the DMM leads to the open leads of the current cable.
√ Power the avionics and record the current.
√ Keep the current cable handy for future use.

4.1.3. Initial Voltage Values

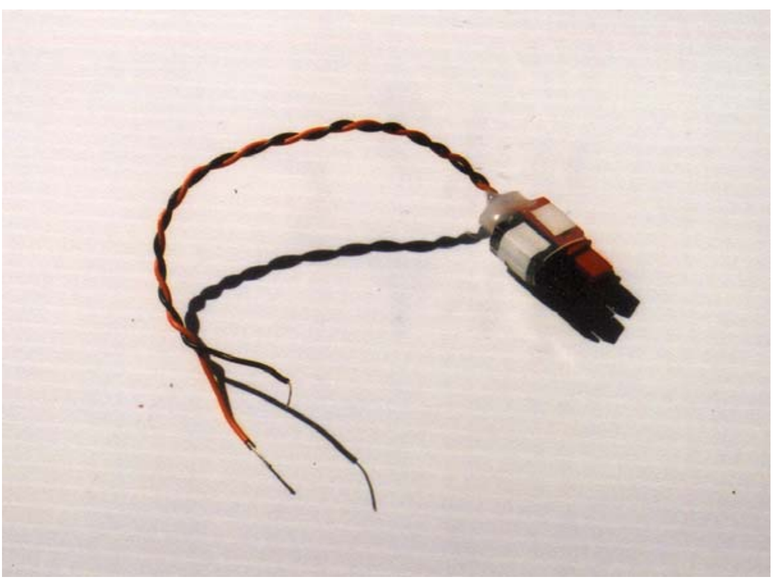
This test compares the ADC readings for the main power voltage and compares it to a DMM reading. The measurement becomes a correction factor in spreadsheets. To perform this test, a voltage cable must first be constructed.

Materials

- Four Powerpole connectors
- #22 gauge wire in red and black
- Voltage Cable label
- 1-1/2" diameter clear heat shrink tubing, cut ½" long
- Hot glue

Construction

√ Cut two pieces of each wire (four wires total).
√ Strip ½" of insulation from both ends of all four wires.
√ Twist one end of the first red wire to one end of the second red wire.
√ Repeat for the black wires.
√ Crimp Powerpole crimps on the end of the doubled-up wires.
√ Select one pair of red and black wires and crimp a Powerpole crimp on the ends.
√ Solder the wires to the crimps.
√ Insert the crimps into the Powerpole housings; match the color of the housing to the wire.
√ Slide the housings together.
√ Back fill the housings with hot glue.
√ Apply the labels to the housings.
√ Heat shrink clear tubing around the labels.
√ Tin the open ends of the wires.



Voltage measuring cable

Procedure

√ Connect this voltage cable between the avionics and battery.
√ Set the DMM to measure voltage (20V scale).
√ Connect the DMM leads to the open leads of the voltage cable.
√ Power the avionics and download the ADC test program.
√ Let the avionics run for a few minutes.

- √ Record the voltage and ADC reading.
- √ Make measurements at several battery voltages and record the voltage and ADC reading.

Enter the recorded voltages and corresponding ADC values into a spreadsheet. A graph of the data should be linear. Calculate the slope of the line and the y-intercept of ADC values versus main power voltages for a spreadsheet formula. Keep the voltage cable handy for future use.

4.1.4. Internal Temperatures

This test debugs the ADC value of the internal temperature for comparison to the measurements taken by a thermometer. After watching the temperature for an hour, any tendency of the capsule to self-heat is also determined (which is not as important as the initial calibration).

Procedure
Place a thermometer inside the airframe and seal the capsule. Power up the capsule and download the ADC test program. After several minutes open the airframe and measure the interior temperature with the thermometer and compare this measurement to the ADC value. Watch the temperature over one hour and record every few minutes. Determine the average temperature and whether the capsule self-heats.

4.1.5. Missed Packets

The final test determines the percentage of skipped packets from the Flight Computer or Tracker that can be expected. This test involves sending telemetry from a flight computer or tracker and verifying that both that GPS sentences can be read and be telemetered. Take the near spacecraft outside where the GPS antenna can "see" satellites.

Procedure
If testing a flight computer, then download the telemetry test program. Otherwise, just attach the GPS to the tracker or TNC. Switch the HT frequency away from the national APRS frequency (144.390) so the test does not interfere with legitimate packet traffic. Power up the capsule outside where the GPS receiver can see satellites. Watch packet telemetry on a PC. You want to make sure the TNC is properly transmitting telemetry. Look at the raw GPS data; make sure a GPS fix exists and that the TNC is not reporting old data. Confirm that the GPS is reporting the correct altitude.

Do not be alarmed when all TNC packets do not get through. Determine what is nominal for the capsule. You may want to take the capsule for a test drive and record its packets throughout the test.

4.2. Event Testing

Now that the capsule is confirmed to operate and its nominal values and calibration data are recorded, test the capsule for its ability to function through the events of a near space flight. In some ways, these tests are less important that the previous tests, but should still be completed if this is your first near spacecraft.

4.2.1. Shake Test

Burst is chaotic. The capsule shakes and bounces around during the descent. Pack a capsule as if it were going on a mission and give it good shake. The capsule’s avionics should function normally during the test. During a typical landing, the capsule lands at a speed of about 1200 feet/minute or 20 feet/second. According to what we learned in high school physics, a speed of 20 feet/second is generated when an object falls for 0.6 seconds under the acceleration due to gravity. In a descent of 0.6 seconds, the same object falls five feet. Therefore a drop from five feet simulates a descent speed of 1200 feet/minute. If you want to simulate the landing of the capsule on the avionics, then drop the capsule from a height of five feet above the lawn (most flights recovery in open fields rather than cement sidewalks). Perform this test without booms in place, as they do not need to be tested. The capsule should not stop operating after landing. To be honest with you, I don't have the nerve to attempt this test, but my near spacecraft experiences this on every flight.

4.2.2. Recovery Test

Read Chapter Six, Section 5.1 for directions on testing near spacecraft (and parachutes) during recovery.

4.2.3. Thermal Testing

Remove the avionics from the airframe and seal them (including the batteries) into a clear plastic bag along with a thermometer. The bag is to prevent condensation, which can foul the thermal test. The antenna is too large to seal inside, so tape around the opening in the bag for the antenna coax. Be sure to seal the bag in a dry environment. First refrigerate the sealed avionics for a couple of hours. Immediately after removing from the refrigerator, confirm the GPS is capable of achieving a satellite lock and the TNC and HT are transmitting. If the avionics are reporting the temperature, compare the ADC reading to the thermometer reading.

Typically, the airframe interior temperature stays above freezing during a flight, except possibly during the early descent. The next test chills the avionics to a lower temperature and confirms it works at the worst expected temperature.

Repeat sealing the avionics and batteries inside a clear plastic bag, along with a thermometer. Again, leave the antenna outside the bag. Place the sealed avionics inside the freezer compartment and chill for thirty minutes. Remove the avionics and confirm the GPS is able to get a satellite lock and the TNC and HT are transmitting telemetry. If the telemetry is sending the avionics temperature, compare the reading to that of the thermometer. It was during just such as test that Jeff Melanson (KD7INN) discovered a failure concerning the Etrex GPS receiver. When its batteries cool down too far, the Etrex shuts down.

4.3. Failure Symptoms

The next three tests, a cold test, a brownout test, and a GPS test, will operate the avionics to more extreme conditions. A well-insulated airframe is unlikely to fail the cold test, so it can be skipped if desired. The brownout/blackout test is more important and yields important results. The final test, GPS lock failure, shouldn't occur in near space, but it's handy to have a record of the symptoms.

4.3.1. Chill to Kill

Pack the airframe inside a plastic bag to avoid condensation problems (near space is very dry). Pack the airframe inside a large Styrofoam cooler with blocks of dry ice. Protect the capsule from direct contact with dry ice by wrapping the dry ice in a cloth towel. Telemetry from the capsule can be received outside the Styrofoam box during this test. Monitor telemetry and determine if the ultra cold of dry ice causes a failure. These temperatures are about the most extreme you can expect for a flight.

4.3.2. Brown-outs And Black-outs

This test runs the batteries down. The results from this test indicate two things: what events to expect as the avionics begin to fail, and an estimate of how long a near spacecraft is expected to function during a flight.

One thing to notice is that when the voltage to the flight computer or tracker's microcontroller drops too low, it undergoes a brownout. BASIC Stamp modules contain a brownout circuit which protects the microcontroller from behaving erratically or corrupting memory when the voltage drops too low. The last thing we want is for a flight computer to go on a rampage because of a low voltage condition (just imagine the results if this occurred in a Boe-Bot). When a brownout occurs, the BASIC Stamp module shuts down and reduces the load on the flight battery. With the reduced load, the flight battery voltage rises high enough to restart the module, which pulls the voltage back down to brownout conditions. This occurs until the flight battery is drained low enough that the voltage cannot rise high enough to restart the BASIC Stamp. Eventually the BASIC Stamp module experiences a blackout and shuts down completely. The occurrence of a brownout can be determined when a BASIC Stamp restarts several times in quick succession at the beginning of its stored program. Frequent resets during a flight are a bad sign.

Begin this test with a fully charged set of batteries. Record the start time and record the telemetry log from the avionics. Record the time the first brownout occurs and the time the BASIC Stamp module shuts down with a blackout. Record the ADC voltage reading when brownouts begin. Multiply the measured current draw from test 4.1.2 by the time required to reach brownout. The result determines the capacity the batteries under that current load. Record this result, as it is needed in section 5.2.

4.3.3. Lost GPS Lock

Cover the GPS antenna with a sheet of aluminum foil. Record the results in telemetry. The important field to look at is the number of satellites in the $GPGGA sentence. How does the calculated GPS position change as satellite locks are lost?

5.0 Avoiding Problems

The following list of suggestions will reduce the chances of an in-flight failure. However, the list is not comprehensive. Experience will permit you to develop a more complete checklist.

5.1. Suspend Time with a Complete Near Spacecraft (sans balloon)

Assemble the modules into a complete capsule, along with the recovery system. Suspend the near spacecraft from a tree or balcony by a strong cord. Power up the avionics and observe the telemetry. Verify there is no there a problem with clearance between the modules and their antennas. Also verify there is no problem with radio frequency interference (RFI) among the components.

5.2. Check the Current Again

The nominal current for the avionics was determined and recorded during test 4.1.2. After the near spacecraft is configured for its next mission, measure the current again. Does the current seem excessive? Divide the capacity of the flight batteries (calculated in test 4.3.2) by the measured current to estimate how long the capsule can function under this configuration. If it won't last the entire flight, then do not launch the near spacecraft. Reconfigure the flight or determine if there is a bad component.

5.3. Proper Treatment of Batteries

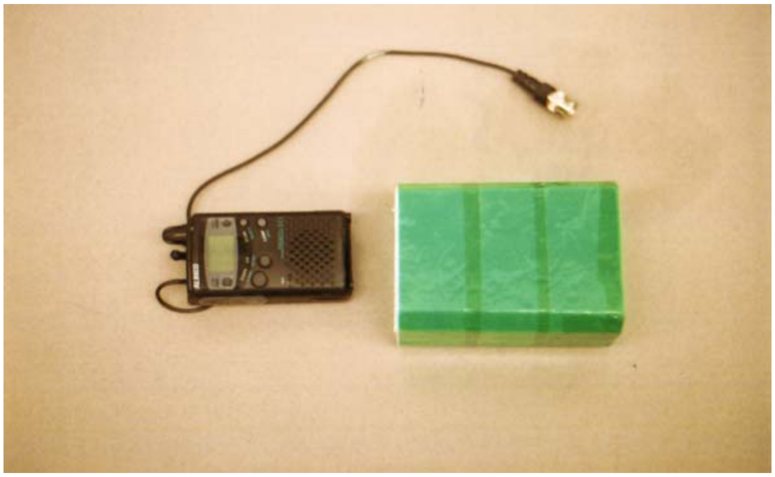
Some cells must be stored in a charged state while others must be stored in a discharged state. Know the requirements of the chemistry of the flight batteries and store the cells properly. Keep cells from freezing or getting too hot before launch. The assembled capsule can be stored in a cold location the night before a launch, but the batteries need to be kept at home and brought to the launch that morning. Be sure to properly recharge flight cells. As an example, do not recharge NiCds unless they have been fully discharged. Also, do not discharge cells to a voltage lower than is recommended for their chemistry. Test the cell voltage after charging and again in the capsule once the capsule is powered up. If using rechargeable cells, bring an extra set of charged cells to the launch site as a backup.

5.4. Shielding and RF Problems

The full-up test of Section 5.1 will ensure there is no RFI. To further guard against RFI, cover HTs with boxes covered in aluminum or copper tape. From the author's experience, the DJ-S11 does not appear to create a RFI problem. To be safe, shield any untested transmitter (like an ATV transmitter). Various types of aluminum and copper tape are available for this purpose. Other options include physically moving the transmitter or its antenna to a new location (e.g. separate module) or reducing the transmitter power.

5.5. Packing Components Inside the Airframe

Loose components need to be immobilized inside the airframe. Items with push buttons like HTs must be packed inside of boxes (Styrofoam works) so their buttons cannot be pushed during a flight. If changes to settings can be locked out (as with the DJ-S11), then they should be locked out. Seal boxes with rubber bands.



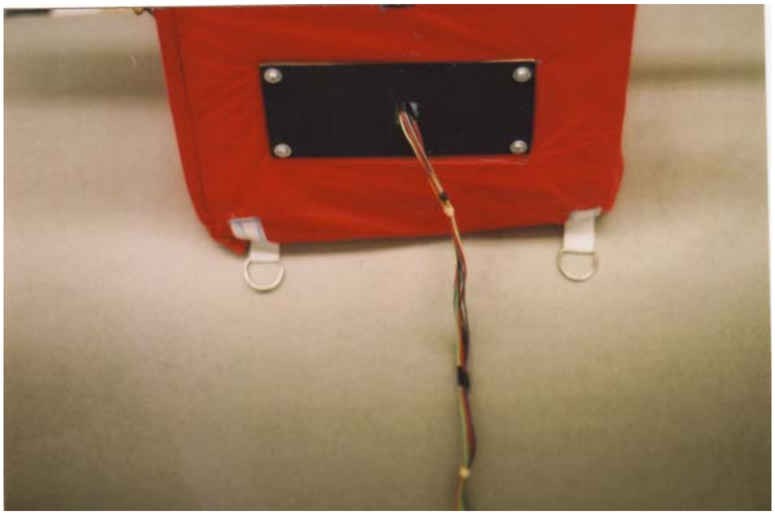
An HT and its warm box - *More important than warmth, this box ensures HT buttons are not pressed during a mission.*

Pack the remaining open space inside the airframe with Styrofoam peanuts or foam blocks.

A Styrofoam-filled module *- The packing peanuts keep components from bouncing around, especially during descent.*

5.6. Immobilizing Cables

While less of a risk, it is still a good idea is to immobilize cables. Tie together umbilical cables between modules with short lengths of twister seals.



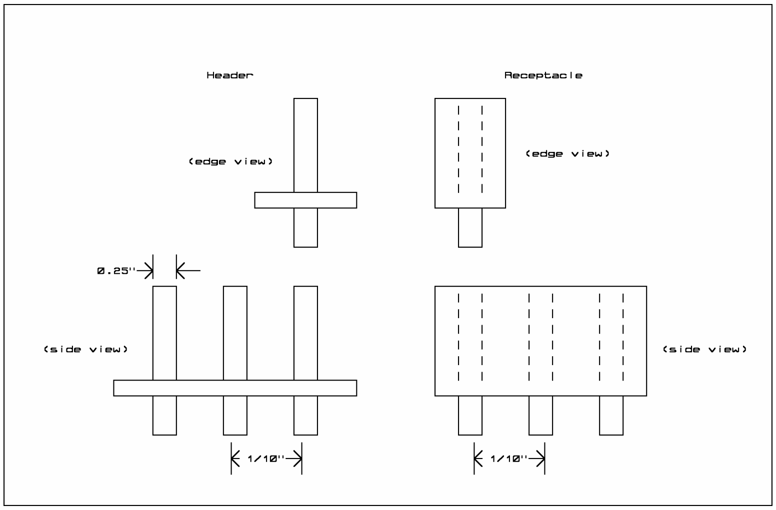
Umbilical Cable *- To keep the cables of an umbilical from snapping against each other, wrap a twister seal around the cables every couple of inches. Twister seals make it easier to break apart the cables of the umbilical after a mission.*

The cable between the avionics pallet and the Control Panel should be covered in a plastic spiral cover.

Spiral Wrap *- Keeps the cables between the avionics pallet and control panel neat and under control.*

5.7. Avoiding Shorts

Use female receptacles in place of male headers where possible. Receptacles keep power and ground connections more isolated from one another when a washer is dropped inside the capsule than male headers. Cover all exposed power and ground pins with Styrofoam or other non-conducting blocks when possible.



Male headers and female receptacles - *Use male headers where servos may be plugged in. It's easier making connectors for female receptacles.*

5.8. Warm Boxes

Build extra insulation for temperature sensitive components, like batteries. Warm boxes stop cold airflow over components inside of them. Label the warm boxes so the component inside of them can be determined without pulling everything apart. Chapter Four, Section 4.2 contains directions for making warm boxes (battery boxes).

5.9. Label Everything

Label every power cable, every polarity, every port, and every box inside an airframe and on the avionics pallet. Labels help to prevent improper and possibly destructive connections between components. The author had the wonderful experience of watching wiring inside a near spacecraft catch fire, from a battery that wasn't labeled.

5.10. Warm Before Launch

Warming the interior of each airframe before launch is beneficial to batteries and avionics. The interior will still cool down during the flight, but not as fast, since it starts in a warmer state. Warm the airframe and avionics with a handheld hair drier on low setting. Be careful not to melt or damage components with the heat.

5.11. Integrate a Backup Tracker

Unless it is absolutely necessary, never launch a mission without a backup tracker. The backup can be as complex as a second module carrying an independent flight computer and experiments or as simple as a reusable lunch bag carrying a Tiny Trak. The backup requires a separate battery, radio, antenna, and GPS receiver for reliability.

6.0 Failure Modes and Failure Analysis

Exercising caution before a mission reduces the chances of a mission failure. However, someone, somewhere will experience a failure. Should this happen, there are several observations to make if a mission should fail during a flight. The results are compared to the record from the previous tests performed in this chapter. Here are a couple of things to look for in a failure.

6.1. Cold

Convert temperature ADC measurements into interior temperatures. Did the interior temperature drop lower than expected, or to the point of battery failure? The results of tests performed in sections 4.2.3 and 4.3.1 indicate the border between acceptable and unacceptable temperatures.

If it appears lower temperatures are responsible for a flight failure, the avionics may restart after landing when the interior temperature comes back up. It's important that someone drive back to the predicted recovery zone and listen for telemetry from the near spacecraft.

6.2. Dead Batteries

Graph ADC voltage readings. Determine if the batteries discharged sooner than expected. This is a symptom of a short circuit or improperly recharged batteries. To reduce the chances of this occurring, measure the current draw of the assembled capsule and measure the voltage of the batteries under a load, once the capsule as been powered up. Look for evidence in the telemetry for the flight computer restarting itself as a result of a brownout. Compare main power voltage to interior temperature. As cells chill, their voltage drops. A drop in temperature may be the factor causing a drop in main power voltage.

6.3. Short Circuits

Look for a dramatic rise in battery voltage and possibly a rise in the airframe's interior temperature. A drop in voltage should follow the voltage spike. But the batteries may completely fail as their voltage drops, preventing the transmission of main power telemetry. Placing a temperature sensor inside the battery compartment is a good idea. If the cells shorted out, there may be a temperature spike in the cells that the temperature sensor can report.

6.4. Lost GPS Lock

Become familiar with GPS sentences so you can read the TNC log in APRS. In fact, start doing this from the first flight, even if it does not fail. Evaluate the GPS sentences by looking at fields like number of satellites, or the time UTC. When a GPS receiver begins to lose a lock, the number of satellites drops and eventually the time UTC field is left blank. The GPS receiver requires the largest amount of current, so look at the ADC voltage reading. Because of its large current requirement, a GPS receiver may be the first to fail as the batteries discharge. If the ADC voltage reading isn't dropping significantly, then the GPS may have failed internally, or by getting too cold. Again, placing a temperature sensor inside the battery compartment is a good idea.

6.5. Pulled Cables

Look for a total loss of telemetry when previous battery voltages and interior temperatures are at acceptable values. A loss of telemetry at balloon burst is a good bet for a pulled cable or antenna. KNSP observed a total loss of telemetry on Flight 98B from pulled cables at balloon burst.

6.6. Document Events

After a flight anomaly, save everyone's flight log and construct the entire mission log by patching holes in one log with records from a second log. Have several people look at the reconstructed log looking for problems rather than depending on just one person to evaluate the reconstructed log during the failure analysis.

6.7. When Things Go Wrong, a Checklist

Here is a list of items to look for during a failure analysis:

- Did the flight computer reset itself?
- Did the main voltage drop too low?
- Did the main voltage abruptly rise?
- Did the interior temperature drop too low?
- Were the GPS sentences incomplete?
- Was there an unusual loss of packets?
- Did anyone hear malformed packets at the time they were lost?
- Did the failure appear to occur right after burst?

Good to Know - The Flight of Explorer II (1935)

During my summer vacation in 2001, I made a visit to the geology museum of the South Dakota School of Mines and Technology in Rapid City. While there, I discovered a model of a gondola called Explorer II. The two aeronauts in this gondola created a new altitude record back in 1935 and became national heroes as result. The flight was launched nearby, in a location called Strato Bowl. This piqued my interested, so I did more research, which led me to the book *The Pre-Astronauts*, by Craig Ryan, published by The Naval Institute Press. With a little research I discovered the location of Strato Bowl. I made plans to visit it during my next summer vacation (being a teacher has its benefits). During the summer of 2002, I took a trip to Kansas for the Great Plains Super Launch (GPSL 2002). On the way I made several stops for hiking and camping in Yellowstone and the Black Hills. While in the Black Hills, I put a visit to Strato Bowl on my list of things to do.

Strato Bowl is located at the end of a canyon in the Black Hills of South Dakota where it forms a hollow on one side of a "box canyon". A large flat ground forms the base and there are and steep walls on three sides. The fourth side is open toward the north. There is an observation spot to the east, up on the rim of this open canyon.

In January 1934, The National Geographic Society and the Army Air Corp (predecessor to the USAF) announced plans to loft a laboratory into the stratosphere. It was planned to set the balloon altitude record. As a result of this announcement, the Soviets made an attempt to beat the Americans with their own high altitude balloon flight. Three aeronauts rode inside a sealed and pressurized gondola to a new altitude record, 72,178 feet. During descent, the Soviet aeronauts released too much gas from their balloon. One by one the cables attaching their gondola to the balloon popped loose. It's very likely the aeronauts were not aware of the cables coming off the balloon. At an altitude of 1,500 feet above the ground, the last cable popped loose, letting the gondola plummet earthward were the aeronauts were killed upon impact. A recording barometer however did survive, indicating their record altitude.

With this disaster fresh in their minds, the National Geographic Society and the Army Air Corp began constructing a balloon for their mission into the stratosphere. The balloon was constructed from three acres of rubberized cotton sheets glued together with rubber cement. This large balloon was named Explorer and hydrogen was used as its lifting gas. The pressurized gondola in which the aeronauts would ride into the stratosphere was 8.5 feet in diameter and welded together from a material called Dow metal. It was painted white on top and black on the bottom for thermal control reasons. From the announcement of the launch to the actual launch took only seven months.

The first flight of the Explorer balloon was named Explorer I. It carried three aeronauts well into the stratosphere to perform experiments on cosmic rays, measure ozone, take air samples, and determine if bacteria or spores exit in the stratosphere. Almost 250,000 cubic feet of hydrogen was used to fill the Explorer balloon. The launch occurred from the Strato Bowl at 6:45 AM on July 28, 1934. The crew maintained constant radio contact with the ground station, W10FX. The gondola transmitted on a frequency of 13.05 MHz and was identified as station W10XFH.

At 60,000 feet, the balloon began ripping apart. At that altitude the air was too thin to support life. Since the aeronauts did not carry partial pressure suits, they were forced to remain inside the sealed gondola until it had descended to below 20,000 feet where they could safely open the gondola's hatch. During the descent, the aeronauts used their radio to report to listeners across the US the current status of their emergency. By the time the gondola had descended to 20,000 feet, the Explorer balloon was severely ripping apart. Sheets of rubberized cotton fell off the balloon, turning it into more of a parachute than a balloon. The aeronauts finally opened the hatch, donned warm clothes and parachutes, and prepared to jump.

At an altitude of 5,000 feet above a farm field outside of Holdrege, Nebraska, the hydrogen remaining inside what was left of the balloon exploded, letting the Explorer I gondola free fall to the ground. The first aeronaut out of the gondola at 3,000 feet above the ground was Captain Anderson. The last one out of the gondola at 500 feet above the ground was Major Kepner. His altitude of 500 feet was just high enough for his parachute to open and safely land him on the ground. There's a famous painting on the cover of a National Geographic Magazine of the time showing one of the aeronauts caught in the hatch while a second aeronaut is stepping on him to help push him out.

***Escape Painting** – In the back of the exhibit box.*

The Explorer I crashed into a Nebraska cornfield and was crushed. The bail-out of the aeronauts and the impact of the gondola were recorded on film by aircraft. After all this, the Explorer I missed

making a new world altitude record by only 624 feet! The third aeronaut on the ill-fated flight of Explorer I was Captain Stevens. In 1924, Captain Stevens was the first person to take a photograph of the Moon's shadow on Earth during an eclipse. He made this photograph from a balloon.
It took another year to build a new balloon and gondola. The Explorer II balloon had a maximum volume of 3.7 million cubic feet, the largest balloon at that time. The combined weight of the balloon and gondola was nearly seven tons, about two tons less than the previous gondola and balloon. This time the balloon used helium gas for lift. 1685 tanks of helium were on hand at the Strato Bowl to fill the balloon. The first attempt to launch Explorer II ended on July 12, 1935, one hour before liftoff when the balloon collapsed, letting the helium escape. There was one other change. This time there were only two aeronauts in the gondola, Captain Orvil Anderson (Pilot) and Captain Albert Stevens (Commander, Scientific Observer, and Photographer). A crew of two was used on Explorer II for of two reasons: a crew of three was too cramped inside the gondola, and it appeared that a crew of three was bad luck.

Filling the giant balloon with helium began the night before launch at 6:30 PM. A twenty-foot long panel in the balloon ripped during inflation, putting a hold in the filling. After making repairs to the balloon, filling restarted.

The command "Up ship" was given and at 6:45 AM on November 11, 1935 as an estimated 21,000 people gathered on the rim to watch Explorer II lift off. Just after liftoff of the giant balloon, a downdraft threatened to push the balloon into the side of Strato Bowl. To prevent this, 75 pounds of fine lead shot was released from the gondola, increasing the ascent speed of Explorer II. The lead shot landed on the launch crew below and the gondola cleared the rim of Strato Bowl by fifty feet.

At an altitude of 15,000 feet, Captain Anderson slowed the ascent of Explorer II so that instruments could be rigged and the ports sealed. Then the balloon began its ascent into the stratosphere at a rate of 400 feet per minute. Four hours after lift-off (about 10:55 AM), Captain Anderson slowed the balloon's ascent to 200 feet per minute as the balloon reached its full volume. Explorer II had reached an altitude of 72,395 feet, the world's record at that time. The aeronauts held their altitude for one hour and forty minutes. The aeronauts inside were the first humans to report seeing the earth's curvature. A fan mounted to an arm mounted to the side of the gondola attempted to control the rotation and position of the gondola. However, the fan was ineffective in the stratosphere's thin air. As a result, the Sun's glare prevented the crew from making observations from all of the gondola's view ports.

Experiments on this flight included meteorological measurements of the stratosphere. The stratosphere's electrical conductivity (ionization levels), air samples, cosmic ray measurements (researchers were trying to determine the direction rays entered the atmosphere), winds aloft, and effects of stratosphere and cosmic rays on molds were all observed and recorded. The first motion pictures taken in the stratosphere were made on this flight. Remember, at this time, the stratosphere was a great unknown. The crew of Explorer II maintained radio communications with the US, with Europe, where they gave a radio interview in London, and even with the pilot of an airplane flying over the Pacific Ocean. The air temperature inside the gondola dropped to –23 degrees F during the ascent, freezing food they brought along, like hard-boiled eggs. From the ground, people were able to watch the entire flight of Explorer II.

At 12:30 PM, Explorer II began its descent. At an altitude of 1,000 feet, the aeronauts began tossing science instruments and air conditioning equipment out the gondola on their own parachutes. This protected equipment from a possible rough landing and kept chemicals in the air conditioning equipment from spilling and possibly harming the crew. Then they donned leather football helmets for additional protection. Explorer II landed at 3:10 PM in a prairie near the town White Lake, South

Dakota. The landing was so gentle that only a single bumper burst. Henry Ubel, a civilian, was the first person on the scene. He claimed the Explorer II landed like a feather and estimated the collapsed balloon covered one acre of ground. The entire flight had taken eight hours, thirteen minutes.

The rubberized cotton envelope of Explorer II was cut into 1,000,000 bookmarks and given to members of the National Geographic Society. The outbreak of World War II prevented any more manned attempts for the next twenty years, until Project Strato-Lab and Man High were launched in the mid 1950's.

Visiting Sites Related To Explorer II

Directions to the Strato Bowl
If you wish to visit Strato Bowl and see more information on Explorer I and II, then you have to drive to the Black Hills of South Dakota. In this area I have found three places concerning Explorer I and II to visit.

To get to Strato Bowl, follow these directions:

- Drive I-90 towards Rapid City.
- Exit I-90 in Rapid City on Exit 57.
- Go south on I-190.
- I-190 ends on Route 44, also called Omaha Street.
- Continue further south, two more blocks.
- Make a left turn on Main Street. Note: Main Street is split into two roads of one-way traffic. Take the road going to your left, or east.
- Make the next right onto Mount Rushmore Road; you're now going south.
- Shortly afterwards, Mount Rushmore Road becomes Highway 16.
- Eleven miles later is the town of Rockerville. Note: Highway 16 splits up and goes around the town.
- The two roads you want, Gondola Road and Strato Bowl Road, are located just before Rockerville. You're very close when you see the service station and the rock and mineral store, both on the right side (north). Highway 16 begins going up hill a bit after you pass them. The exits for Strato Bowl and Gondola Road are on the north side (your right), with Strato Bowl Road just at the split of Highway 16 around Rockerville. There is a sign at Strato Bowl Road, so you can be certain you're on the correct road.

Strato Bowl Sign

On to Strato Bowl Proper

The Strato Bowl is located at the end of Strato Bowl Road, at GPS coordinates 43.97705 degrees north and 103.34658 degrees west. The road is winding and has plenty of trees on both sides. The road ends at a private drive and is surrounded with private homes. When I got there, I thought the gate was barring the rest of the way to Strato Bowl, so I didn't try to get to the site. However, I did notice an area on my right, a very flat and open field with trimmed grass. So I drove back to Highway 16 in hopes of going to the Strato Bowl Observation Point.

Strato Bowl *– Flat and open field.*

To The Strato Bowl Viewing Area

Go back to Highway 16 and drive away from Rockerville. About ½ mile away from Strato Bowl Road is the next exit, Gondola Road. The sign is on your right; there is no street sign for Gondola Road on the eastbound lane of Highway 16. Again, you want to go north on Gondola Road. The road ends in closed gate; there is enough room to park several cars off Highway 16. From here you hike the trail to the Observation Point. The hike is a very nice walk, about ½ mile long. Near the end the trail forks; take the left fork in the trail. As you approach the end of the trail you will see the guardrail and plaque of the Observation Point. From there you can look down into Strato Bowl.

Plaque *– "From the floor of the Stratobowl below on November 11, 1935, The Stratoshere Balloon Explorer II rose to the world altitude record of 72,395 feet. The ascent was a made for scientific research under the joint auspices of the U.S. Army Air Corps and the National Geographic Society. Captain Albert W. Stevens, Air Corps commander and scientific observer. Captain Orvil A. Anderson, Air Corps Pilot."*

From the Observation Point I saw a road that ended in a gate near several homes. I had a strong suspicion that this was the same area I stopped by on my drive to Strato Bowl. So I drove back down. And I'll be darned if that wide-open area I saw the first time didn't look a lot like Strato Bowl that I saw from the observation point. A couple of pictures and a few minutes later I was able to talk to the owners and confirmed that it was indeed Strato Bowl.

***Strato Bowl** – As seen from the observation point.*

While you're at the Observation Point, why don't you try for the Geocache in the area? I tried, but couldn't find it. A couple of months later I learned that it had been stolen about the time I visited. If you do find it, leave something near space-related in the ammo can, such as a patch that has been on a mission. If you are unfamiliar with the sport of Geocaching, you can learn about this GPS-assisted global catch-and-release treasure hunt at www.geocaching.com.

To See More about Explorer I and II

The largest display about Explorer I and II that I have seen is located at the South Dakota Air and Space Museum, outside the gate of the Ellsworth Air Force Base. The display includes pieces of Explorer I and a scale model of Explorer II, both the gondola and the balloon. Be sure to bring some quarters with you to purchase a souvenir newspaper about Explorer II. The newspaper is a reprint of the Rapid City Daily Journal and has several days of coverage about the flight.

The gondola *– In the museum.*

To get to the Air and Space Museum, follow these directions:

- Take I-90 east towards Box Elder.
- Exit I-90 at the Box Elder exit, Exit 66.
- Go north from the exit for about a mile.
- On the left (west) is the Front Gate of Ellsworth Air Force Base; straight ahead is the South Dakota Air Space Museum. Parking is free as is the museum (a donation is recommended).

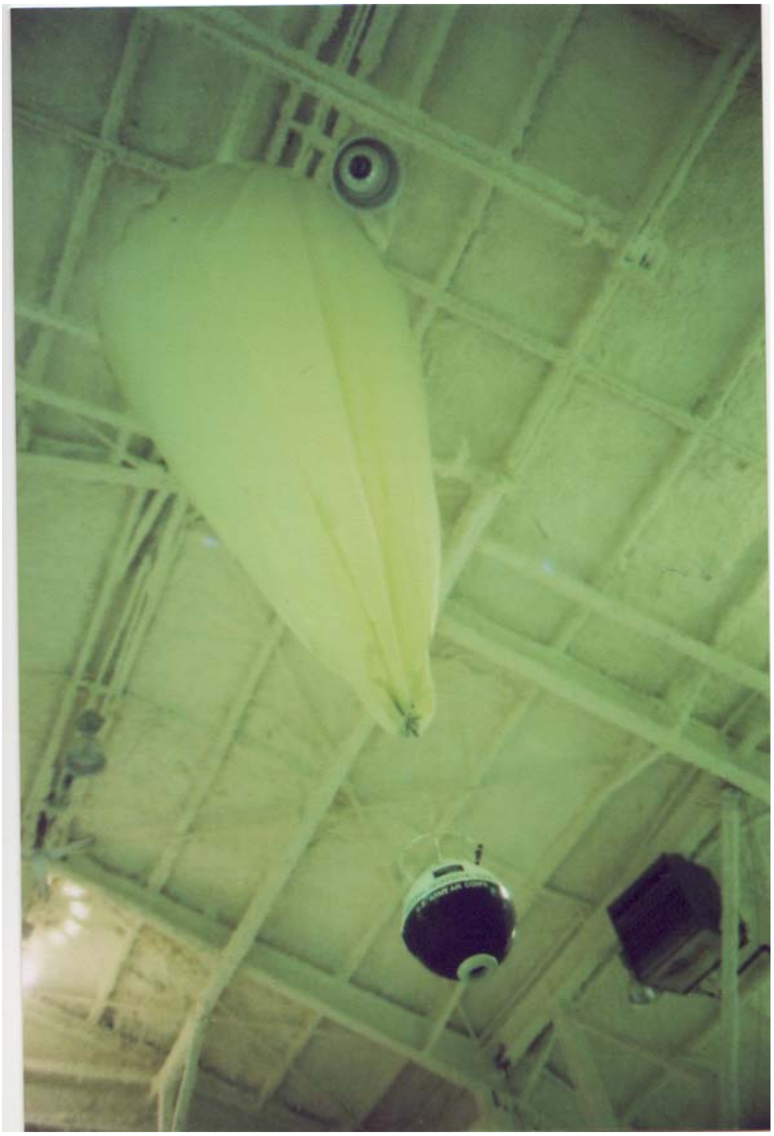
There's a lot more to the museum that just the Explorer I and II display. At the time of this writing, you could take a bus to tour a Minuteman missile silo.

Another place to see a model of Explorer II and a great museum of rocks and minerals is at the Museum of Geology at South Dakota School of Mines and Technology. The campus is located in Rapid City, so you'll have to head west from the museum.

To get to the Museum of Geology, follow these directions:

- Drive I-90 towards Rapid City.
- Exit I-90 in Rapid City on Exit 57.
- Go south on I-190.
- I-190 ends on Route 44, also called Omaha Street.
- Continue further south, two more blocks.
- Make a left turn on Main Street. Note: Main Street is split into two roads of one-way traffic. Take the road going to your left, or east.
- Drive approximately two miles as the road gradually curves towards the south.
- The museum and campus are on your right.

I will admit that I got lost in town trying to find the museum. After driving around like an idiot, I finally stopped and asked for directions. After I got to the museum, I found parking on campus a few hundred feet from the museum that was free parking. The Explorer II display is on the stairs, halfway between the first and second floor.



Explorer II *– Scale model.*

How about a Super Launch at Strato Bowl? I had a discussion with the landowners of Strato Bowl (once they found out what I was doing so close to their home). The owners of Strato Bowl charge hot air balloonists $25 to use their pasture to launch their balloons. Amateur near space explorers are smaller operations, so they may charge less for our sort of launches. So if we can generate enough interest, let's plan a Strato Bowl Super Launch (SBSL) sometime in the near future. Please contact me if you're interested.

My sources for this article were *The Pre-Astronauts*, by Craig Ryan, published by The Naval Institute Press, 1995 and the *Rapid City Daily Journal* souvenir newspaper, available at the South Dakota Air and Space Museum.

[A] Coroplast™ is a trademark of the Coroplast™ company (www.coroplast.com).
[B] STYROFOAM* Brand Foam, Trademark of The Dow Chemical Company
[C] One source of neoprene foam is Foamies®, manufactured by Darice. Foamies® are available at art and craft stores.
[D] Powerpole is a registered trademark of Anderson Power Products.

CHAPTER SIX

Near Space Recovery Systems

"What happens to the parachute if it rains?"
"It gets wet."
- Conversation with a fourth grader

Chapter Objectives

1.0 Recovery Requirements

FAR 101, the Federal Aviation Regulation Section 101 that governs untethered balloon flight, requires that we fly near space flights in π such a manner that they are not a hazard to uninvolved persons and their property. Because a basic near space capsule costs at least $500 in parts, you have an additional incentive to recover it without damage. A latex balloon with sufficient helium is guaranteed to burst, so a recovery system guaranteed to operate is vital. This chapter explains how to construct (or purchase, if you want to go that route) the most popular recovery system, the parachute. Specifically, the hemispherical parachute is discussed. In addition, a means to terminate a flight and initiate recovery is also described. Note that a flight termination system is not required for the basic near space mission, but it can prevent the loss of a near space capsule when something goes wrong, like the balloon becoming neutrally buoyant, events which have occurred on Balloons Over Idaho (BOI) and Sky Science Over Kansas (SSOK) missions.

1.1. The Parachute

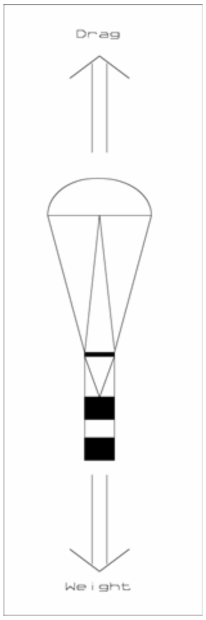
The simplest and most frequently used recovery device is the parachute. The balloon carries the parachute by its apex, which places the parachute in a position where it opens immediately upon balloon burst. A length of load line (about 30 feet long) separates the parachute from the balloon. Once the balloon bursts, we want what's left of the balloon to drop over the side of the parachute, rather than on top of it. A load line this long ensures this will occur. In near space the air is too thin for an opened parachute to break the capsule's descent very much. Even though the near space capsule is descending faster than 100 mph, the parachute is opened and ready to recover the near spacecraft at a safe speed.

A near spacecraft and its recovery parachute, a beautiful thing to see.

There are several requirements for a parachute. First, the parachute must be large enough to slow down the descending capsule to a safe landing speed. Second, the parachute must be constructed of materials that are not porous to the wind or stiff in the very cold temperatures of near space. Third, the parachute must be durable and must limit the size of any rips or snags put in the canopy. Fourth, it must be made of materials insensitive to UV exposure. Finally, it should be constructed of bright colors that can be seen from the ground, and that contrast with any landscape where it might recover.

2.0 How the Parachute Works

The parachute design in this chapter is a hemispherical cap that creates drag by catching moving air. A descending capsule travels at a terminal velocity that occurs when weight (always pointed down at the center of the Earth) is opposed by the same amount of drag (which always opposes the direction of movement).



There are two opposing forces acting on a descending near spacecraft, weight pulling down and drag pulling up. When the forces are equal the near spacecraft falls at a constant speed.

The force of weight is given by the equation,

$$\mathbf{W = m*g}$$

Physics, Halliday and Resnick, John Wiley and Sons, 1978.

Where m is the total mass of the descending equipment (balloon, capsules and parachute) and g is the acceleration due to gravity (which changes by 1% in middle near space, but can be treated as a constant in this case).

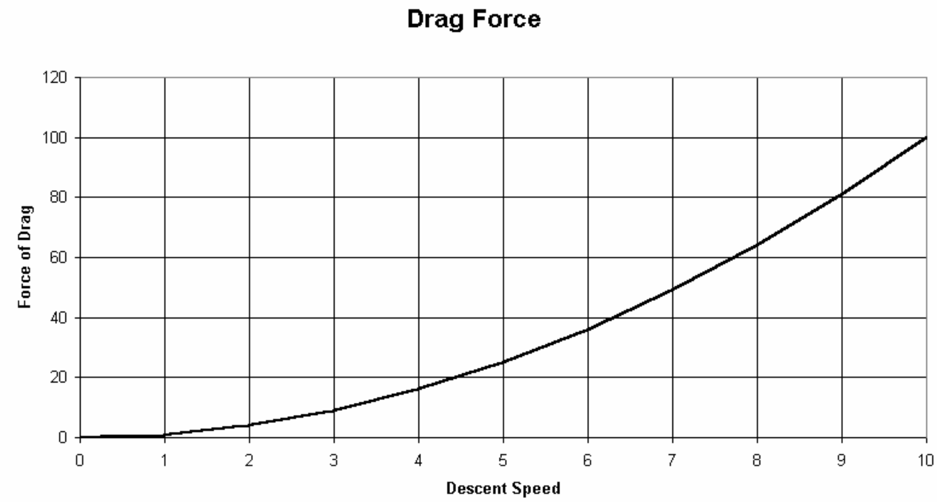
The drag created by a parachute is given by the equation:

$$\mathbf{F_d = C_d * A * d_m * (v^2/2)}$$

Encyclopedia of Physics, Lerner and Trigg, VCH Publishers, 1990.

Where C_d is the coefficient of drag (a dimensionless constant) of the parachute, A is the area of the parachute exposed perpendicularly to the air during descent, d_m is the density of the air the parachute is traveling through (and very nearly equal to the pressure), and v is the velocity the parachute is moving through the air. Of these factors, the coefficient of drag and area of the parachute are constants for a given parachute.

At balloon burst, the payload begins descending with increasing downward speed. Fortunately for the payload, the amount of drag generated by the parachute increases faster than the speed of descent increases. This is because drag depends on the square of the speed. Therefore, if you double the speed of descent, the amount of drag created by the parachute increases by a factor of four. This applies to more than parachutes; it's true in general for all objects falling through a fluid media (however, I wouldn't be surprised to see that this relationship doesn't hold at extremely high speeds).



The force of drag depends on several factors. The one of most interest to us is its dependence on the square of velocity. Double the speed, and the force of drag increases by four times.

At some velocity, the drag equals the force of gravity pulling the payload down. At this point there is no net force (remember, the force of weight acts in the opposite direction as the force of drag). When there is no net force acting on the parachute, the parachute no longer accelerates and falls at its terminal velocity. Dense bodies tend to fall with a greater terminal velocity than less dense objects because the higher density body has more mass per exposed surface area. The denser body has a greater ratio of weight pulling it down to surface area slowing it down. To increase the ratio of surface area to mass of a descending near spacecraft, we use parachutes as recovery devices.

In near space there is one more complication that we don't usually concern ourselves with here on the surface. In addition to surface area, the drag also depends on air density. If the air density doubles, so does the drag experienced by a moving object. Increasing the altitude decreases the air pressure, and therefore the air density. For a falling body, its terminal velocity decreases as it approaches the ground.

The terminal velocity of a body can be calculated by equating the force of gravity to the force of drag. By rearranging the terms, we end up with the following equation for terminal velocity.

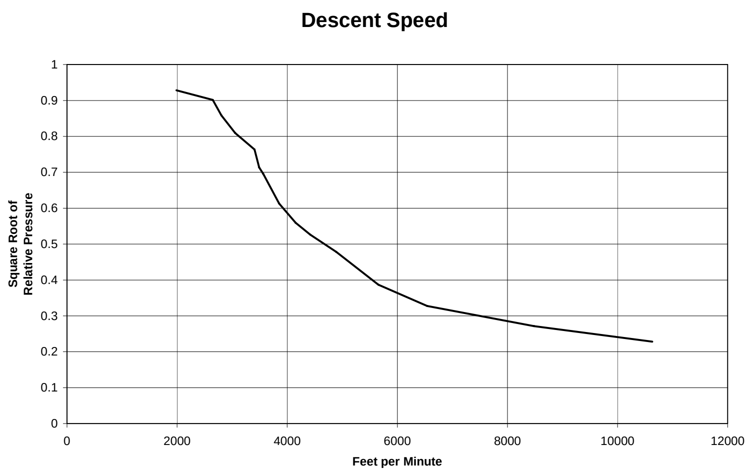
$$\mathbf{V_t = [2*W/C_d*d_m*A]^{1/2}}$$

In this case we see that every term in this equation is a constant except for air density. We therefore conclude that the terminal velocity of a falling body is proportional to the square root of the air density. A graph of air density compared to air pressure as a function of altitude shows that the terms air pressure and air density are closely proportional to each other. We get similar results if we substitute air pressure for air density.

As far as a descending parachute is concerned, it is descending through the air at a constant speed. This speed is called the Indicated Air Speed (IAS) and is affected by the mass of the air passing by the parachute in a given amount of time. Air mass is influenced by the air's density, and since air density depends on the altitude, the IAS is also influenced by altitude. The speed at which the parachute descends through the air relative to the ground is called the True Air Speed (TAS). The TAS is equal to the IAS only at sea level, where the air pressure is approximately one bar. At higher altitudes, and therefore at lower air density, the IAS is greater than the TAS by a factor of the inverse square root of the air density. So if the air density is 1/4 of its value at sea level (this occurs at an altitude of 36,000 feet), the IAS is $1/1/[4]^{0.5}$, or twice as great as the TAS.

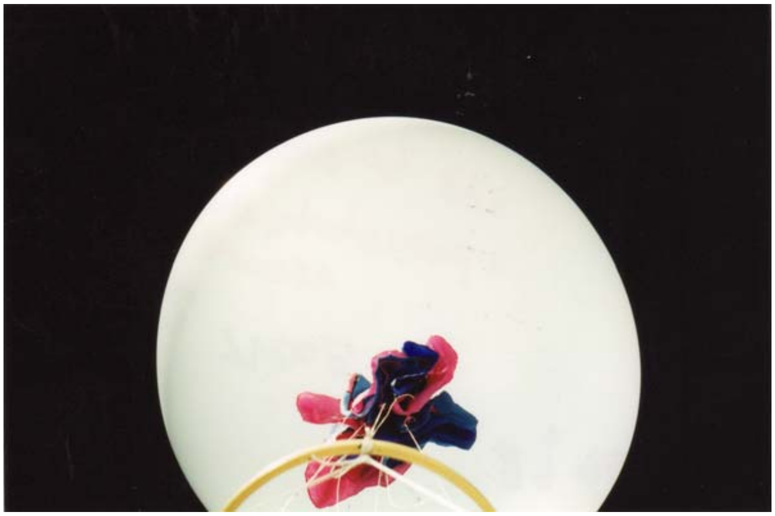
As another example, suppose a parachute lands a payload at 22 ft/sec (TAS of 22 ft/sec). At 100,000 feet where the air pressure density is only 10 millibars, or 1% of surface air pressure, or 1/100th of sea level pressure, the parachute descends at a speed ten times greater than it does at sea level, or at 220 ft/sec. So do not be alarmed when you see your near spacecraft at 100,000 feet begin its descent at a speed of 145 mph. But do be alarmed if the descent speed continues to be 220 feet/minute below altitudes of 50,000 feet. Note: Changes in air density closely match changes in air pressure. If air pressure is substituted for air density, the calculated descent speeds are almost identical.

Let's look at another example. I've taken data from one of the TVNSP flights that reached an altitude of 90,000 feet before the balloon burst. Entered in a spreadsheet are the altitude, UTC time, and air pressure according to the Standard Atmosphere model. A graph was generated from the descent speed at altitude and the inverse square root of the air pressure at altitude (times a constant scaling factor). The resulting graph is illustrated below. Notice that the inverse square root of air density tracks the TAS of the parachute almost perfectly.



Altitude vs. Descent Speed -
Due to the extremely low air pressure in near space, the initial descent speed of the near spacecraft can be ten times higher than at sea level.

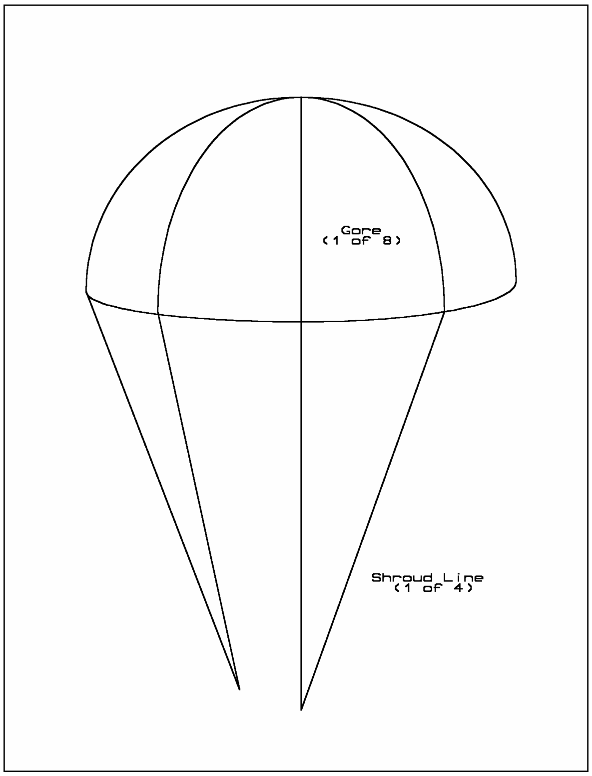
The author recommends you generate a similar graph or table from your first flight data and laminate it. The graph or table should be left with Mission Control so they know what kind of speeds to expect during descent. Seeing a fast descent for the first time puts people into a panic.



Before balloon burst -
The parachute and balloon shortly before balloon burst. The parachute drapes below the balloon. Note how black the sky is and that the parachute is not experiencing any wind.

After balloon burst -
The parachute shortly after balloon burst. It appears that some of the balloon remains are wrapped around the parachute ring. At this point, descent speed is around 100 mph!

3.0 Making a Hemispherical Parachute



The hemispherical parachute -
Imagine cutting a ping-pong ball in half.

A simple sheet of fabric can make a parachute (as well I remember when I was in grade school) but is wasteful of material. The hemispheric parachute is a simple design and efficiently uses the fabric it is constructed from. Expect to spend about $75 making a seven-foot parachute. If time is more important than money, or if the handcrafting a parachute doesn't appeal to you, then purchase a complete parachute from a high-power rocket company, like RocketMan. Check the list of suppliers at the end of the book for recommendations.

As the hemispherical parachute descends, air pressure builds up inside of it and eventually escapes. In the simple hemispherical parachute, built-up pressure escapes from under the parachute's canopy by forcing the parachute to rock or tip from side to side. One way to reduce this tendency to rock back and forth is to cut a spill hole in the top of the parachute. Spill holes keep the pressure from getting so high that the parachute has to rock from side to side to release it. The spill hole needs to be about 20% the diameter of the parachute.

3.1. Materials

- Canopy fabric, amount depends on parachute diameter (16 yards should be the maximum) Note: More than one color of fabric can be used on the parachute canopy.
- A 150 foot roll of 150# test woven Dacron[A] kite line
- 50 feet of ½" twill tape (for a seven-foot parachute)
- Four or five sheets of poster board
- Eight bearing swivels, 100# test
- One bearing swivel, 200# test
- Cotton thread
- Colored pencil in a color that contrasts with the canopy color
- Fabric label or fabric marker
- Scissors or soldering gun with a cutting tip

3.1.1. Notes on Parachute Fabrics

I recommend making the parachute out of ripstop nylon, the kind found in local fabric stores. This material is coated with a water repelling film, making it less porous to the air, but still supple and flexible. Kite fabrics have a "harder" coating to them, making them more crinkly. The lower porosity of the fabric means a smaller parachute is required to slow the near space capsule down. In addition to reducing fabric porosity, the urethane coating also protects the ripstop nylon from damage due to UV exposure (which is at greater levels in near space). Being a ripstop fabric, the growth of rips and tears in the parachute canopy is reduced by the thicker threads woven into the fabric. Finally, ripstop nylon is readily available and dyed in many bright colors. Use a combination of several different colors of ripstop when making the parachute so it has the best chance of standing out. If you decide to use a single color, then think about using a florescent color to increase the parachute's visibility. If the cost of ripstop fabric (about $7/yd) is a concern, then another source of parachute canopy material is a retired hot air balloon envelope. After 500 hours of use, the FAA requires that these fabric envelopes be replaced. You can purchase a lot of ripstop this way on a budget. If you decide to use balloon material, you'll have fewer color options. You'll also have to wash the fabric several times to get the gas smell out of it.

3.2. Procedure - Determine the parachute's diameter

Notes on Parachute Diameter

The equation below is typical of parachute formulas used in model rocketry. It calculates the diameter of a circular parachute (flat sheet of round fabric) based on the weight of the payload to land at 15 mph and a typical coefficient of drag.

$$\textbf{Diameter (inches)} = [\textbf{weight (pounds)} * 0.454]^{1/2} * 39.6$$

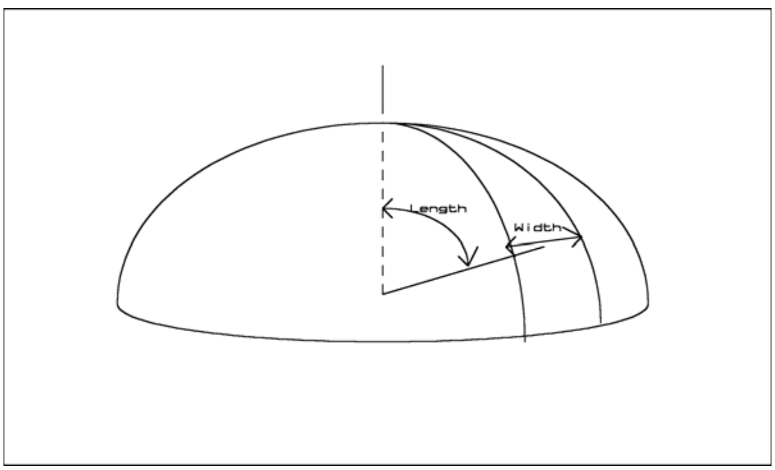
From http://www.info-central.org/recovery_psize.shtml

I modify the results by assuming the calculated diameter is actually half of the circumference of a sphere. So multiply the results by $\pi/2$, or about 1.5 to determine the diameter of the hemispherical parachute. The results match the diameter of the hemispherical parachute I currently use. One factor has a big influence on the accuracy of an equation like the one above. That is the porosity of the fabric being used to make the canopy. If a “leaky” fabric (with a higher porosity) is used, then increase the diameter of the parachute.

For most cases, assuming a payload weight of 13 pounds is sufficient. Why 13 pounds? Because you can assume the parachute weighs one pound, which must be added to the near space capsule weight of 12 pounds.

Making a Parachute Gore Pattern

The parachute described here is a simple hemispherical cap made from eight identical gores. To increase the parachute’s stability, there is a hole in the top of the parachute to vent excess pressure inside the canopy. The vent is 20% of the parachute's final diameter. The pattern for this hemispherical parachute was calculated by dividing a hemisphere into 90 rings, each one-degree thick. The diameter of each ring with respect to the central axis of the parachute is proportional to the angular elevation of each ring. From this the diameter of each ring was calculated. Next, from the calculated diameters, the circumference of each ring was determined. At this point the distance of the ring from the apex of the parachute and its circumference has been determined. Divide each circumference by eight (the number of gores) and the width of the gore at each point has been determined. Add a little billow to the parachute by adding another 5% to 10% to the gore width.



Gore dimensions are calculated by measuring the width and length of pie-shaped wedges cut out of a hemisphere.

3.2.1. Generating Your Own Pattern

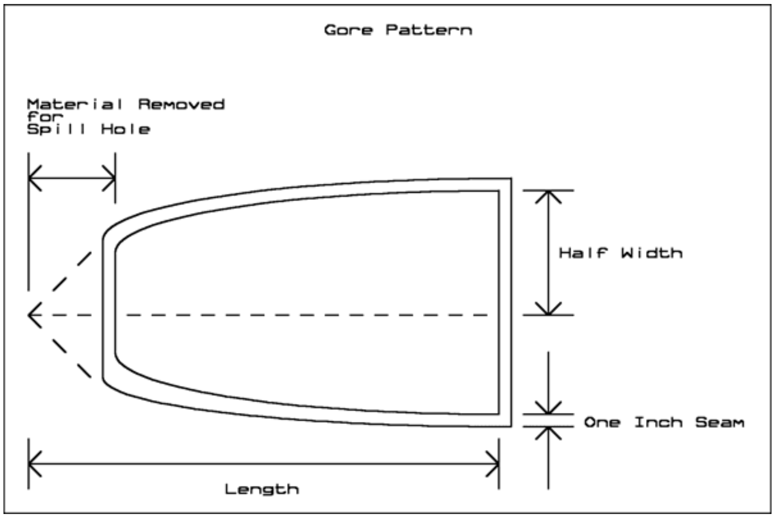
If you wish to design your own parachute using your own spreadsheet program, the commands I used are shown below.

Spreadsheet Commands

	A	B	C	D	E	F
1	Diameter	(feet)				
2						
3	Degrees	Radians	Radius of Ring	Half Width of Gore	Length along Gore	Half width of Gore
4			units	units	inches	inches
5						
6	1	= +A6/57.3	= SIN(B6)	= (+C6*3.14159)/8	= (+A6*$C$1)*0.105	= (+D6*$C$1*6)+1

Procedure
Enter the diameter of the parachute to design in cell C1 (diameter in feet). Column A values begin at one degree (cell A6) and increments in units of one degree until the angle of 90 degrees is reached. Remember, the number generated in column F is half the width of the gore at the distance down the center of the gore indicated in column E.

Before cutting parachute gores out of fabric, a pattern in poster board is needed. The poster board pattern is placed on top of a sheet of fabric and the outline of the gore traced in pencil. Then the fabric can be cut into eight near identical gores. Several pieces of poster board are needed to make a gore pattern. The maximum dimensions of the gore pattern determine the number of sheets of poster board required to make a gore pattern. Tape the poster board sheets together to make a single sheet large enough to fit the pattern. Draw a straight line down the center this sheet of poster board. Mark along the length of this centerline at every point listed in column five of the spreadsheet. Draw a perpendicular line from each marked point that extends both directions away from the centerline. Mark a distance on the perpendicular line equal to the distances indicated in column six of the spreadsheet. Every 15th line, make an extra dot near each end to indicate where seam-matching marks will be transferred to the fabric. Ignore the spreadsheet values where the angle is less than about 9 degrees, as that is the location of the spill hole. You can use your spreadsheet's graphing ability to take a peek at the final pattern, but remember the graph will not by default print the X and Y-axis to the same scale. Your final pattern should look similar to this one below.



The pattern for a single gore. Make eight of them.

Before cutting the poster board pattern, add a one-inch seam allowance to the top and bottom edge. There already is a one-inch seam allowance included on the sides.

3.2.2. Tables of Gore Patterns

If you would rather not calculate your own gore pattern, I have included several calculated gore patterns below. Add a one-inch seam allowance all the way around the dimensions given below.

Six Foot Diameter Parachute			
Length (in.)	**Half Width (in.)**	**Length (in.)**	**Half Width (in.)**
0.0	4.3	27.6	24.8
1.3	5.3	28.9	25.5
2.5	6.4	30.6	26.2
3.8	7.5	31.4	26.8
5.0	8.6	32.7	27.4
6.3	9.6	33.9	27.9
7.5	10.6	35.2	28.5
8.8	11.6	36.4	29.0
10.1	12.7	37.7	29.4
11.3	13.6	39.0	29.8
12.6	14.6	40.2	30.2
13.8	15.6	41.5	30.6
15.1	16.5	42.7	30.9
16.3	17.5	44.0	31.2
17.6	18.4	45.2	31.4
18.8	19.3	46.5	31.6
20.1	20.1	47.7	31.8
21.4	21.0	49.0	32.0
22.6	21.8	50.3	32.0
23.9	22.6	51.6	32.1
25.1	23.4	52.8	32.1
26.4	24.1		

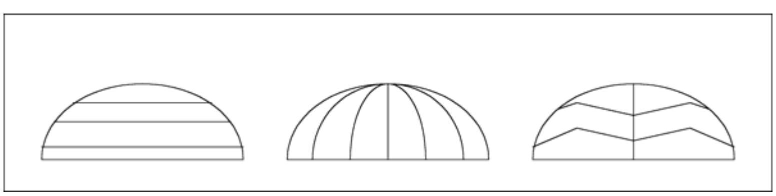
Seven Foot Diameter Parachute				
Length (in.)	**Half Width (in.)**		**Length (in.)**	**Half Width (in.)**
0.0	4.8		32.2	28.8
1.5	6.0		33.7	29.6
2.9	7.3		35.2	30.4
4.4	8.5		36.6	31.1
5.9	9.8		38.1	31.8
7.3	11.0		39.6	32.4
8.8	12.2		41.0	33.0
10.3	13.4		42.6	33.6
11.7	14.6		44.0	34.1
13.2	15.8		45.4	34.6
14.7	16.9		46.9	35.1
16.1	18.0		48.4	35.5
17.6	19.1		49.8	35.9
19.0	20.2		51.3	36.2
20.5	21.3		52.8	36.5
22.0	22.3		54.2	36.7
23.5	23.3		55.7	36.9
24.9	24.3		57.2	37.1
26.4	25.3		58.6	37.2
27.9	26.2		60.1	37.3
29.3	27.1		61.6	37.3
30.8	28.0			

Eight Foot Diameter Parachute			
Length (in.)	**Half Width (in.)**	**Length (in.)**	**Half Width (in.)**
0.0	5.3	36.9	32.8
1.7	6.8	38.5	33.7
3.3	8.2	40.2	34.6
5.0	9.6	41.9	35.4
6.7	11.0	43.6	36.2
8.4	12.4	45.2	36.9
10.0	13.8	46.9	37.6
11.7	15.2	48.6	38.3
13.4	16.5	50.3	38.9
15.1	17.9	51.9	39.4
16.8	19.2	53.6	40.0
18.4	20.5	55.3	40.4
20.1	21.7	57.0	40.9
21.8	23.0	58.6	41.2
23.5	24.2	60.3	41.6
25.1	25.4	62.0	41.8
26.8	26.6	63.7	42.1
28.5	27.7	65.3	42.2
30.2	28.7	67.0	42.4
31.8	29.8	68.7	42.4
33.5	30.8	70.4	42.5
35.2	31.8		

Transfer the desired gore pattern to poster board. Every 15th line, make an extra dot near each end to indicate where seam-matching marks will be transferred to the fabric.

Note: If you don't want to make 90 separate measurements on the gore, throw out every other one; the result should be just as good. Be sure to make as many seam-matching dots.

Note: There's no reason the gore has to be in a single piece. The gore pattern can be cut into two pieces, and a different color of fabric used on each piece. Be sure to include an extra seam allowance where the panels overlap and extra twill tape to sew over the extra seams.



Some possible parachute patterns.

Transferring Gore patterns to Fabric

Align the poster board pattern along the major threads in the ripstop.
Trace the gore pattern on to the fabric with a contrasting colored pencil.   Make an extra mark on the fabric on each side at every location where you indicated seam-matching dots on the pattern, about ½ inch in from the edge. Trace a total of eight gores onto the fabric.

Cutting the Fabric

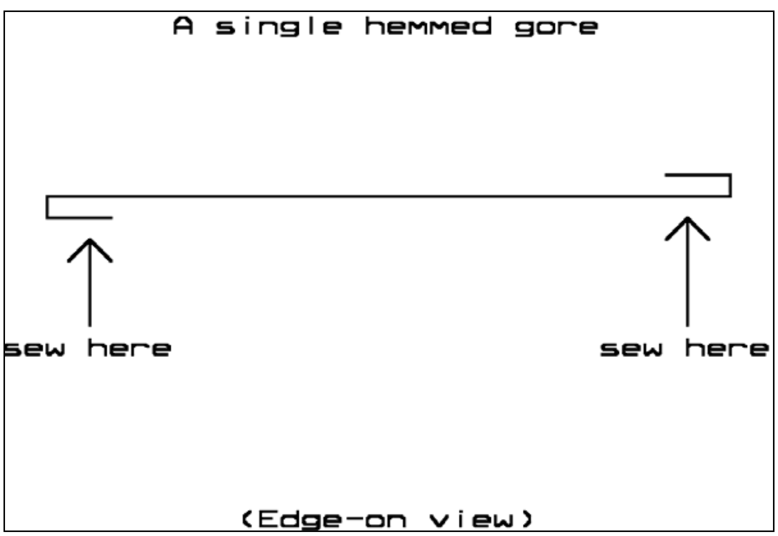
To cut the gores out of the ripstop nylon, it's best to use a hot soldering iron equipped with a cutting tip. The hot tip melts the nylon threads of the fabric together, keeping the fabric from unraveling.

Sewing the Gores into a Canopy

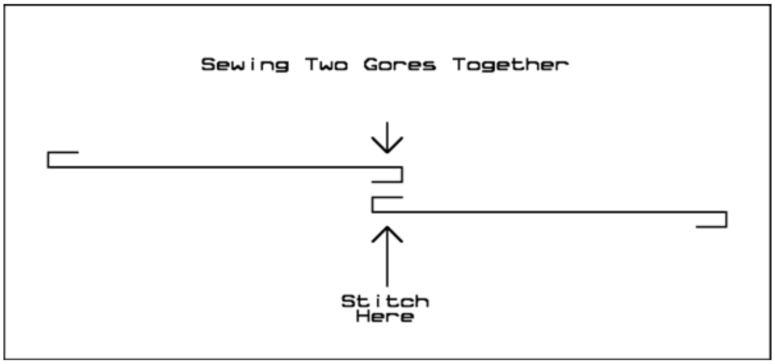
Note: I am not a seamstress; so if you're an expert, please do not get upset with my sewing directions. At the time of this writing I have constructed five parachutes successfully and experienced no failures. No doubt there is a better way to construct a parachute than I am describing here (sounds like another topic for a sequel to this book).

Sew the parachute with a strong cotton thread and use a needle with an eye to match the diameter of the thread. Lock the beginning and ending of each seam by backstitching a few times, running the sewing machine briefly in reverse each time.

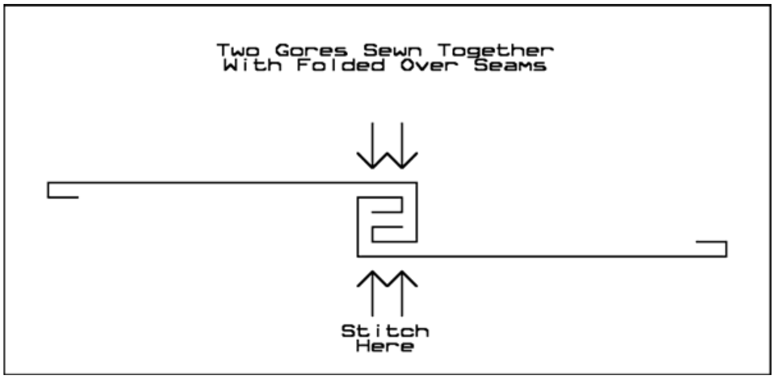
- √ Draw a line ½" from the edges of the long sides only on each gore.
- √ Fold the fabric along these lines, folding the right-side edges up and over and the left side edges down and under. You may run a fingernail along the seam as you fold to "iron" in the creased hem.
- √ Sew these folded hems in place with a single line of stitching on each gore.
- √ Take two gores and overlap their hemmed edges, with a down-folded hem facing an up-folded hem so the seam allowances are sandwiched in between.
- √ Align and pin the top and bottom edges of the two gores, and also align and pin the seam-matching marks you made.
- √ Sew down the middle of the overlapping edges. You will be sewing through four layers of fabric. Pull out the pins as you approach them; try to avoid sewing over pins.
- √ Rotate the sewn seam by 180 degrees, interlocking the folded seams. You may use pins to keep the seam rotated and taut.
- √ Sew down the interlocked seams. You will now be sewing through six layers of fabric.



Overlapping seams before sewing them together.



The top and bottom seams of the sewn parachute canopy.

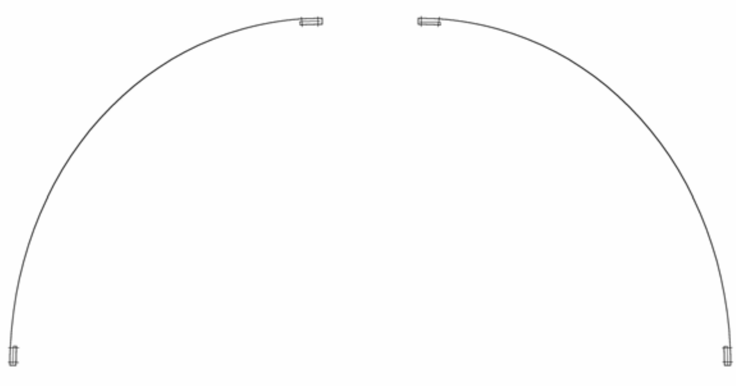


Rotated Seams - Interlocked

Add the next gore in the same fashion, until all the gores are sewn together to form a single sheet. Close the parachute by sewing the first and last gores together. If you're like me, the edges of the canopy will not line up. In this case, I start the seam at the spill hole first and make that my reference.

Top and Bottom Seams of the Parachute

Trim the top and bottom edges of the parachute canopy to make even edges all the way around. Hem the top and bottom edges by folding the edge over by ½ inch and sewing it down, then turning this hem by ½ inch again and sewing through all three layers. The doubled over seams protect the raw edges of the fabric from the force of the passing air during descent and add strength to the parachute's edges.



X-Ray View of Top and Bottom Parachute Seams

Twill Reinforcement

The eight gore seams of the parachute canopy will be overlaid with twill tape. The twill tape will add reinforcement to the seams, and will also form loops at the bottom edge of the canopy where the shroud lines will connect. Only four pieces of twill tape are used, each covering one seam, crossing over the spill hole, then covering the seam directly opposite. Therefore, you will need to cut four strips of 1/2" wide twill tape to a length that begins at one end of the parachute, crosses over the top (apex) and back down to the opposite side, plus an additional twelve inches for shroud line loops.

Twill tape

- √ To calculate the required length, multiply the radius (one half the diameter) of the parachute by π and add twelve inches.
- √ Cut four lengths of ½ inch twill tape to the calculated length.
- √ Mark each tape at four inches and at six inches from each end. Note: Ideally, the six-inch mark on the twill tape will align with the bottom edge of the canopy. The four-inch mark is where the twill doubles back on itself and gets sewn to the underside of the canopy
- √ Use the gore pattern to determine the radius of the canopy's spill hole.
- √ Find and mark the center of each tape.
- √ From the center of each twill tape, place two diameter marks on the twill tape at a distance equal to the spill hole radius plus an additional couple of inches for slack. Note: These marks are where the twill tape begins to be sewn to the canopy.

The table below gives the expected spill hole radii. However, since sewing skills vary, the diameter of the spill hole never comes out as expected. The better your sewing skills, the less slack the twill tape requires. The author recommends two inches of slack for the first parachute (the excess is tied off at a later time).

Parachute Diameter	Spill Hole Radius
5 ft	4.7 in.
6 ft	5.6 in.
7 ft	6.5 in

Note: A second method to determine the placement of the diameter marks is to measure the current diameter of the spill hole. To do so, grab two opposite ends of the spill hole and pull them a part as far as they will go. This collapses the spill hole. Measure the distance between the extreme points, which is half the circumference of the spill hole. Divide this distance by π to calculate the radius of the spill hole.

- √ Lay the tape on top of the canopy and over a seam (between two gores).
- √ Align the spill hole radius markings with the top edge of the canopy.

- √ Starting at the spill hole, sew along one edge of the twill tape.
- √ About 4 inches before sewing to the edge of the canopy, fold the end of the twill tape two inches past the edge of the canopy. Ideally, the edge will line up with the six-inch mark, and you can fold the tape under at the 4 inch mark.
- √ Align the end of the tape with the underside of the seam.
- √ Continue sewing the twill tape to the end of the canopy, making sure you sew the end of tape to the underside of the canopy. This will leave a two inch loop at the bottom of the canopy.
- √ Turn the canopy around and continue sewing up along the other edge of the twill tape, returning to the beginning position at the edge of the spill hole.
- √ Examine the twill tape loops at the bottom of the canopy to make certain that the ends are secured firmly underneath. It the tape spilled out of place and was not sewn down properly, resew the ends of the twill tape from the inside.
- √ Reinforce the area were the twill tape meets the edge of the canopy at top and bottom by sewing crosswise over and slightly beyond the tape several times.
- √ Repeat for the three remaining twill tapes.

Twill tape after being sewn to canopy.

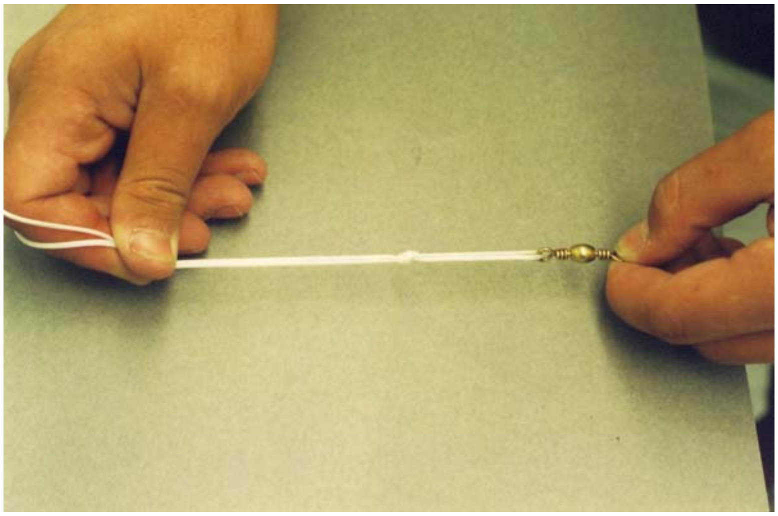
- √ Gather together the twill tapes at the top of the canopy (over the spill hole).
- √ Align the center marks of each tape.
- √ Cut a twelve-inch length of woven Dacron kite line and tie on a strong, 200# bearing swivel in its center.
- √ Tie the other ends of the line around the center of the twill tapes.
- √ Take out the slack in the twill tapes by tying a knot in the twill tapes between the bearing swivel and spill hole edge. The position of the knot depends on the amount of slack in the twill tape, so be prepared to experiment with the knot placement.

3.2.3. Shroud Lines

Each shroud line begins at twill loop on the canopy, drops to a bearing swivel at the parachute ring, and returns to the next twill loop on the canopy. Shroud line knots are covered with heat shrink tubing to reduce the chances of the knot from coming undone. Make the shroud lines from 150# woven Dacron kite string. Use kite line rather than purchasing the twisted nylon cord, as the woven kite line stays together as a unit better than the twisted cord does.

- √ Cut four shroud lines, each with a length four times the parachute's diameter.
- √ Mark the center of each shroud line.

√ Run the shroud line through one loop of a 100# bearing swivel.
√ Center the mark in the loop and tie an overhand knot, trapping the bearing swivel inside the loop formed by the knot. The bearing swivel will be used to attach the parachute ring.

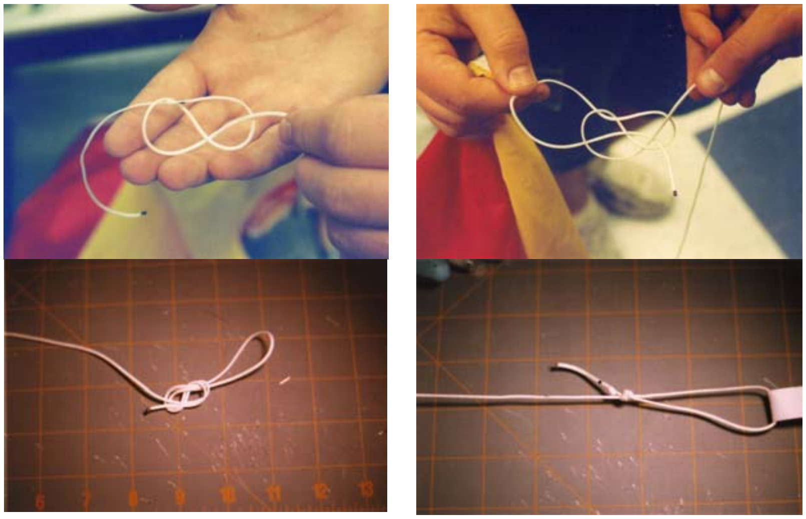


The end of the shroud line. It terminates in a bearing swivel.

√ Mark each end of the line 6" from the end
√ Cut eight two-inch lengths of thin heat shrink tubing, a little more than twice the diameter of the shroud lines.

√ Slip two pieces of tubing on each shroud line (from opposite ends) and push them toward the center of the shroud lines where they are temporarily out of the way.
√ Tie one end of a shroud line to a twill loop at the bottom of the chute, matching up the knot with the mark that was made 6" from the end of the line. Use a blood knot as it will resist pulling loose of the parachute during descent.
√ Tie the other end of the Dacron line to a neighboring twill loop, again aligning the knot with the mark on the line.
√ Repeat this for the other three Dacron loops.
√ Do not yet shrink the tubing over the knots until the shroud lines are checked.

Test the parachute as follows:
√ Take the parachute outside and grab the shroud lines at their bottoms, on the center marks you made.
√ Run as fast as you can and the parachute should open, making it difficult for you to continue running. You should do this when the neighbors aren't looking.
√ Look at the opened parachute and make sure it looks symmetrical and that none of the shroud lines are grossly slack.
√ If the shroud lines do not match, then untie the longest shroud line and retie it to match the others, and then repeat the parachute test again.
√ If the parachute looks good, cut the excess string from each knot back to about 1/2" and carefully use a lighter to melt the ends slightly.
√ Slide the heat shrink tubing over the knots and shrink it down, taking great care not to damage the nylon lines with the heat gun.



Tying the Knot –
Step 1 - Top Left
Tying the shroud line to the canopy. Start by making this "figure 8".
Step 2 - Top Right
Pass the free end of the shroud line though the canopy, then loop the end back through the knot, exactly as in came through originally.
Step 3 – Bottom Left
Without canopy to make it clearer
Step 4 – Bottom Right
Knot tightened and an overhand stopper knot added

3.2.4. Documentation

At least two items should be recorded on the canopy (where they can't get lost). Document the following items on the canopy:

- Diameter of parachute
- Weight of the parachute

Either write these measurements on the canopy with a fabric marker, or have the measurements embroidered onto a cloth label and sew the label to the canopy.

Along with the previous two, there are three other recommended markings. The first is useful when untangling the shroud lines and the other two are just nice to know items. To simplify untangling the shroud lines, label the bottom of each shroud line with a tag. The tag contains the number of the shroud line. The numbers are written in either clockwise or counterclockwise sequence, as are the positions on the parachute ring. The shroud lines are disconnected from the parachute ring while they are being untangled. Labeling the shroud lines and parachute ring makes quicker work of reattaching the shroud lines to the parachute ring.

The author labels the gores in the canopy. The numbers on the gores uniquely identify each gore. If the canopy is damaged during a mission, the damaged gore can be recorded using its identification number.

Finally, I personally like to record the number of missions the parachute has been used on. I set aside an area of the canopy and label it with the word, "Flights". After each flight or mission, I draw another hash mark. Use a permanent ink fabric marker to make the parachute's hash marks.

Recording the number of missions

4.0 The Parachute Ring

The parachute ring keeps the shroud lines of the parachute from twisting up during a near space mission. The ring does not take the stress of the weight of the near spacecraft pulling down and the balloon trying to lift up, the parachute shroud lines do that. Instead, the parachute ring only forces the shrouds lines apart so they don't tangle. Described below are two methods of making parachute rings. The simplest design uses a needlepoint ring and has been tested by KNSP and TVNSP. The more elaborate design uses mini-capsule containing recovery aids and had not been adequately tested yet at the time of this writing.

4.1. Needle Point Loop Design

Needle point parachute ring

This is the fastest method to create a parachute ring.

4.1.1. Materials

- Twelve-inch diameter wood needlepoint loop
- Epoxy
- 1/8" thick Basswood stock
- Woven Dacron kite line (150# recommended)
- Twelve bearing swivels (at least 100# test)
- Eight one-inch split rings
- Heat shrink tubing 1/8" diameter
- Heat shrink tubing 1/4" diameter
- Fine tip fabric marker

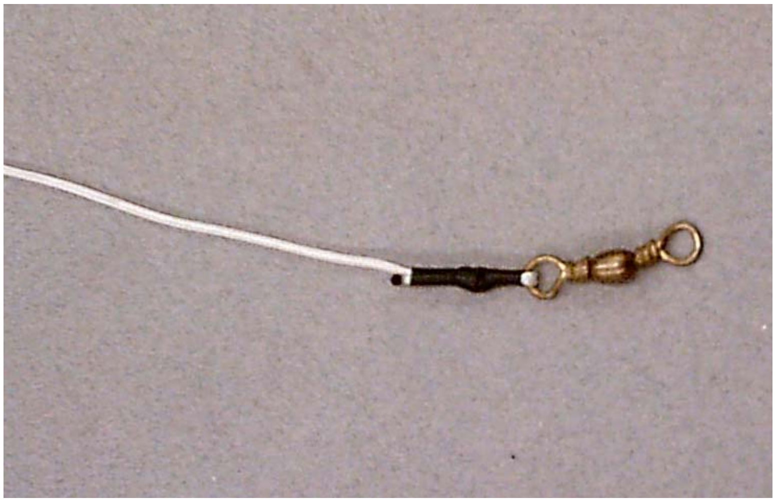
4.1.2. Procedure

The loop actually consists of two rings. The inner ring is a solid piece of wood and the outer ring is split with a clamping mechanism. Assembling a parachute ring requires that the individual rings be epoxied together to make a single, stronger ring. After the epoxy is set, the clamp is removed and the remaining gap filled. The parachute ring is completed after adding loops of Dacron kite line.

A needle point ring before it is converted into a parachute ring. Opened ring shows the clamp and rivets

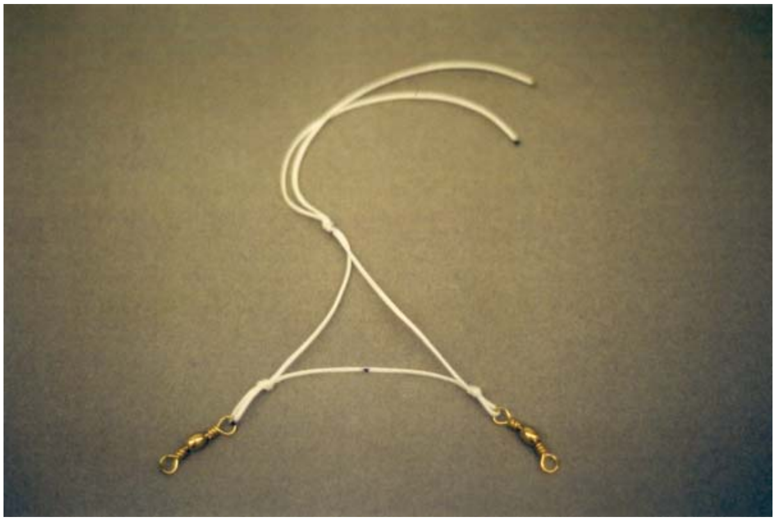
√ Loosen the outer ring of the needlepoint loop.
√ Separate the inner ring from the outer ring.
√ Coat the outer surface of the inner ring with epoxy.
√ Slip the two rings back together and tighten down the clamp.
√ Let the epoxy set overnight.
√ Remove the clamp by grinding off the rivet heads with either a metal file or a Dremel with an abrasive cutting wheel. Note: leave the metal rivets in the ring; just grind off the heads of the rivets.
√ Cut and epoxy a piece of basswood to fill the gap left between the clamps.
√ Clamp the basswood into place until the epoxy sets.
√ Drill four equally spaced holes (1/8" diameter) in the parachute ring.
√ Cut a length of woven Dacron kite line, ten feet long.
√ Melt the cut ends of the Dacron line with a lighter, carefully.
√ Slide eight bearing swivels on the Dacron line.
√ Slide a one-inch length of 1/4" heat shrink tubing on the Dacron line.
√ Lay the ends of the Dacron line together and tie a doubled, overhand knot.

√ Slide the heat shrink tubing over the knot and shrink it.



Heat Shrink Tubing – *Securing the knot.*

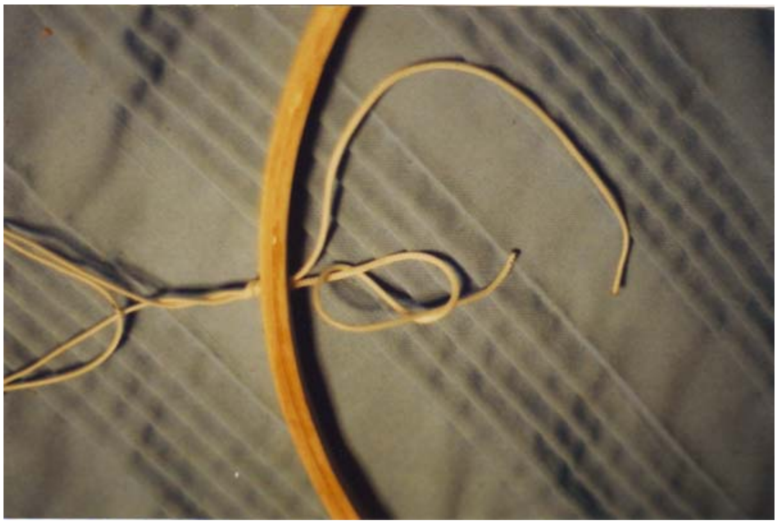
√ Stretch out the loop of Dacron into a straight line, positioning the covered knot about 6 inches from one end.
√ Mark the opposite ends with a fabric marker.
√ Stretch out the loop again, this time by placing the marks together.
√ Mark the new ends. This will make four marks on the loop.
√ Use these marks to find the midpoint between each pair, making 8 equally spaced marks on the loop.
√ On each mark, position a bearing swivel and tie a knot, trapping the bearing swivel.
√ Now there should be eight bearing swivels tied around the Dacron loop, equally spaced.



Trapped bearing swivel

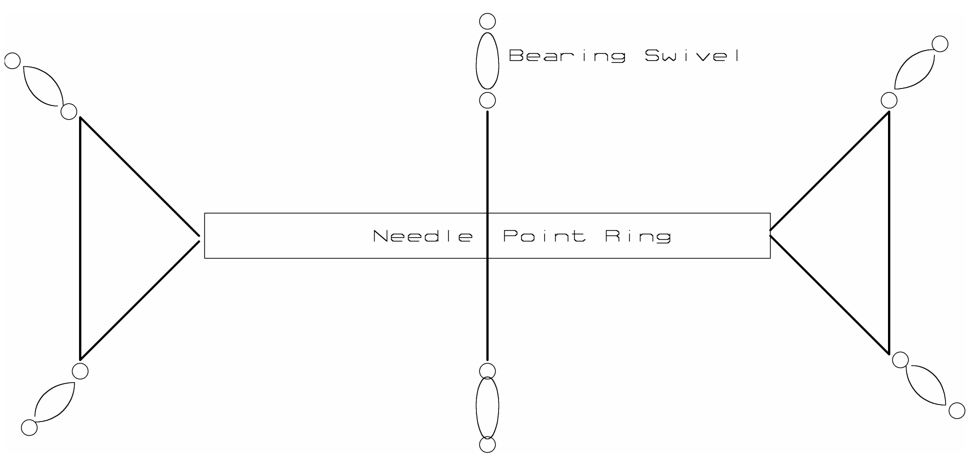
√ Cut four lengths of woven Dacron, 14” long.
√ Perform the following steps on each piece:
√ Mark the midpoint of the Dacron cord (this is point “B”).
√ Mark two more locations on the 14” Dacron; two inches in each direction from the previous mid-mark (Label these marks as “A” and “C”).
√ Slide one bearing swivel on the Dacron at mark “A” and tie an overhand knot, trapping the bearing swivel at mark “A”.

√ Slide a short length of heat shrink tubing over the knot and shrink the tubing to prevent the knot from loosening.
√ Slide a second piece of heat shrink tubing over the Dacron and push it up against the first knot temporarily; do not shrink this tubing yet.
√ Slide a second bearing swivel on the Dacron to mark "C" and tie an overhand knot, trapping the bearing swivel at mark "C".
√ Slide the second piece of heat shrink tubing from its temporary location to cover the second knot and shrink the tubing.



Line gong through the needlepoint loop

√ Pass the two free ends of each 14" Dacron line through a hole in the needlepoint loop from the outside of the needlepoint loop.
√ Lay the free ends of the 14" Dacron line together and tie a doubled overhand knot on the inside of the ring.



Parachute ring and lines.

√ At this point the needlepoint loop has four small loops of woven Dacron tied to it, with each tiny loop containing two bearing swivels.
√ Connect every other bearing swivel of the ten-foot Dacron loop to the bottom bearing swivels of the parachute ring with split key rings.
√ When completed, the ten-foot Dacron loop forms a zigzag beneath the parachute ring. The alternating bearing swivels are connected to the top module of the near spacecraft.

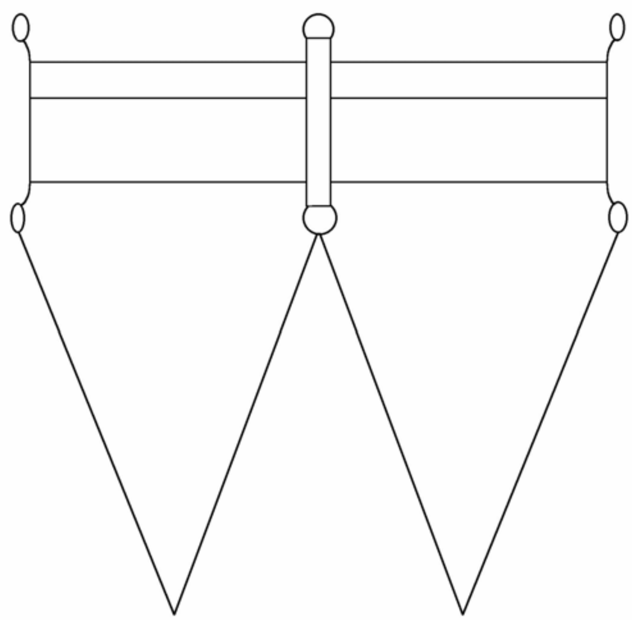
√ Connect the top bearing swivels to the ends of the parachute shrouds with one-inch split rings.

4.2. Mini-Capsule Parachute Ring

An alternative to a simple wooden hoop is to construct a mini-capsule in place of the hoop. The mini-capsule keeps the shroud lines apart while allowing recovery aids and flight termination systems close to the parachute. This should be considered an experimental design. The author has constructed one mini-capsule, but it has not been thoroughly tested at the time of this writing.

4.2.1. Mini-Capsule Design

Build a near spacecraft module as described in Chapter One, but only a few inches tall. Add the normal abrasion jacket and link loops. Add the same 10-foot Dacron loop used in the parachute ring to the bottom link loops of the mini-capsule.



Mini-Capsule Design

4.2.2. Electronics For Mini-Capsules

Good electronics to incorporate into a mini-capsule are recovery aids, like trackers and beacons, and flight termination systems.

Mini-Trackers

A good recovery aid is the Tiny Trak II based near space tracker, as described in Chapter Two, Section Three. A flexible 2 m or 70 cm dipole antenna, with the top element tied loosely to a shroud line or a 70 cm wire dipole makes good antenna choices. Let the bottom element of the flexible dipole antenna dangle free.

Audio Beacons

Another recovery aid, although of a different nature from the previous one, is the audio locating beacon. Commercial models are available through high power rocket dealers. Quite a serviceable one can be constructed for about $6 from Radio Shack. Check Section Seven of this chapter for details.

Flight Termination Systems

Since the HT's receive capability isn't used in the Tiny Trak based near space tracker, a programmable DTMF decoder can be incorporated into the mini-capsule. This keeps the flight termination system close to the parachute. Again, consider this experimental, as there are no formal plans in this book for DTMF-controlled Flight Termination Units. Complete Flight Termination Systems are discussed in Section 6 below.

4.2.3. Wrapping Up

Your parachute and parachute ring is complete. The authored tested his first parachute by dropping it from a tall building, but found this hard to do successfully. Below, a different way to test the parachute for proper opening, drag, and stability is explained. The testing lets you characterize the parachute's performance.

5.0 Parachute Testing and Proper Storage

I recommend that you test your completed parachute before use; don't rely on the parachute to work properly (although it probably will) during a mission without first testing it. Testing ensures the parachute opens without tangling, and determines the landing speed of the parachute for different payload weights. With the landing speed of the parachute and knowledge of air pressure at various altitudes you can generate a descent profile of the parachute. Proper storage of the parachute between missions increases the reliability of the parachute. A parachute that is stored wadded up in a tight ball may not function properly during descent.

5.1. Parachute Testing

One way to test the parachute at various air speeds is to rent time on a wind tunnel. This author assumes this is not a realistic option. Instead, to accurately measure the descend speed of the parachute, you'll perform drop tests. The drop test measures the parachute's performance under various payload weights and records the descent speed of the parachute.

Parachute and near spacecraft raised beneath the tethered balloon.

This test is fun. The TVNSP crew performed this test in a soccer field in Boise and attracted quite a bit of attention. This test requires the use of a tethered helium-filled weather balloon to carry the parachute and capsule over 100 feet above the ground for a drop test.

Parachute away! *The release pin was pulled loose and the parachute descends.*

5.1.1. Materials

Collect the following items for the parachute drop test:

- Latex balloon (the balloon can be used for a mission if handled carefully)
- Two rolls of strong nylon twine
- 2" – 3" metal ring
- ½" wood dowel, cut six inches long
- Hard hat(s)
- Completed parachute
- Near spacecraft modules
- Small, soft weights and/or packing material
- Duct tape
- Gloves
- Scale to weigh capsules and balloon lift
- Helium
- Ground-based APRS tracker
- Camcorder or camera (you'll want to record this test as it is awesome fun)

5.1.2. Construction

√ Construct the release mechanism
√ Drill a hole perpendicularly through the dowel near one end, with a diameter large enough to pass the nylon line through. This is the release pin.
√ Taper the other end of the release pin to a dull point.
√ Tie a nylon cord through the hole in the release pin.

Release Pin *- Round the end to help prevent snagging.*

- √ Prep the near spacecraft
- √ Program the tracker or flight computer to transmit the GPGGA sentence every couple of seconds. The time and altitude data will be recorded in this test.
- √ Move the HT off the APRS frequency so the test does not interfere with local APRS traffic.
- √ Test that the tracker/flight computer is transmitting properly.
- √ Attach the second module to the tracker module.
- √ Test that the weights fit inside the empty module and are secure.

Parachute Prep

- √ Tie a large loop (about six inches in diameter) to the top of the parachute with sisal line.

5.1.3. Procedure

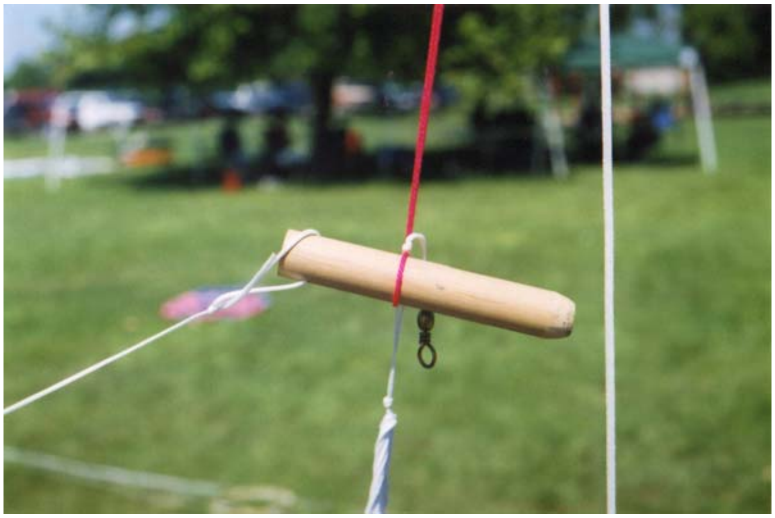
- √ Weigh and record the near spacecraft. Include the parachute's weight in the total.
- √ Attach the parachute to the near spacecraft.
- √ Power up the near spacecraft.
- √ Start up a mobile APRS tracker (this is a good opportunity to test a chase vehicle's tracker).
- √ Start logging APRS data (see Chapter 11, Sections 1.1.3 through 1.1.5 for directions on setting up the TNC and APRS).

Consult Chapter 10, Section 3 for directions on filling and sealing a weather balloon. In place of the 30-foot long load line, use a line over 100 feet long. In this test the lanyard ring is used as the parachute release. After filling the balloon, but before beginning the test, tie the free end of the load line to a car or other object that the balloon cannot carry away. Select several people as the Balloon Crew to operate the balloon. It is their task to raise and lower the balloon for each test. All of them must wear gloves for protection against string burn.

Raising the tethered balloon *- It's safest to wear a hard hat, as there's stuff falling from the sky in this test!*

The release line is a separate line from the load line and is operated by a single individual, the Release Operator. It is best that this person be separate from the Balloon Crew to prevent the load line and release line from tangling. This person must wear gloves and a hard hat as the release pin is overhead when they release the parachute from the tethered balloon.

√ Pass the loop of sisal at the top of the parachute through the lanyard ring on the weather balloon and lock it into place with the release pin.



***Release Mechanism** - Release pin connecting the line to the balloon and the loop on the parachute's apex together. Next stop, 100 feet AGL.*

- √ The Balloon Crew raises the balloon on the load line. Note: keep tension on the parachute until the weight of the capsule is pulling on the parachute.
- √ After the balloon is at altitude, confirm the parachute and release line are not tangled.
- √ Have the Release Operator call "HEADS UP!" before pulling the release pin loose.
- √ Observe that the parachute opens properly.
- √ Under no circumstances attempt to catch a falling capsule when its parachute has failed as the risk of injury is too great in comparison to the cost of the capsule.

- √ Repeat the Parachute Test with various weights inside the empty module, recording the total weight of the capsule in each test.

After completing the tests, carefully lower the balloon and remove the tape wrapped around the nozzle. It will take a while to dump the helium out of the balloon. However, if the balloon is handled with care, it can be repacked inside the bag it came in and used for your first flight. **CAUTION: The interior of the balloon is filled with talcum powder, so be sure no one attempts to breathe the helium being vented.**

A Final Observation to Make
Mirages occur when pockets of air warmer than the surrounding atmosphere bend or refract light from its original path. One effect is the shimmering observed over warm pavement of more distant objects as pockets of warm air rise and mix with the cooler air higher above the pavement. Helium is a very low-density gas and is capable of refracting light in just the same fashion. As you vent helium from the balloon, observe the scene behind the helium stream leaving the balloon nozzle and look for shimmering.

5.1.4. Analysis of Drop Test Data

- √ Change HT frequency back to 144.390 MHz.
- √ Confirm that the parachute opened promptly when released and did not collapse.
- √ Look for asymmetries in the canopy if there is a problem. Make sure the shroud lines look even and are under the same amount of tension.
- √ The time and altitude are the two most important fields during the drop test. Use only the last few GPGGA sentences, when the capsule is descending at a constant rate.
- √ Record the capsule weight and last three or four GPGGA sentences from each drop.

- √ Calculate a descent speed for the parachute. Note: As an example, use the last three GPGGA altitudes and UTC times.
- √ Calculate the change in altitude by subtracting the last altitude from the third altitude.
- √ Convert the change in altitude from meters to feet by multiplying meters by 3.28.
- √ Calculate the change in time by subtracting the last UTC time from the third UTC time, being sure to take into account any roll over in minutes. You want the results in seconds.
- √ Divide the change in altitude by the change in time.
- √ Record the descent speed and capsule weight in a spreadsheet.
- √ Record the same data for each drop test.
- √ Create a graph of parachute descent speed as a function of payload weight (use best fit).
- √ The graph should be close to a straight line (linear).

Why Are There Errors?
The descent speed of the parachute may not be as low as calculated. Factors that affect the true descent speed of a parachute includes sewing errors, variations in parachute diameter or spill hole size, and canopy porosity.

5.1.5. Generating a Descent Profile

You just measured the characteristic descent speed of a parachute at your local elevation. The Descent Profile determines the speed of the recovering near space capsule as a function of altitude.

- √ Begin by creating a spreadsheet with altitudes for every 1000 meters, starting at your elevation.
- √ Add a second column with the Standard Atmosphere density at those altitudes (found in the table below).
- √ Create a third column of altitude in feet by multiplying the first column by 3.28.
- √ Create a fourth column of the inverse, square root of air density.
- √ Create a fifth column of predicted descent speeds by multiplying the fourth column by the landing speed of the parachute and divide by the inverse air density at the elevation the drop test was performed.
- √ Graph the third (altitude in feet) and fifth columns (descent speed in feet per minute).

Spreadsheet Commands

	A	B	C	D	E
1	Altitude	Density	Altitude	1/Density$^{1/2}$	Descent Speed
2	meters	newtons/meter^2	feet		feet/second
3	1000		= +A3*3.28	= 1/SQRT(+B3)	= +D3*15

Standard Atmosphere	
Altitude (m)	**Density (kg / m^3)**
0	101325.0
1000	89874.6
2000	79495.2
3000	70108.6
4000	61640.2
5000	54019.9

6000	47181.0
7000	41060.7
8000	35599.8
9000	30742.6
10000	26436.3
11000	22632.1
12000	19330.4
13000	16510.4
14000	14101.8
15000	12044.6
16000	10287.5
17000	8786.7
18000	7504.8
19000	6410.0
20000	5474.9
21000	4677.9
22000	3999.8
23000	3422.4
24000	2930.5
25000	2511.0
26000	2153.1
27000	1847.5
28000	1586.3
29000	1363.0
30000	1171.9

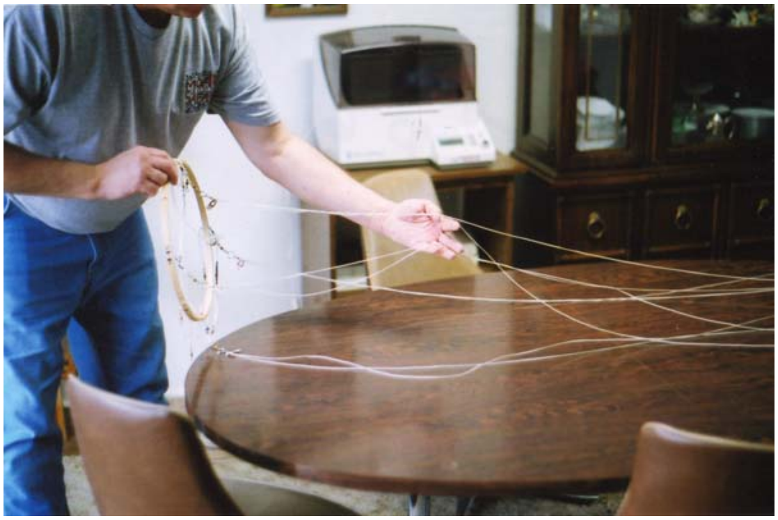
The resulting graph predicts the descent profile for this particular parachute for a given weight. The descent speed of a parachute above 100,000 feet is usually greater than 150 feet per second, or 100 miles per hour. Again, don't let this worry you. The air pressure at this altitude is so low that high speeds are necessary to generate enough drag. As far as the parachute is concerned, it appears that the force of the rushing air on the parachute at this altitude is equal to the force of the slower rushing air at a lower altitude. The force on the parachute is constant all the way down. One test to perform is to calculate the actual descent of the parachute during a mission and comparing the results to the predicted descent speeds.

5.2. Storing And Transporting Parachutes

5.2.1. Storing Parachutes Between Missions

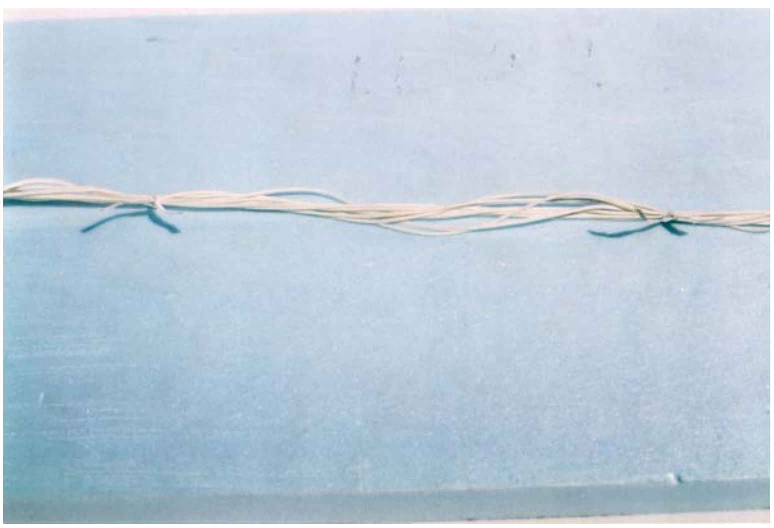
Parachutes should never be stored folded up. Instead, let the parachute's apex hang from a nail in the wall or ceiling. Place the parachute where it is protected from direct sunlight and drafts of cold or hot air.

5.2.2. Untangling Shroud Lines



Oh joy! Untangling shroud lines!

Someone must have responsibility for untangling the shroud lines during a mission's Flight Readiness Review (FRR). Link the split rings at the ends of the shroud lines together with a fifth split ring to keep the lines from tangling again. Mike Manes of EOSS recommends wrapping the stretched-out, untangled shroud lines with several twist ties. That's such a good idea that I wish I had thought of it.



To keep shroud lines under control, wrap wire twist ties around the bundled shroud lines. (A suggestion from Mike Manes of EOSS)

Alternatively, a parachute transport bag also helps keep shroud lines from tangling during transport.

5.2.3. Transporting a Parachute to a Launch

Only on the night before a flight should the parachute be folded into a transporting bag. One good bag for transporting a parachute is a laptop case (after the shroud lines are tied together).

Another option is to sew a transport bag from a heavy-duty nylon fabric. Below are directions for making one type of transport bag. This bag is a long, narrow tube sewn closed at both ends. A Velcro[B] closure along the length of the bag makes it easy to lay out the parachute inside, and avoids snagging the parachute in a zipper. A flap of fabric inside the opening protects the parachute's shroud lines from making contact with the Velcro. Small gaps at the top and bottom of the Velcro closure allow the ends of the parachute to protrude, preventing it from sliding down and tangling inside the bag.

Materials

- Two yards of heavy cloth like a nylon canvas
- Several sheets of poster board
- Five feet of ¾" sew-on Velcro tape

Procedure

√ Determine the dimensions of the rectangular bag pattern:
Lay out the parachute and measure its length. The length of the pattern is two inches longer than parachute's length.

√ Determine the circumference of the canopy when it is wrapped in a tight roll. The width of the pattern will be 7 inches wider than this circumference.

√ Make a pattern on poster board and cut out.

√ Trace the cardboard pattern onto the cloth and cut out.

√ Fold over all four sides by one inch, then fold again to form a hem that is one inch wide.

√ Sew the hems down; you will be sewing through three layers of fabric.

√ Cut the Velcro strip six inches shorter than the length of the bag. This leaves a small opening at each end of the tube.

√ Sew one face of the Velcro furry side up on the face-up side on the right hand hem, equidistant from both ends.

√ Flip the cloth over and sew the other side of the Velcro strip on the opposite side of the cloth, with its edge two inches from the edge of the cloth. These two inches of overlapped fabric will be on the inside of the bag, forming a flap to protect the parachute from coming in contact with the Velcro.

√ Fold the rectangle length-wise, forming a tube with the Velcro strips sealed together, and with the two-inch overlap inside.

√ Sew the tube closed across both ends. This will leave a small opening between the Velcro and the end seam at both ends of the bag.

Directions for Use

√ Untangle the parachute during the FRR and tie shroud lines with twist ties.

√ Open the tube and place the parachute inside at the top.

√ Lay the shroud lines inside the bag, keeping them straight.

√ Cover the parachute and shroud lines with the inner flap, leaving parachute's apex ring and the ends of shroud lines extending from the bag.

√ Fold the tube closed by first folding the inner flap over the parachute, then folding the outer flap over to line up the Velcro.

√ Seal the Velcro closure

√ Fold bag in half and link parachute's top and bottom rings together.

√ Roll the tube into a ring.

You can either buy a bag or sew your own.

6.0 Flight Termination Systems

The function of the flight termination system is to cut the balloon and load line away from the parachute during descent. Cutting away the balloon lets the parachute lower the near spacecraft in a gentler manner than when the burst balloon is swinging around the parachute apex at the end of a thirty-foot load line. As long as the near space capsule meets the weight limits imposed by FAR 101, the stack doesn't require a flight termination device. But in the long run, you should carry one of these to prevent losing an expensive near space capsule in case the balloon becomes neutrally buoyant or if a main battery begins to fail during a mission.

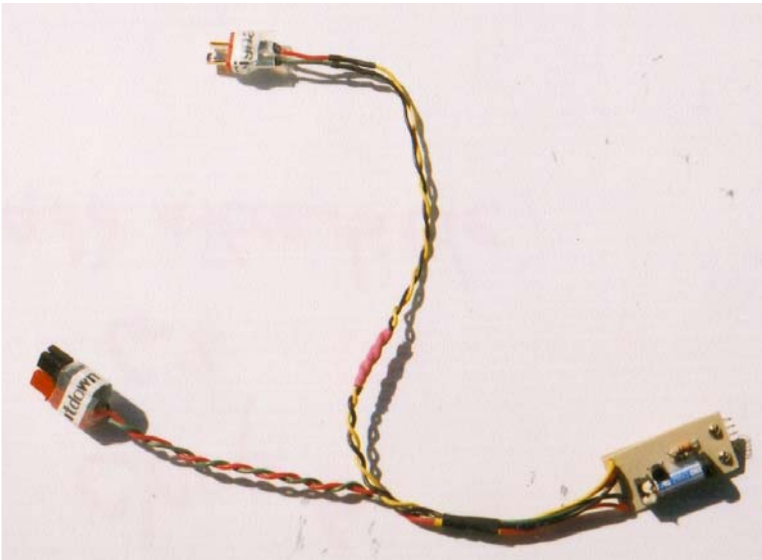
6.1. Types of Failures Requiring Flight Termination

There are two broad categories of failures requiring flight termination, Near Spacecraft Emergencies (NSEs) and Flight Path Violations (FPVs). NSEs occur when some event compromises telemetry, such as when flight cells fail and telemetry is no longer being sent. FPVs occur when the course of the near space capsule deviates substantially from the predicted flight path and it risks landing in hazardous areas, like tall mountains, great lakes, or restricted areas. Another FPV is when the stack becomes neutrally buoyant. When events like these occur, you have no other option than to terminate the flight early. By terminating missions early, the near space capsule lands sooner and closer to its current position.

This section describes the construction of a Flight Termination Unit (FTU). The FTU uses a thermal knife to sever the load line between the balloon and parachute. At flight termination the near spacecraft drops from the balloon, the recovery parachute deploys, and the balloon begins rising much more rapidly. Since near space missions described in this book are flown on latex balloons, the balloon is guaranteed to terminate, meeting the requirements of the FAA (a balloon capable of lofting a near spacecraft does not become neutrally buoyant when the near spacecraft is released). The FTU design in this section allows one or more sources to terminate a mission. Using separate batteries and termination signals lets the FTU meet the FAR 101 requirement for multiple, independent, and redundant termination methods for larger payloads. At the time of this writing, the FTU described in this section has only been tested in flight with timers and on the ground with a pager.

6.2. The Near Space Flight Termination Unit (FTU)

The FTU is an electronically controlled thermal knife designed to cut the load line between the parachute and the balloon.

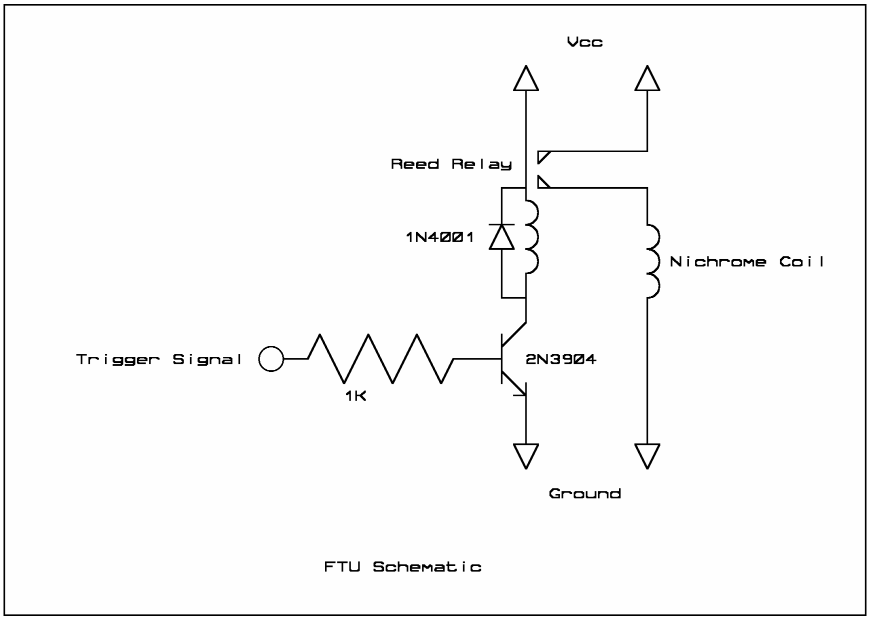


The FTU

Several signaling sources can operate the FTU. The first method described in this section is with a stopwatch. With a stopwatch, the FTU acts as a stand-alone device that ensures the termination of a flight in cases where the balloon becomes neutrally buoyant. The second termination method is a telecommand method and uses triggering devices like a pager, flight computer, or DTMF decoder. Flight computer connection to the FTU allows a software command to terminate the ascent when events like when balloon burst is detected, a low main voltage alarm occurs, or telecommands to the flight computer are transmitted from ground stations. Pagers and DTMF decoders allow telecommands from ground stations to terminate near space missions at the detection of a failure. The stopwatch method is described in detail, while other methods of triggering the FTU are described only in general details. I have not had the time to complete my tests of telecommanding the FTU, so I leave it as an exercise for the reader.

6.2.1. Theory of Operation

Refer to the schematicbelow. The resistance of a three-inch length of 30-gauge nichrome wire is less than one ohm.



Schematic of FTU

According to Ohm's and Watt's Laws, when sufficient voltage is present on the nichrome wire, the voltage creates enough current and power to make the nichrome wire glow incandescently. Nichrome is also designed to tolerate such high temperatures without melting or otherwise failing. Temperature sensitive cords, like nylon or Dacron, melt from the heat produced by a glowing nichrome wire coil. According to Ohm's Law, when six volts is present on a 0.75 ohm nichrome wire, it generates a current of:

I = V/R (Ohm's Law)
I = 6/.75 (substitute the voltage and resistance into the equation)
I = 8 Amps

According to Watt's Law, when eight amps of current flows through a volt difference of six volts, the current generates a power of:

P = I*V (Watt's Law)
P = 8*6 (substitute the current and voltage into the equation)
P = 48 Watts

Dissipating a power of 48 watts within a coiled three-inch length of nichrome wire generates enough heat to make the nichrome wire coil glow orange hot within a second. Any nylon or Dacron cord threaded inside of this glowing coil melts the cord into two pieces very quickly.

However, a stopwatch, microcontroller, pager, or DTMF decoder is incapable of sourcing or sinking enough current (8A) to operate a coil of nichrome wire. The FTU uses a reed relay to sink the necessary amount of current. This creates a new problem. Not every stopwatch, microcontroller, pager, or DTMF decoder can source or sink enough current to ensure the reed relay operates reliably. To ensure reliability, a bipolar, NPN transistor triggers the reed relay. External signaling devices can provide sufficient current to saturate the transistor when the proper base resistor is used. When the proper value is used, the current from the signaling device is low enough not to damage it, but high enough to saturate the transistor.

The entire FTU sequence of operation goes as follows: initially there is no current flowing into its base. With no base current, the resistance between the transistor's emitter and collector is so high that effectively, no current flows, so the transistor behaves like an opened switch. When triggered, a small current flows from a signaling device into the transistor's base, saturating the transistor. The resistor (R1) limits the amount of current flowing into the base of the transistor (Q1), protecting the transistor from excessive current. However the value of R1 must be small enough to allow sufficient current to flow into the base of Q1 to saturate it. When saturated, there is virtually no resistance between the transistor's emitter and collector. The transistor now acts like a closed switch, letting current flow from between the battery and the coil of the reed relay. When the relay's coil is energized, contacts inside the relay close, letting several amps of current flow through the nichrome wire coil. The current flowing through the coil produces enough heat to melt the load line passing through the coil. When the signal to the transistor ends, the transistor is no longer saturated, completely cutting off current to the relay's coil. As a result, the contacts in the relay open, stopping the flow of current to the nichrome coil. Diode (D1) protects the transistor, Q1, from current induced by the coil (inductor) within the relay. When current stops flowing through the relay, the magnetic field created by current flowing through the coil collapses, generating a new current flowing in the opposite direction. It's this current that the diode protects the transistor from.

6.2.2. Materials

- FTU PCB
- One resistor, with a value between 330 ohms and 10k ohms[C]
- One 1N4001 diode
- One 5-volt reed relay, Radio Shack 275-232
- One 2N3904 transistor
- Three inches of 30 gauge nichrome wire
- #2 mounting hardware (nuts, bolts, and washers)
- One pair of Powerpole[D] connectors
- Stopwatch or other triggering device[E]

6.2.3. Construction

Modifying the Stopwatch

Locate on the back of the stopwatch the four small screws that hold the two halves of the stopwatch's case together. Use a small jeweler's Phillips screwdriver to remove them. They're small, so set them in a safe location where they can't drop or roll out of sight. Inside the back of the stopwatch you'll notice a one-inch diameter brass disk with the piezo crystal. Use small cutters or an Exacto knife to trim the plastic lip holding the piezo speaker down. Remove the speaker. Save the speaker for fun science experiments. Now turn your attention to the front half of the stopwatch case. Keeping the face of the stopwatch face down, rotate the stopwatch so that the buttons are at the top. Be careful not to knock the three stopwatch buttons loose. They are spring-loaded and are easily replaced should they come loose. Remove the lanyard from the stopwatch.

√ Notice that the piezo speaker received its power from two spring contacts mounted to the back of the stopwatch PCB. These two springs provide the connection to the timer signal (and power). Use either 26 or 24 gauge stranded wire to extend the springs.

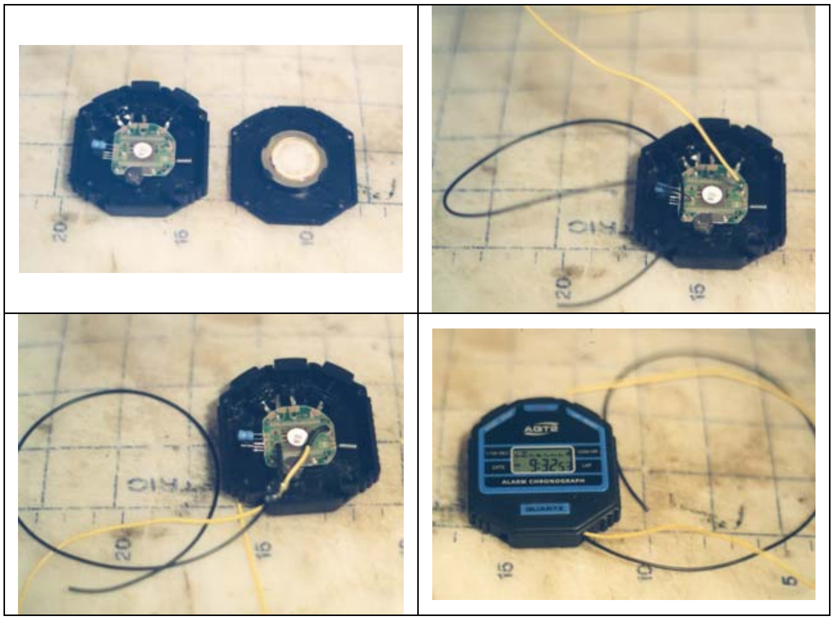
√ Cut a six-inch length of two pieces of wire, red for positive and black for ground.

√ Strip back ¼ inch of insulation from one end of both wires.

√ Stick the stripped end of the bright wire into the right spring and stick the dark wire into the spring on the left side.

√ Get a soldering iron hot and heat up one spring and its wire.

- √ Use solder sparingly and solder the wire into the spring. Do this as quickly as you can, and don't let the soldering iron touch the stopwatch PCB.
- √ Repeat this to the other spring.
- √ After the soldered has cooled, cut short lengths of 1/16" heat shrink tubing and slip them over the soldered springs.
- √ Shrink them down, increasing the strength of the wires' connection to the springs.



Find the springs connecting the piezo speaker and solder wires inside the springs.

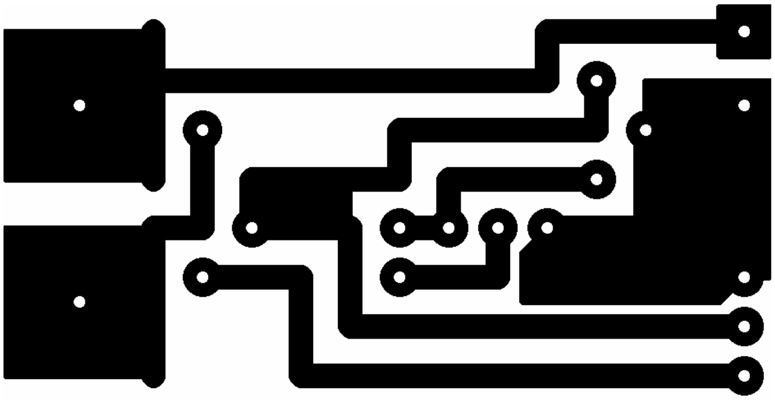
- √ Fold the wires down and pass them outside the stopwatch case through one of the lanyard holes.
- √ Use a small amount of hot glue and seal the wires to the opening of the stopwatch, to provide a strain relief.
- √ Close the back plate of the stopwatch and screw it back on.

Now, instead of ringing, the stopwatch sources a current when the alarm rings.

Assembling the PCB

Soldering Discrete Components

Refer to the folllowing diagram when placing components into the FTU PCB. Only the diode and transistor are sensitive to orientation. With the PCB turned with the nichrome pads at the top, the transistor is mounted with its flat face to the right. The diode is mounted so that the band of the diode is at the top.



Top Silk of FTU

Solder the components in this order.

1. The reed relay
2. The 2N3904 transistor
3. The 1N4001 diode
4. The current limiting resistor

Recommended resistors are:

Pager:	500 Ohm
CC/PS:	10k Ohm
DTMF:	1k Ohm

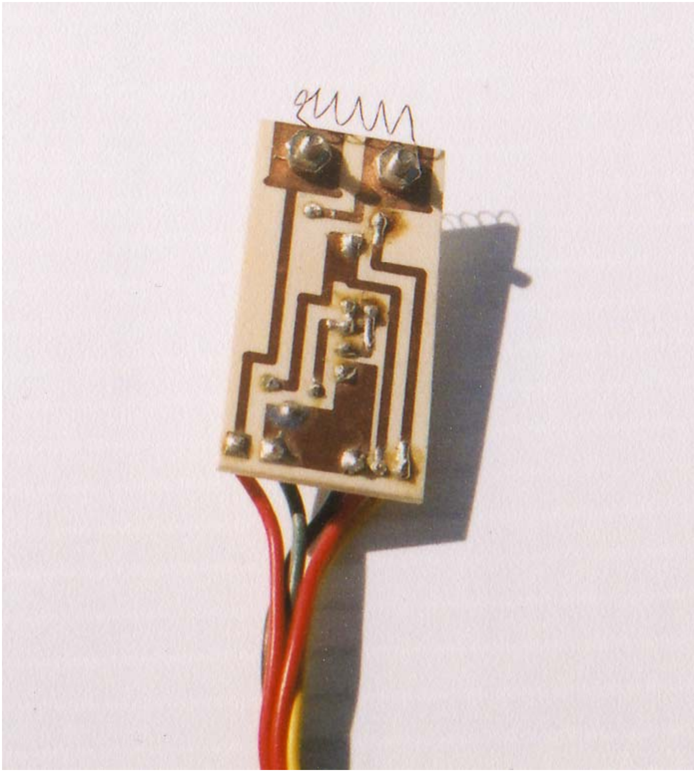
Coil Power Connection

Power to heat the nichrome coil comes from the two bottom right pads of the PCB (the coil power pads). Depending on the current from the triggering device, the power source for the nichrome coil may be the same power source for the transistor. For example, if a stopwatch is used to trigger the FTU, the nichrome coil battery must be used to also operate the transistor. However, if a flight computer that is capable of sourcing several milliamps of current is used to trigger the FTU, then the nichrome coil's battery is not needed to operate the transistor. If using the coil's battery only for the coil, then solder heavy wire, 12 gauge or higher, to the coil power pads. The length of the wires should be as short as realistic for the application. If instead the FTU is sharing the battery between the coil and the transistor, then split the positive wire from the battery into a "Y" and solder one arm of the "Y" to the coil power pad marked POWER and the other arm of the "Y" to the pad marked +5V (on the bottom left of the FTU PCB).

Crimp and solder pins and attach Powerpole housings on the ends of the coil power wires. The polarity of these wires does matter, so use one black and one red housing. Backfill the Powerpole housings with hot glue for additional strength.

Making and Mounting the Nichrome Coils

Wrap three inches of 30-gauge nichrome wire around a 1/8" dowel, like a jeweler's screw driver, leaving ½" to ¾" of wire sticking straight out from the ends of the coil. These ends are connected to the FTU coil pads (not the coil power pads), located at the top center of the FTU PCB. Nichrome does not solder well, so 2/56 hardware is used to bolt the coil to the FTU. Bend a kink into the ends of the coil arms to lock the bolts around. Enlarge the coil pads if necessary to get the mounting hardware into the PCB. Tighten the bolts securely, locking the ends of the coil to the FTU



The nichrome coil.

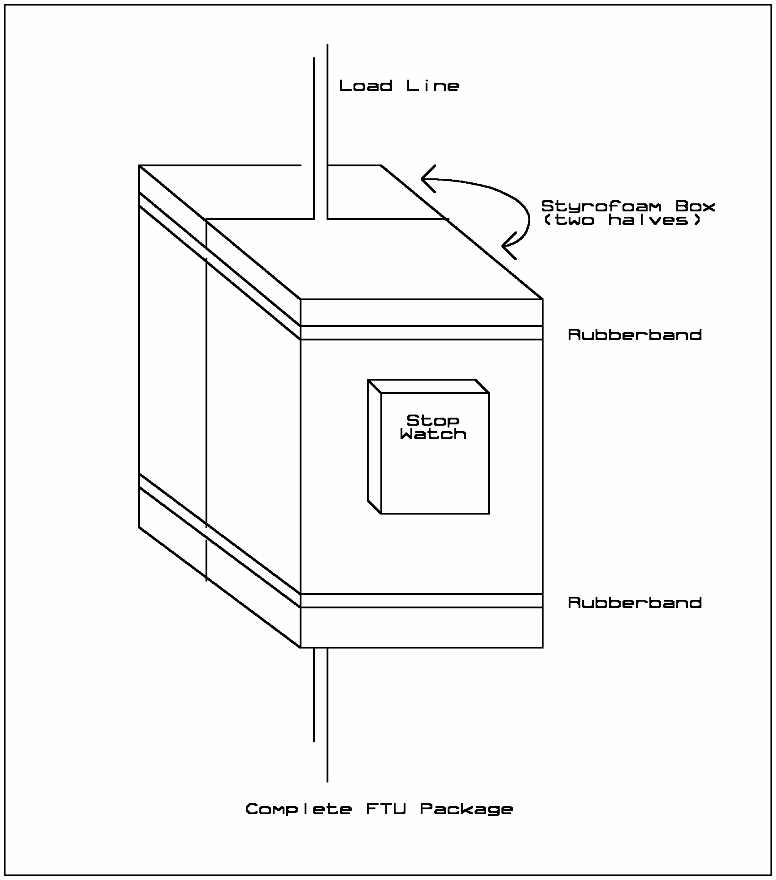
Triggering Device
If using a stopwatch or pager, solder the wires extending from the stopwatch to the FTU to the bottom pads marked SIGNAL and GROUND (the stopwatch does not connect to the +5V pad). If instead of using a stopwatch, you use a triggering device that provides enough current to operate the transistor, then connect wires from the triggering device to the three bottom left pads marked SIGNAL, +5V, and GROUND. The pad marked +5V will not trigger the FTU until the SIGNAL pad is energized. The length of the triggering wires depends on the application. If using a lightweight triggering device like a stopwatch or pager, then the wires can be short and the triggering device kept close to the FTU. If the triggering device is a flight computer or DTMF decoder from a radio, then the wires must terminate in Powerpole connectors. A wire cable, like 20-gauge zip wire (speaker wire) can make the run from the flight computer or radio to the FTU. Finally, there is no reason the pager or stopwatch must be permanently connected to the FTU PCB. A set of Powerpole connectors on the pager/stopwatch and a second set on the PCB will let you disconnect the triggering device from the FTU.

Mounting the Flight Termination Unit
Securely mount the FTU PCB to a base that is fire resistant. A 1/8" thick sheet of polystyrene plastic works well. Make the backing large enough to hold the FTU, its battery, and the stopwatch, if used. Tie everything down to the plastic base with nylon wire ties.

To protect against fires, the FTU and its nichrome coil must be mounted inside a block of Styrofoam[F]. Also, any device triggering the cutdown must limit its signaling time to only a few seconds. However, in the case of the stopwatch, it has such a low duty cycle that it can ring for a minute without significant fire risk.

Make the Styrofoam block in two halves so that the two halves trap the FTU between them. Cut a notch into the top and bottom of both halves where the load line enters and exits the nichrome coil.

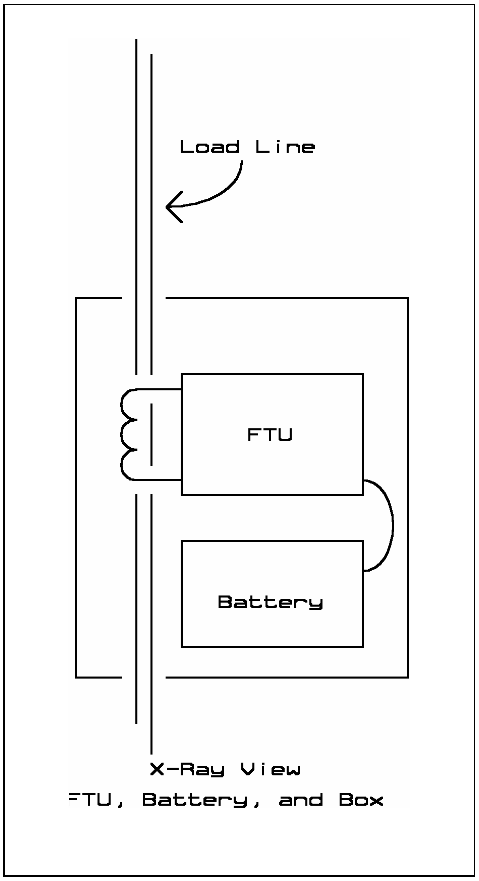
Epoxy dowels or Popsicle sticks to the foam halves so that rubber bands can clamp the foam halves around the FTU. On one of the foam halves, tie a heavy cord and a split ring. This line and ring secures the FTU to the apex of the parachute after the load line is cut free.



The closed FTU on a load line.

6.2.4. Operation

The night before a launch, test that the nichrome coil battery has sufficient capacity to make the coil glow. Then cut 12" of load line and thread it through the cooled nichrome coil. Tie loops into both ends of the line. Close the foam halves around the FTU PCB, leaving the ends of the load line sticking outside the block. Clamp the foam halves together with rubber bands, trapping the FTU inside. Test that the load line can slide within the block, but be careful not to pull the load line out of the block. Secure the FTU to the apex of the parachute with the split ring and the bottom end of the load line coming out of the FTU. The parachute now has two attachments to the FTU, one being the FTU's load line, and the other is the split ring.



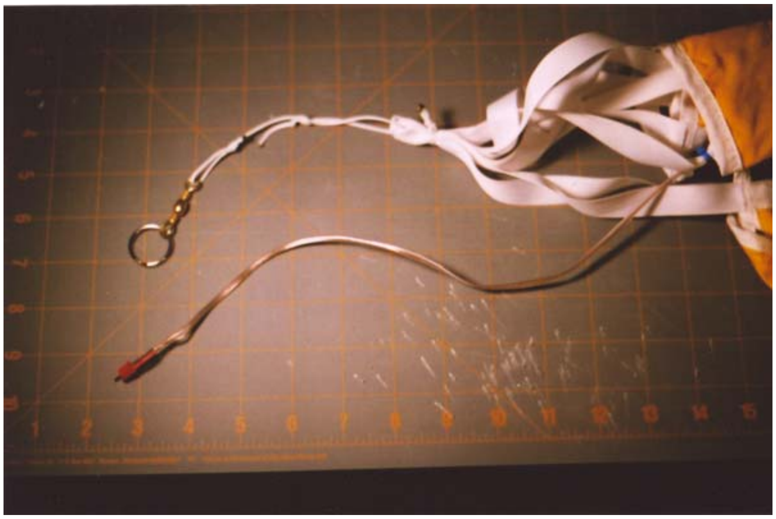
X-Ray View *- FTU, battery, box, and load line.*

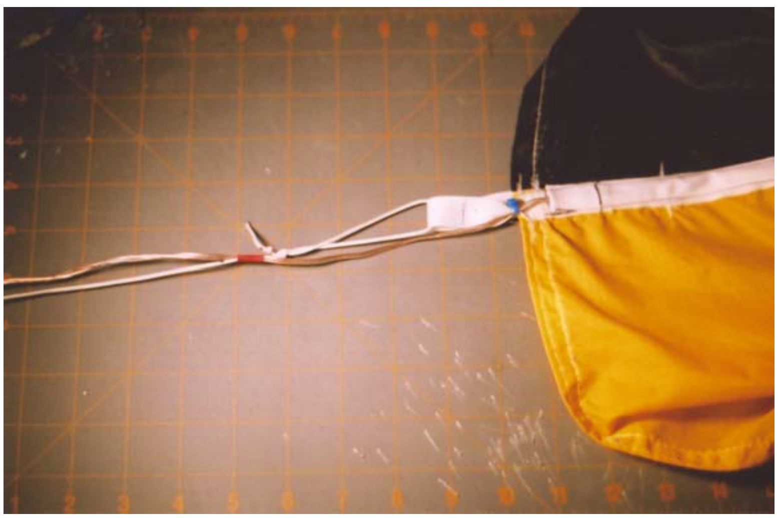
The next morning, during balloon fill, tie one end of the load line to the loop at the top of the FTU and the other end of the load line to the balloon. Tape all knots.

If using the stopwatch, set the timer. Be sure the time is long enough for the balloon to reach its predicted max altitude. If using a pager instead of the stopwatch, then be sure to disconnect the pager from the FTU before switching on the pager. Pagers test their alarms when first powered up and the pager self-test will trigger the FTU if the pager is attached (it's embarrassing to launch a balloon without the near spacecraft). After the pager self-test, attach the pager to the FTU signal connectors. If using a flight computer to trigger the FTU, then make sure the signal from the flight computer is low at power up. If there's a risk the signal may be high momentarily, then disconnect the signal line from the FTU at flight computer power up. Also, make sure the flight code loaded into the flight computer will not trigger the FTU before launch. While the stack is still on the ground, GPS altitude errors may fool the flight computer into thinking the balloon has burst. It's best if the flight computer will not check for balloon burst until several minutes after launch.

6.2.5. CC/PS as Flight Termination Signals

The Block 1 and Block 2 CC/PS are capable of sourcing 20 mA of current. This is sufficient current to trigger the FTU's NPN transistor with a 1k resistor in series with the base. The command cable should be sewn into the parachute's canopy, then tied to a shroud line on the parachute ring. Create a "tube" from twill tape along a previously sewn twill tape. Pass the cable through the tube after it is sewn. The tube lets the parachute canopy flex without binding from the command cable. From there a cable can connect the CC/PS to the command cable. A command cable that drops through the spill hole of a parachute risks tangling shroud lines. Make the command cable from thin speaker cable. The cable contains two stranded wires, enclosed in flexible insulation.





A parachute with the signal lines for the FTU sewn in –

Top – Cutdown signal line at apex of canopy

Bottom – FTU Signal line at bottom of canopy

If the CC/PS has control of the FTU, then it should terminate the flight when the main battery voltage drops too low. Experiment with low voltage conditions on the ground before giving the CC/PS control of the FTU.

To terminate the flight, use the following BS2p commands (assuming the FTU signal is connected to I/O pin 8)

```
FTU    con    8

high FTU
pause 5000
low FTU
```

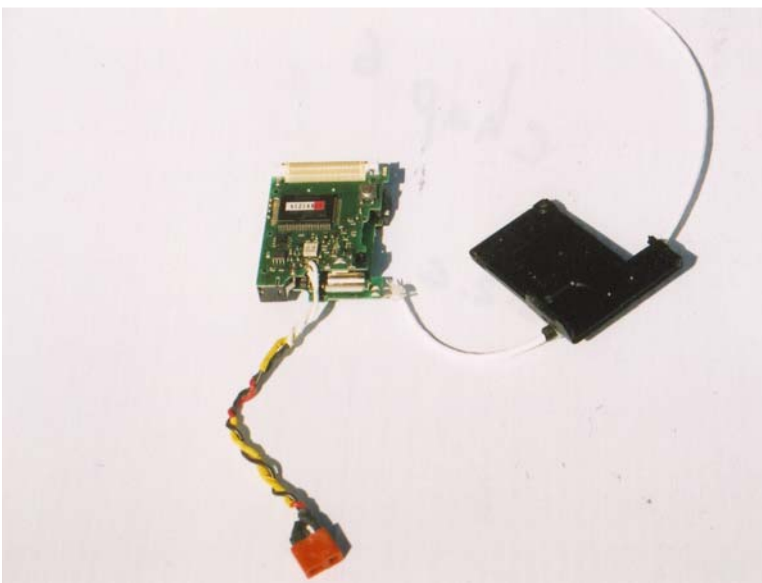
6.2.6. Pagers as Flight Termination Signals

The simplest independent receiver you can use to terminate flight is a pager. Pagers have thousands of hours of development and testing to insure reliability and are durable and inexpensive. The following directions explain how to modify a $20 pager so that it can terminate a near space flight.

There are two types of pagers in use. The first kind uses a five number cap code as an ID. When this type of pager is called, a set of five tones is sent over the radio. Only the pager with that specific cap code will respond to the signal and all other pagers will ignore it. The typical frequency used for these pagers is 152.24 MHz, just above the two-meter band. You can use a scanner to hear these tones. The second type of pager uses a seven digit data string made up of digital tones. The tones are sent FSK (frequency shift keying).

Rather than develop a new radio receiver, which could fail due to construction errors, or use a heavy HT, I decided to experiment with a dependable pager. Software at the Paging Service allows passwords to be required to ring a pager, preventing an accidental or malicious termination event. Pagers operate in two modes, beep and vibrate modes. These directions take advantage of the vibrate mode. The vibrator in a pager is a tiny motor with an off-center weight. When the motor spins, the off-center weight rocks the pager, creating the vibration sensation. In its new life, the pager is used sans motor to operate an FTU.

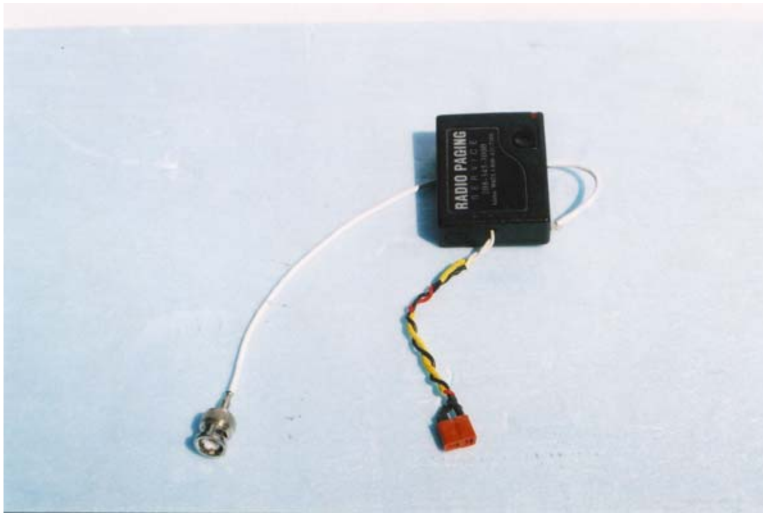
Construction



The opened pager

- √ Purchase a pager (do not modify a rented pager as the Paging Service does look kindly to this).
- √ Open the back of a pager.
- √ Locate the vibrator motor (this is a tiny motor with an off-center weight).
- √ Physically disconnect the motor from the pager case.
- √ Cut the power leads to the motor close to the motor, leaving the leads as long as possible.
- √ Strip about ¼” of insulation from the ends of the motor leads.
- √ Cut two #24 or 26 stranded AWG wires to a length of 12 inches.
- √ Strip ¼” of insulation from one end of the wires and about ½” of insulation from the other ends.
- √ Cut two ½” lengths (at least) of heat shrink tubing large enough to cover the above wires.
- √ Solder the stranded wire to the motor leads and cover the solder joint in heat shrink tubing.
- √ Find a location in the pager case to pass the wire through.
- √ Cut a small notch in the pager case at this location.
- √ Test fit the wires, making sure the pager cover can still close.

√ Close the pager cover.
√ Terminate the wires with connectors like Powerpoles or Dean's Connectors. Note: the author recommends using a different style of connector than is normally used for battery connections in the near spacecraft.



The pager after removing the vibrating motor and soldering wires to the motor's pads on the PCB.

Procedure for Using Pager
√ Before powering up a pager, disconnect the pager from the FTU.
√ Power up the pager.
√ Set the pager to vibrate mode.
√ Wait until pager stops vibrating.
√ Connect the pager to the FTU.

Note: After powering up the pager, the pager performs a self-test. The test will trigger the FTU if it is connected. To prevent a premature and embarrassing surface termination of the balloon, disconnect the pager from the FTU before powering up the pager. After a few seconds you can reconnect the pager.

During a mission the pager listens for a signal to vibrate. If an FPV occurs, Chase Crews or Mission Control calls the pager number. To protect the flight from being terminated by accident, ask the Paging Service to install a password on the pager. Only authorized individuals are given the password.

TVNSP has performed two tests on pagers in near space. The missions experienced pager failures because the radiating pattern from paging tower antennas is concentrated on the horizon. When selecting a Paging Service, make sure they have antennas several hundred miles from the launch site, as these antennas are located on the horizon during a flight.

7.0 Audio Beacons

A good recovery aid to add to all near space capsule is the audio beacon. Amateur rocketry has used similar devices for years to located model rockets in tall grass. A recovered near space capsule may not be visible one hundred feet away from its last recorded GPS location, but the beeping of the audio beacon can be heard. Check with Adept rocketry for one of their loudest models or make your own (recommended).

7.1. Constructing an Audio Beacon

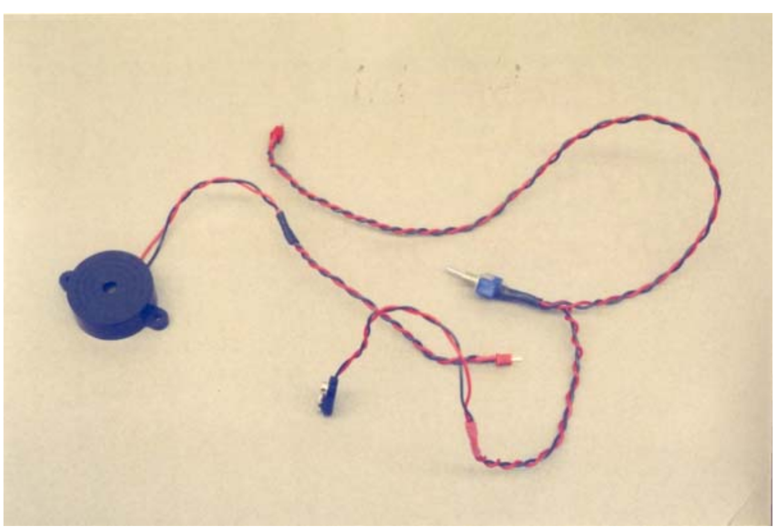
A suitable audio beacon can be constructed from materials available at Radio Shack. In addition to the satisfaction of constructing more of the near space program is the money that is saved.

7.1.1. Materials

- One loud, 12V DC piezo buzzer[G] (Radio Shack 273-060 will work)
- Nine-volt battery snap
- SPST (or SPDT) toggle switch
- Two colors of #24 AWG stranded wire (Red and black are good color choices)
- 3/16" diameter heat shrink tubing
- "Remove Before Flight" tag[H]

7.1.2. Procedure

√ Cut 30 inches of both colors of wire.
√ Strip ½" of insulation from both ends of both wires.
√ Twist 30-inch wires to the leads of buzzer and solder. Use a meaningful combination of colors.
√ Cut four pieces of heat shrink tubing, ½" long.
√ Slide two pieces of tubing onto the soldered wires and shrink.
√ Solder battery snap to other end of the 30-inch wires.
√ Cover soldered connection with heat shrink tubing and shrink.
Note: Ensure the red battery lead is connected to the red lead of buzzer.
√ Cut positive (red) lead ten inches from battery snap.
√ Strip ½" of insulation from each wire end.
√ Cut two pieces of heat shrink tubing and slide one onto each cut wire.
√ Tin the ends of the wires and the terminals of the switch.
√ Solder the wires to the switch terminals.
√ Note: If using a SPDT switch, one wire must be soldered to the center terminal; otherwise, the terminals soldered to are not important.
√ Cover exposed solder joint with heat shrink tubing and shrink.
√ Twist wires to keep them neat.

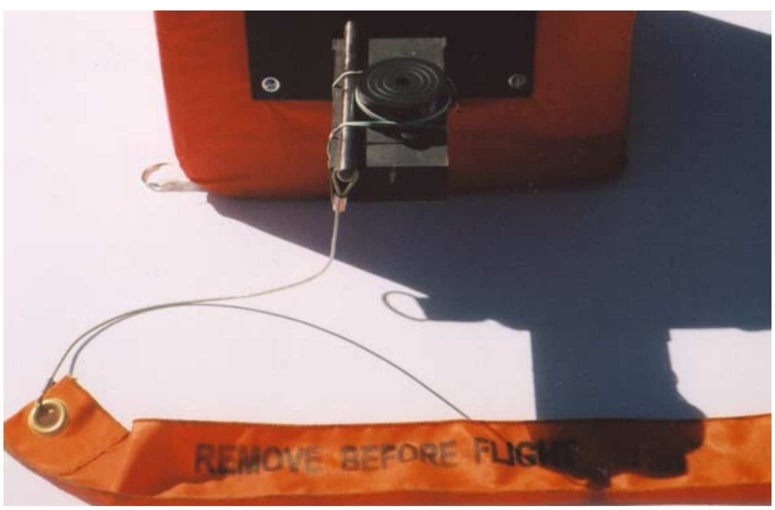


The completed audio beacon

7.2. Recommendations for Audio Beacon

Find a location for the buzzer on the outside of the near space capsule or its recovery system. A good location is on a boom, like the antenna boom. Attach the buzzer to the exterior of the capsule with rubber bands. Then slide the power wires, battery snap and power switch through an opening in an E-Quad Port. Using the pass-through hole for an antenna coax is a good idea. Install the beacon battery where it can't pop loose and then give the capsule a real good shake just to make sure. Since the beacon is loud and annoying, don't power it up until just before launch. Attach a "Remove Before Flight" tag to the beacon power switch to remind launch crews to power up it. A silent beacon is useless dead weight.

Place the audio beacon securely on a boom.



Don't forget a little reminder to start the beacon before launch.

If the mission includes a camcorder, then position the buzzer away from the camcorder. It is best if the buzzer is placed on a different module and on the opposite side from the camcorder lens and microphone. By placing the buzzer as far as possible from the camcorder, the volume of their awful noise is reduced on the camcorder's audio recording. One thing to notice after recovery of the videotape is the change in the audio beacon's volume during the flight because of the reduced air pressure in near space.

Good to Know

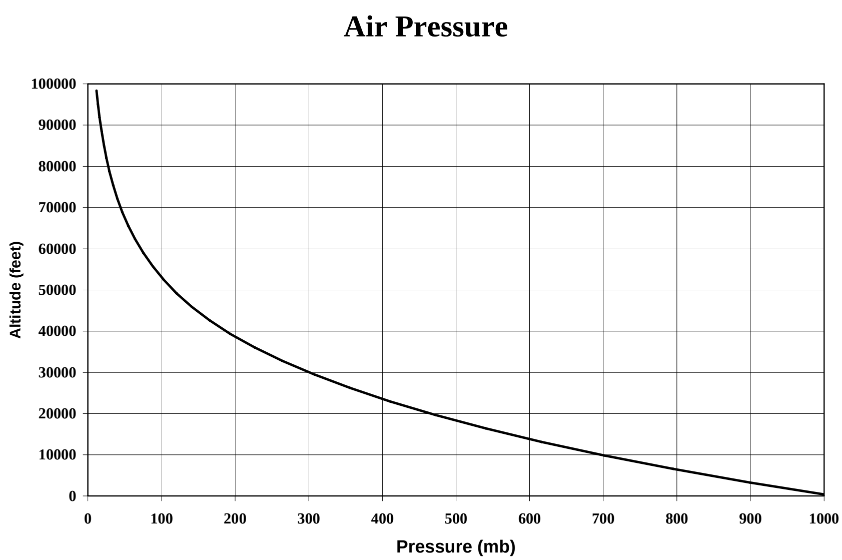
Air Pressure

Air molecules are matter and, like all other forms of matter, have mass. Gravity pulls on anything with mass, giving it weight. What we measure as air pressure is the weight of the air column above us. In terms most Americans are familiar with, the weight of the air column above us is 14.7 pounds per square inch. In the SI, it is equal to 1013 millibars (mb), or 101.3 kilopascals. Think of it this way. Every square inch you can draw on a ground, table, or person has almost fifteen pounds of weight pressing down on it. As seen from above, I measure approximately six inches by twenty-four inches. This gives me a surface area of 144 square inches. At approximately fifteen PSI there is 2,160 pounds of weight pushing straight down on me. I am carrying an automobile's worth of weight on my shoulders. No wonder I feel tired at the end of the day! Since air is a fluid medium it flows around and inside of me, exerting pressure in all directions. The balance of air pressure inside and outside of me keeps me from being crushed by the weight of the air column above me. Without this, I would be crushed just as if there was car placed on my shoulders.

As a balloon ascends into near space, it leaves more air below it and less air above it. So as the balloon climbs higher, there is less weight from the air above the balloon. In the standard atmosphere, air pressure drops by a factor of two every 18,000 feet. The average air pressure at mean sea level is 1013 millibars (mb). A millibar is one thousandth of a bar.

Let's round this figure down to 1000 mb for this exercise in air pressure. If the air pressure is 1000 mb at sea level, then when the balloon reaches an altitude of 18,000 feet, the air pressure will be 500 mb. At 36,000 feet, which is 18,000 feet higher still, the air pressure drops another factor of two. So at 36,000 feet the air pressure is 250 mb. A constant factor of change for one variable for every fixed change in a second variable creates a logarithmic curve.

Here is a second way to state the change in pressure as a function of altitude. For every 50,000 feet change in altitude, the pressure drops by a factor of ninety percent. At 50,000 feet the air pressure is 90% lower than at the surface. Using our first example, the air pressure is 100 mb at 50,000 feet. At an altitude of 100,000 feet, the air pressure is 10 mb, or one percent of surface pressure.



Graph of Pressure vs. Altitude

Vapor Pressure (Boiling Water In Near Space)

According to the book *Chemical Principles and Properties*[I], vapor pressure is the pressure exerted by a vapor when in equilibrium with its liquid. A gas and liquid at equilibrium occurs when the number of molecules evaporating from a liquid in a unit of time equals the number of molecules condensing back into the liquid in the same unit of time.

Vapor pressure for a liquid depends on the temperature of the liquid. When the vapor pressure of a liquid equals the ambient pressure, then the liquid begins to boil. Let us take water as an example. When you bring water to a temperature of 100 degrees C, vapor pressure of the water equals the atmospheric pressure at mean sea level. As a result the water begins to boil. If you try boiling water at the top of a mountain, the water boils at a lower temperature because the ambient air pressure is lower. The water needs to be at a lower vapor pressure, or lower temperature, to boil. Room temperature water (20 degrees C or 68 degrees F) has a vapor pressure of 23.4 mb. This pressure occurs at an altitude of around 82,000 feet. So if you bring room temperature water up to an altitude of just below 82,000, it begins to boil. Body temperature is 37 degrees C. At body temperature, water boils at a pressure of 60 mb. This pressure occurs at an altitude of around 62,000 feet (the Armstrong Line). Before you can reach near space, your blood begins to boil. Of course, the bends will kill you first.

Here is a table from *Chemical Principles and Properties* covering vapor pressures of water at various temperatures.[J]

Vapor Pressure of Water at Various Temperatures				
Temperature (OC)	Vapor Pressure (mb)		Temperature (OC)	Vapor Pressure (mb)
0	6.03		23	27.7
1	6.48		24	29.4
2	6.97		25	31.3
3	7.48		26	33.2
4	8.03		27	35.2
5	8.61		28	37.3
6	9.23		29	39.5
7	9.89		30	41.9
8	10.6		35	55.5
9	11.3		40	72.8
10	12.1		45	94.6
11	13.0		50	121.7
12	13.8		55	155.3
13	14.8		60	196.6
14	15.8		65	246.8
15	16.8		70	307.5
16	17.9		75	380.4
17	19.1		80	467.2
18	20.4		85	570.5
19	21.7		90	691.8
20	23.1		95	834.1
21	24.5		100	1000.0
22	26.1			

Performing Your Own Low Pressure Experiments
Educational Innovations makes a wonderful and affordable vacuum apparatus. However, to make it affordable, it is micro scale. Do not let this be a detractor; it's a great toy. For less than forty dollars you can play with low-pressure effects on water and marshmallows. Order your own micro scale vacuum apparatus, VAC-10, from the Teacher Source, at http://www.teachersource.com.

Near Space Humor
Top Ten Things NOT To Say
When the Near Space Capsule Lands in a Homeowner's Yard

1. "You didn't touch that, did you?"[K]

2. "Are you familiar with the movie *The Andromeda Strain*?"

3. "Hello, we're from the UN!" (This is guaranteed to get you shot in some locations in the rural West.)

4. "We're from the government. We will help you recover from this incident." (Something else to say to get yourself shot.)

5. "We're from the FBI. We'd like to discuss with you what we monitored you doing through that capsule that landed in your yard."

6. "It landed here only 20 minutes ago? Good, you should still be safe."

7. "It depends on what you mean when you say 'dangerous.'" [L]

8. "You have ten minutes to pack your most important possessions."

9. "Your homeowner's insurance should cover this event."

10. "Look at the tip of this pen, please."

[A] DACRON® is a registered trademark of INVISTA.
[B] Velcro® is a registered trademark of Velcro Industries B.V.
[C] The value of the resistor depends of the triggering device. You may have to experiment with various resistors to find the appropriate value.
[D] Powerpole® is a registered trademark of Anderson Power Products.
[E] Use Wal-Mart's inexpensive stopwatch, the ATQ2. It costs $4.95
[F] Trademark of The Dow Chemical Company
[G] Do not use a piezo speaker, as they require a driver.
[H] Available at places like the Boeing Surplus Sales store in Seattle, WA.
[I] *Chemical Principles and Properties*, Michael J. Sienko and Robert A. Plane, Second Edition, 1974, McGraw Hill.
[J] Converted from units of atmospheres to mb by the author. Use this data along with the table of the Standard Atmosphere in section 5.1.4.
[K] Suggested by Mark Conner
[L] Suggested by my mother, Erma Verhage

CHAPTER SEVEN

Remote Imaging from Near Space

"I've seen things you people wouldn't believe."
- Roy Batty (Blade Runner)

Chapter Objectives

1.0 Types of Imaging Available

I find the range of imaging technology available for near space exploration to be absolutely amazing. This range is divided into two broad types, still images and video. Each type is divided into two more categories, those that are transmitted (live images to ground stations) and those that are recorded for later retrieval. This matrix illustrates the range of options available.

	Still Images	**Video**
Recorded	Camera	Camcorder
Transmitted	Slow Scan (SSTV)	Fast Scan/Amateur Television (ATV)

In general, images recorded for later viewing have better quality than transmitted images. The quality of recorded images is seen in both their color quality and image resolution. While of lower quality, transmitted images still have a great interest with Ground Crews because of their live nature. There is a way to combine the two categories of recorded and transmitted images that gives you the best of all worlds: couple the A/V output of a camcorder or digital camera to an ATV or SSTV system. This combination gives a taste of what is to be expected after the near spacecraft is recovered. Of course, this does add weight to the near spacecraft. Now let’s discuss these different imaging devices in more depth.

1.1 Still Cameras

Types and examples of imaging available with cameras include the following
Panchromatic: Basic Black & White, or Infrared
Multispectral: Color Film and Digital

1.1.1 The Good and the Bad

Systems to record still images on film or in memory have several benefits:

1. They're usually a lightweight and self-contained system.
2. They have excellent image resolution.
3. They have good color resolution.

Infrared image of the ground - *The foliage appears red because the chlorophyll in plants reflects infrared along with green. Between the near spacecraft and the ground are clouds in a row formation.*

On the negative side we have some limitations:

1. Some camera systems contain moving parts that may jam during a flight.
2. You can't always operate them electronically out of the box; some kind of modification or mechanical system must be devised.
3. The number of photographs that can be recorded on a single flight is limited to the film or memory in the camera.

1.1.2 Details

One way to reduce the limitations of number of frames and possibility of mechanical failure is to use digital cameras. More “film” can be added to the camera with a larger memory that doesn’t take up more space. With few moving parts, a digital camera is less likely to suffer from a mechanical failure. But with digital cameras you run into the problem of lower resolution than film, unless a relatively expensive camera is used.

The best film images are recorded using cameras with large film formats, like 120 film. The less an image is compressed to fit on film stock, the finer the details that are recorded on the film. Unfortunately these same cameras also tend to be the most expensive to purchase. I have yet to find an affordable 120 camera with motorized controls that I can modify for computer control.

A good compromise film camera is either an APS or 35 mm camera. There are several requirements for a film camera to operate in near space. First, it must have auto film advancing. This lets you concentrate on taking pictures rather than with building complex mechanical devices for advancing the film. Second, the camera must be capable of properly focusing at infinity. Once the near spacecraft is launched, everything visible is at infinity (i.e. more than 30 to 50 feet away). This issue is a big gotcha. Some $20 cameras claim they are focus-free, giving the impression that they are properly focused for distant subjects. Actually, many inexpensive focus-free cameras are focused for subjects twenty feet away from the camera, or the typical distance for which you photograph friends.

Other cameras are made focus free by stopping down their lens. Stopping down a lens means the diameter of the lens of the camera is reduced with a mask (iris), which reduces the light entering the camera. A camera for near space must be either manually set to infinity or capable of setting its focus to infinity by adjusting the lens' focus. If possible, set the camera's focus in advance, as this will not require the camera to move the lens. Some mechanical movements may freeze up in cold of near space. If the mission is flying a camera with a moving lens, get a camera with a lens movement that is internal to the camera body. Just to give an example, I used one camera with a lens that physically moved outside the camera body. After its second flight it quickly discharged any batteries loaded into the camera. I believe the focusing motor shorted out when the camera lens froze into a fixed position, thereby destroying any further use of the camera.

One of my early successful cameras is the Vivitar AF400. It is a veteran of over 20 flights. A servo operated the camera’s shutter button before I learned how to modify the camera to be operated directly by a computer. One early failure was the Big View 35. That camera froze up early one flight. Its last photograph is an interesting image of sunrise at 66,000 feet. The sun became a wide streak on the horizon, as the shutter began to fail and operated very slowly while the near spacecraft rotated. In the next section are directions for modifying cameras, or how to get them modified.

Sunrise at 66,00 Feet – *The sun became a wide streak on the horizon as the camera froze up and the shutter began to fail.*

1.2 Camcorders

1.2.1 The Good and the Bad

Recording video has several benefits:

1. Their images are video and not stills that may be aimed in the wrong direction when recorded.
2. Their moving images have reasonably good resolution in pixels.
3. Video images have good color resolution.

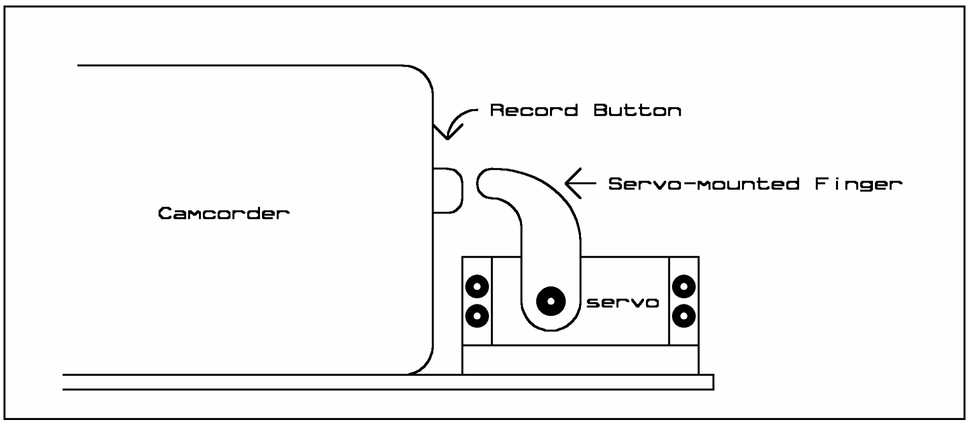
On the negative side, limitations to consider:

1. Camcorders are heavy, about 2.5 pounds for the lightest.
2. I know of no way to operate them electronically; a mechanical system must be devised.
3. Camcorders shut themselves off if when they do not record for five minutes, so they must run continuously from launch.

Perhaps the digital camcorders that are now available will change this. However, cost has prevented me from experimenting with them yet.

1.2.2 Details

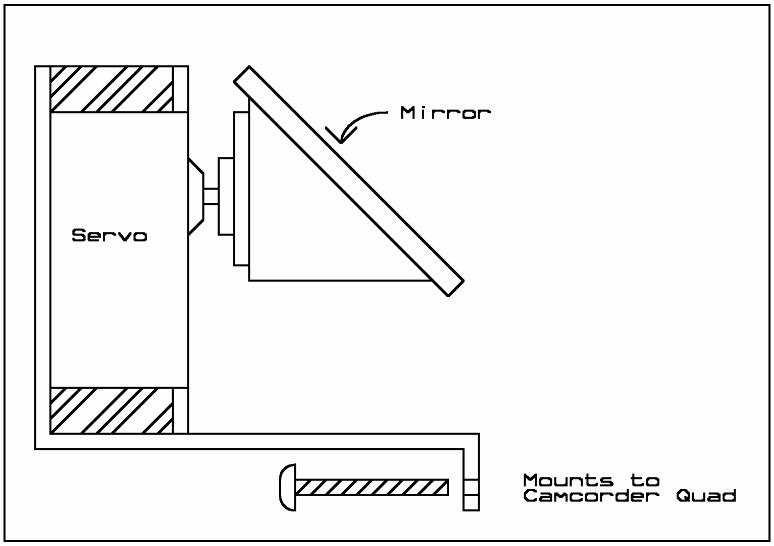
I've had a lot of success with sending camcorders into near space. Quasar is the camcorder I use in near space. The Quasar camcorder is basically a Panasonic, compact VHS camcorder. With a 60-minute videocassette and slow record setting, the compact VHS records two hours of video, enough to record the ascent and balloon burst, but not the landing. Both Jeff Melanson (KD7INN) and Mark Conner (N9XTN) have experience with camcorders that can record longer than two hours. To record the descent of a near space flight with a two-hour tape in the camcorder, the camcorder must be shut off for portions of the mission. A flight computer controlled servo positioned to press the record button turns the recording function on and off. Since the camcorder shuts itself off after five minutes of idling, a flight computer must continually press the record button in cycles of less than five minutes.



Servo-activated camcorder – *When the servo rotates, the finger pushes the record button.*

The camcorder ends up recording snippets of the flight until the camcorder is left recording. Be aware that once a camcorder shuts itself off, you must physically reset the ON/OFF button, a difficult proposition with a servo. It would of course be best if you can lay your hands on a service manual for the camcorder and discover how to "computerize" the camcorder. You'd think with all the moving parts in a camcorder, they'd be a nightmare in the cold of near space. Fortunately camcorders generate lots of heat, so they keep themselves warm in near space.

Unfortunately camcorders are large and heavy enough to make it difficult to rotate them with a servo. The way to get around this is to mount a mirror in front of the camcorder lens at a 45-degree angle. As the mirror rotates, the camcorder’s view changes, giving the camcorder a 180-degree view of the world.



Rotating Mirror – *Mounts to camcorder quad.*

On the negative side, the image is reversed. This may be fine for general viewing, but it makes if difficult to interpret images of the ground below. You may be thinking, "Ah, I'll just add a second mirror!" True, this reverses the reversed image, but it also requires the second mirror be larger than the first mirror to avoid cutting off the image. With the wide angle of view in a camcorder, this gets too unwieldy. Of course you could set the camcorder lens to zoom and reduce the angle of view. But then the image moves too rapidly though the field of view as the near spacecraft rotates. It's best to correct the reversed images through video capture software. There is one more method to avoid rotating large camcorders. Recording VCRs are getting smaller and more affordable. Before long I expect amateurs to send small CCD (charged coupled device) cameras into near space in place of a camcorder. A small CCD camera is easy to servo mount and its video images can be recorded with the VCR onboard the near spacecraft. By using a splitter, it may be possible to record high quality images onboard the near spacecraft while transmitting poorer quality ATV to Chase Crews.

Later in this chapter are directions how to make a camcorder cradle and a servo controlled mirror for rotating the direction of view of a camcorder.

1.3 Slow Scan Television

1.3.1 The Good and the Bad

Slow Scan has several benefits:

1. The images are transmitted slowly as audio tones over the radio (slow transmission decreases the bandwidth required for the signal and improves its quality over long distances).
2. The images are live images.
3. The imaging method is very similar to how NASA does their imaging.

Limitations to consider:

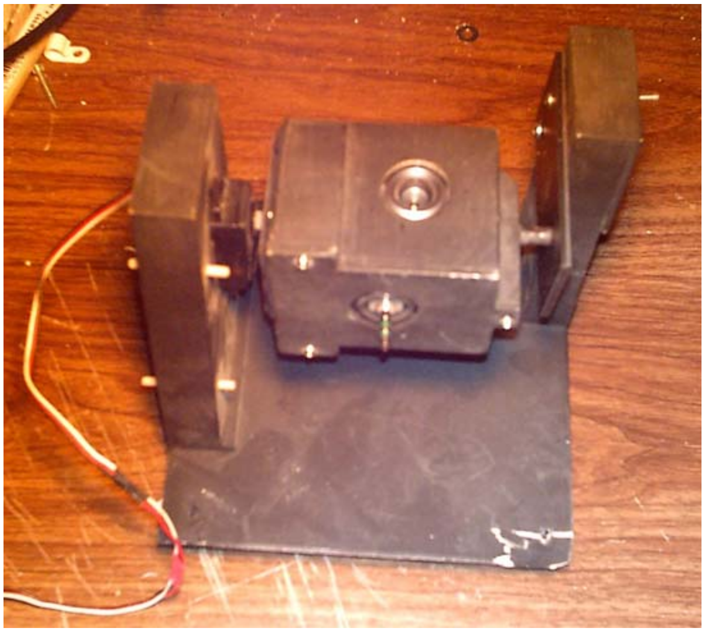
1. They may not have the best image resolution.
2. They may not have the best color.
3. The images take time to transmit.

1.3.2 Details

The easiest SSTV unit to adapt for near space is the Kenwood VC-H1. This compact unit requires a HT to send images, so there are two HT sized devices onboard the near spacecraft. The aspect I like best about the VC-H1 is that its imaging head can be removed from the main body, where the imaging processing occurs. The VC-H1 camera head sends images to the VC-H1's main body for capture and processing for transmission over the attached HT. The captured image is converted to audio tones, which indicate the color and intensity of each pixel. It takes the VC-H1 32 seconds to transmit images in Robot format. Since the transmission rate of a SSTV image is slow, the image quality received doesn't degrade as much with transmission distance as ATV images do. Images recorded at 120 miles way are as good as those recorded 20 miles away from the near spacecraft.

To prepare the VC-H1 for near space work, remove the imaging head and connect it to the VC-H1 body with an audio cable from Radio Shack. The processing unit is kept inside the capsule, while the imaging head is mounted to a scan platform. Building a scan platform is covered in Chapter Five, Section 3.4, and building a camera box for the VC-H1 is covered in this chapter, Section 3.1.

Kenwood VC-H1 Slow Scan Television – *The camera head can be removed from main body.*



VC-H1 Scan Platform

The VC-H1 can be set to transmit images every three minutes. This simplifies the process of acquiring images. Alternately, a communications cable for operating the SSTV from a PC is available. Once you know the communications protocol, a flight computer should be able operate the unit.

1.4 Fast Scan/Amateur Television (ATV)

1.4.1 The Good and the Bad

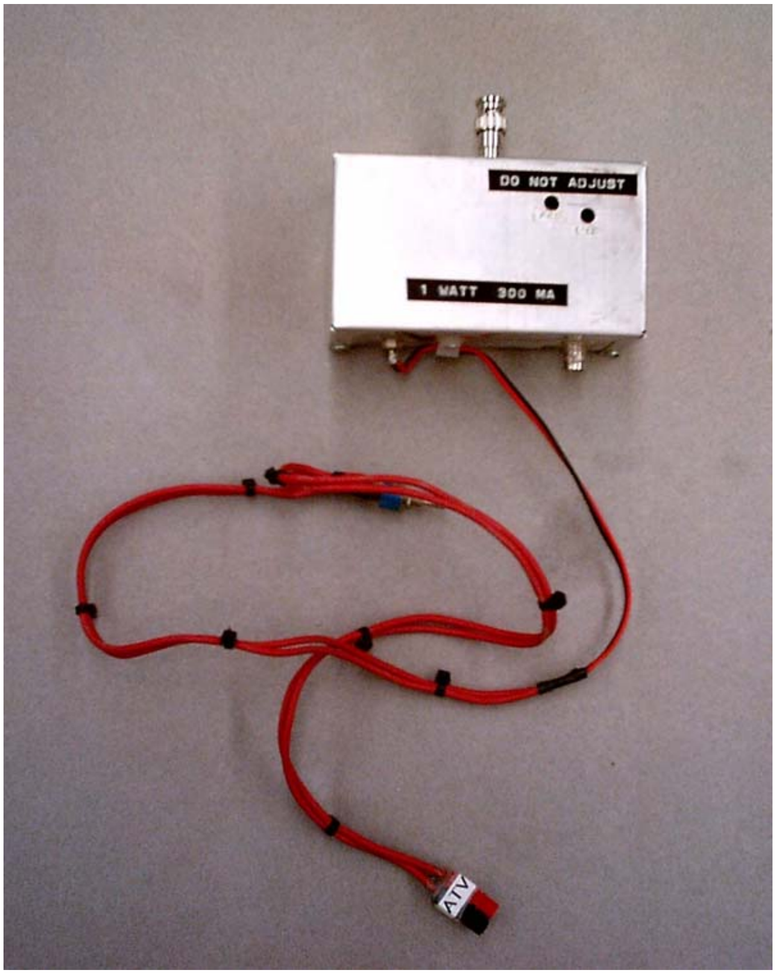
Transmitting video has several benefits:
1. The images are video, not just snapshots that may be aimed in the wrong direction.
2. The images are live from near space.

On the negative side we have limitations:
1. ATV transmitters can be power hogs.
2. Signal quality drops off rapidly with distance or altitude. Good images require beam antennas, a difficult antenna to use from a moving chase vehicle.

1.4.2 Details

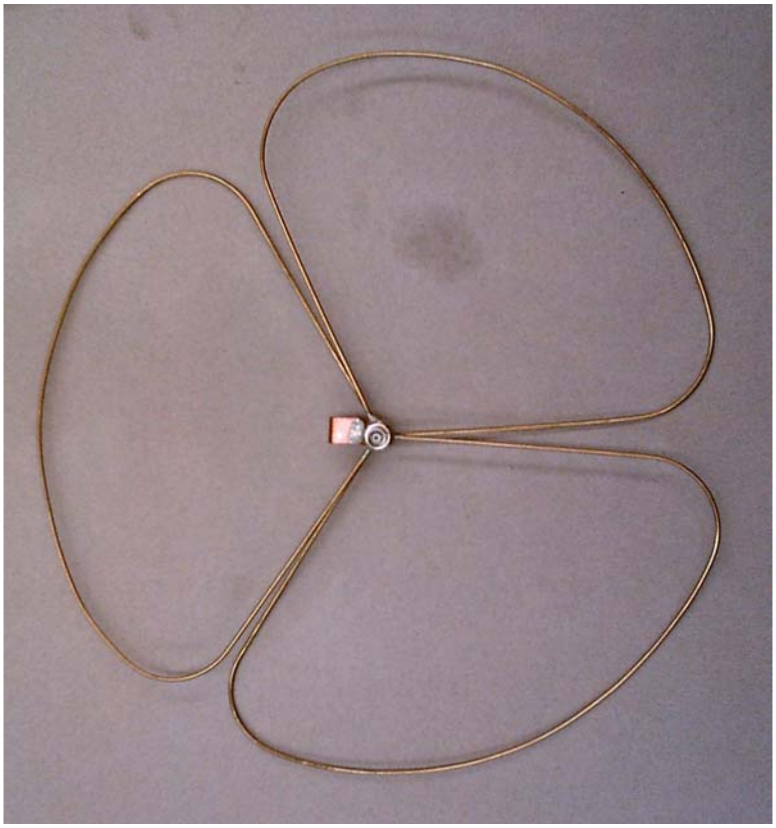
A CCD camera and 1 watt transmitter makes an excellent, lightweight ATV set up. However, a one-watt ATV signal drops off rapidly with distance. You get wonderful video at launch and great video from the landing, if you're lucky enough to be close. I've looked into sending up an amplifier. As I recall, a ten-watt amp requires about 3 amps of current at 12 volts (about 25% efficient). A good battery is needed to power the amp. A good set of NiCds or lithiums are probably the best battery to use. Three amps of current for a three-hour flight require a battery pack of 9000 mAh. This much capacity is available in some “D” cell form-factors. Operating at 12 volts for three hours, the battery produces 36 watts of total power. The surplus lithium “D” cells available from S&G Photographic can produce this level of power, but the batteries are getting older and more expensive.

Pretty much the only place to get ATV equipment is through PC Electronics. The transmitter best for near space is the TX5A. It is a bare board that you mount inside a metal enclosure. Use bypass capacitors to bring power into the enclosure, as this filters out any AC ripple in the power supply.



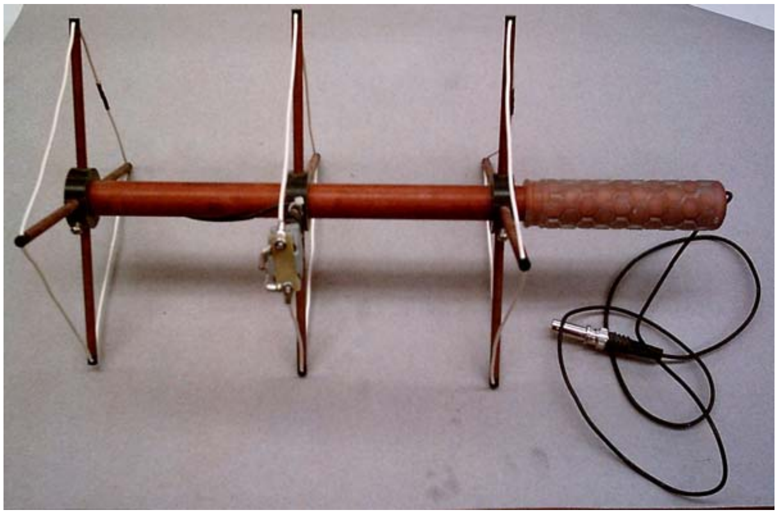
Fast Scan/Amateur Television (ATV) Transmitter

Dave Clingerman of Olde Antenna Labs has done a wonderful job for me building the bare board into an enclosure; I'd recommend his work to you also. Images from ATV are best sent over a mini-wheel antenna. This antenna is circular in design, giving it a very uniform radiating pattern. The polarization of this antenna is horizontal. The construction of the mini-wheel antenna has been described in past issues of ATV Quarterly. You can also purchase them directly from Olde Antenna Labs.



Mini-Wheel Antenna

Mount the ATV antenna beneath the airframe as rotation of the stack leads to spin modulation of any antenna mounted off one side of the near spacecraft.



ATV Quad Antenna

Input to the ATV transmitter is from a CCD camera. Small, lightweight CCD cameras with color output are now available for less than $50. Lightweight CCD cameras like this are mounted to scan platforms. Suitable CCD cameras are available from Super Circuits.

2.0 Modifying Cameras for Flight Computer Control

2.1 Cameras to Use and Cameras to Avoid

Older cameras and some inexpensive cameras use a mechanical shutter system. When the shutter button is depressed, mechanical linkages open and close switches and relays, triggering the camera to operate. A computer can only control this style of camera if the shutter button is depressed by a servo or solenoid. The mechanical alignment needed for this type of camera is not impossible, but it is not reliable, either. Oregon Scientific makes an inexpensive digital camera that the author has experimented with. From our experiments, we learned that the camera shuts downs too quickly when not in continuous use. As a result, photographs must be taken in rapid succession. This requires a large memory card, and it is best if it is a 64 Mb card. Read the directions that come with the camera, and look for battery saving features that shut down the camera.

Most currently available 35mm cameras include four important features: electronic shutter, auto-focus, electronic exposure control, and auto film advance. When the shutter button is depressed, an electric connection is made inside the camera, triggering a sequence of events. First, when the first contact is made in the shutter switch, the auto-focus of the camera determines the distance to objects in the camera's field of view and focuses accordingly. At the second contact, the camera shutter opens, exposing the frame for the proper length of time. After the exposure is made the film advances to the next frame. Three of these four features are required to easily modify the camera for computer control.

There are some focus-free cameras with a fixed focus lens. These cameras don't require focusing because the lens is permanently set for a fixed distance of some few tens of feet. These kinds of cameras are suitable for photographing friends but not landscapes. In near space, everything is infinitely far away. A focus-free camera of this type will only return blurry pictures.

Automatic exposure control is useful, but not essential. If the exposure and f-stop can be set in advance, then automatic exposure control is not needed.

Auto-film advance is required to make modifying a commercial camera to computer control practical. Without this feature, a servo is required to advance the film after an exposure. Just like mechanical shutter controls, the alignment issues make cameras without auto-film advance impractical to convert to computer control.

So, the features needed for a near space camera are as follows:

A. The shutter button must be a simple switch closure. The shutter button cannot be connected to a mechanical release. The electrical switch is replaced with a transistor and resistor. Once the switch is replaced the flight computer is capable of operating the camera.

B. The auto-focus must really focus during the exposure. Do not use a camera with a fixed focus unless the focus can be manually set to infinity.

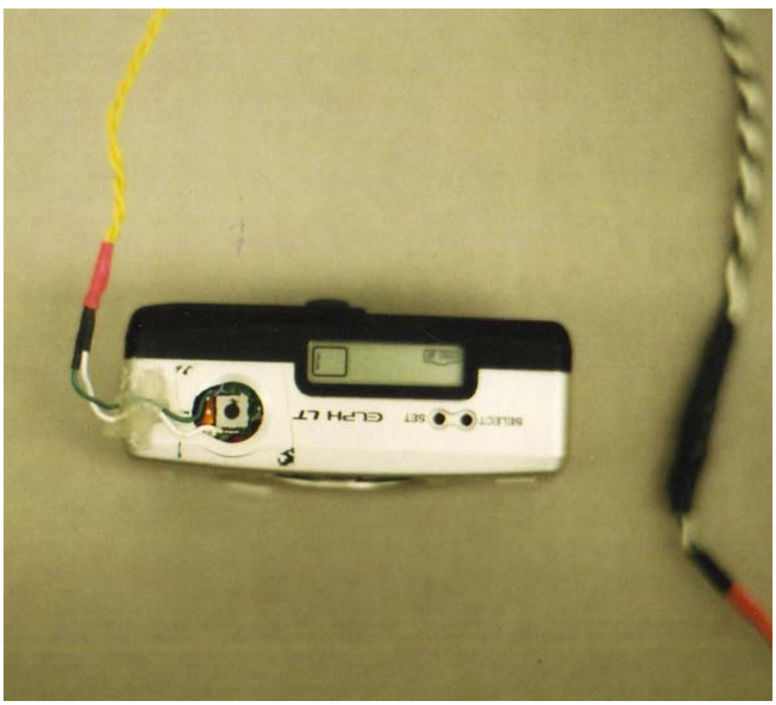
C. The camera must be capable of determining the proper exposure on its own, or the exposure time for each frame must be set before launch.

D. The camera must have auto film advance. Once a picture is exposed, the motor inside the camera must automatically advance to the next frame.

2.2 Getting the Camera Modified

If you're worried about ruining a new camera, then have a camera shop modify a 35mm camera for you. Two cameras that can be modified are the Canon Sure Shot Owl and the Canon Elph APS. Most other modern cameras can be modified, but talk to the camera shop first. It should only cost $45 to modify a camera. Here are the instructions you want to give to the camera repair shop modifying your camera. You want the camera opened up and two wires soldered to the button pads. If there is a switch closure position for the auto-focus, then you want that shorted to the shutter switch position. When the modification is completed, the camera will focus its lens and take a photograph when the bare ends of the wires are touched together. When the two wires are separated, the film will advance to the next frame. If the camera doesn't automatically advance, don't panic right away. Some cameras need to be loaded with film to take a picture and advance. So I'd recommend you get some exposed film (or waste a roll) and mount it inside a reusable film cartridge. Have a camera store show you how to do this. With this test roll, you can check out cameras at will. If you have trouble finding a camera store to modify your cameras, try Mr. Ken Tromburg at Photek, in Boise, Idaho[A]. He has modified several cameras for me over the years and I have been very happy with his work.

2.3 Modifying the Shutter of the Canon Elph At Home



Canon Elph Camera *– With shutter modifications*

Bill All (N3KKM) of NSBG told me how to modify the Canon Elph. He originally found these instructions on an amateur rocketry site on the web. Unfortunately, when Bill told me how to make this modification, he couldn't find the site. So whoever you are, thanks! The Canon Elph is an inexpensive and easy camera to modify. The following steps explain how to modify the shutter switch of the Elph.

Section 2.4 of this chapter, Adding a Transistor Switch, explains how to complete the process for the Elph and any other camera with wires soldered to its shutter switch. The procedure works for other cameras if you can safely close them after the modification.

2.3.1 Materials

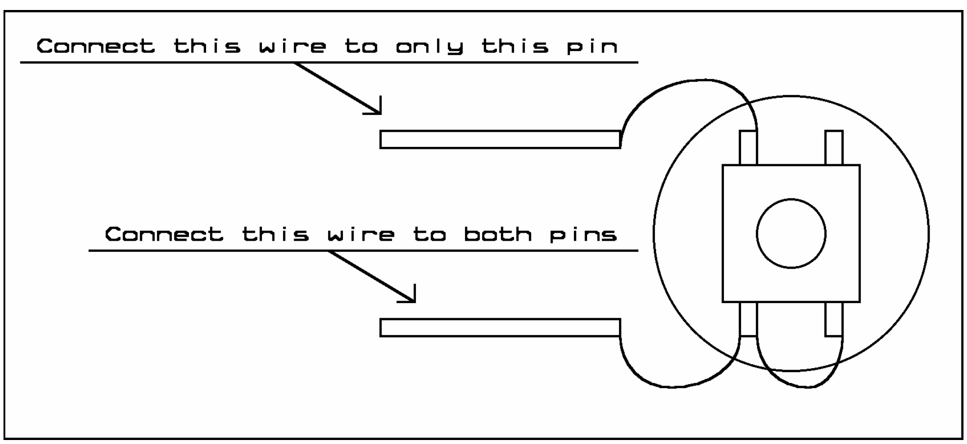
- A small jeweler's Phillips screwdriver
- Two colors of very thin stranded, insulated wire, try #30 AWG
- Black electricians tape
- Hot glue

2.3.2 Procedure

√ Remove the screws holding the camera case together (the screws are tiny Phillips).
√ Turn the front of the camera to face you.
√ The flash capacitor is located on the right side of the camera – **DO NOT** fool with this end of the camera.
√ Open the case, at least enough of the silver front of the camera to access the shutter button.
√ Remove the plastic button.
√ Identify the micro-switch underneath the plastic shutter button.
  - o There are four soldered pads on the switch:
  - o The front two focus the camera and trigger the exposure.
  - o The back left pad is the ground.
  Note: The front refers to the side of the camera with the lens.

Perform the following test on the switch:

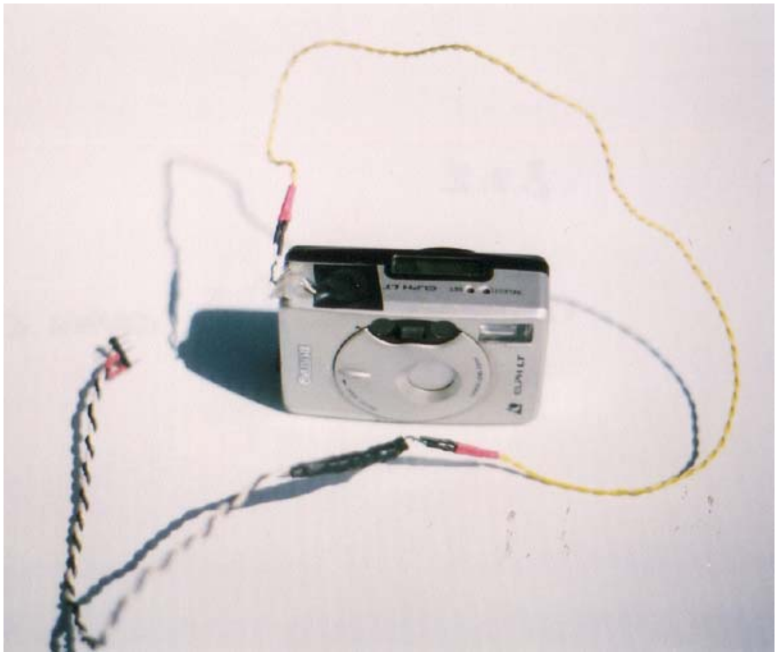
√ Cover the flash with electricians tape so you are not blinded.
√ Cut a short length of wire and strip insulation from both ends.
√ Short the front left pad and back left pad together.
√ Short the front right pad and back left pad together.
√ You'll notice one combination focuses the lens and the second exposes a frame.
√ Cut two pieces of thin wire to a length of one foot (make one wire a dark color).
√ Strip the insulation from both ends of each wire.
√ Solder the dark wire to the back left pad.
√ Solder the other wire to both pads on the front of the shutter switch.



Shutter Switch Wiring Diagram

√ Pass the two wires through the open hole of the plastic case where the shutter button used to be.
√ Test the electrical connection by shorting the two free ends of the wires together (the camera should operate).
√ Close the camera case and replace the screws.
√ Cover the open hole with a piece of black tape.

√ Use a little hot glue to "tie" the wires to the camera case (as a strain relief).
√ Twist the wires together to keep them under control.
√ Go to the next section to complete the modification.



Modified Camera – *With wires twisted*

2.4 Adding a Transistor Switch to a Modified Camera

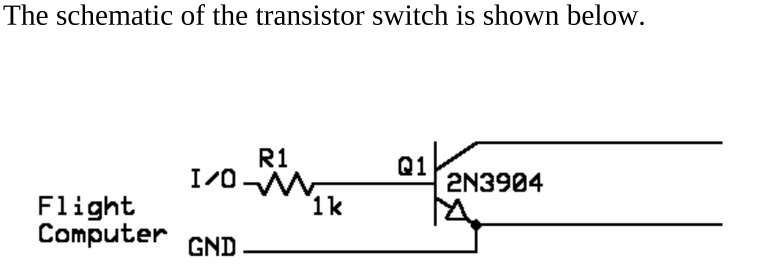
Once you have a camera with two wires soldered to its shutter switch, you'll need to solder a transistor and resistor to the wires.

2.4.1 Materials

- 1k Ohm resistor
- 2N3904 transistor
- Two colors of #24 AWG stranded wire
- Connectors for the wires to the flight computer
- Perf board
- Hot glue
- Heat shrink tubing large enough to cover the transistor switch perf board
  (I can get by with a ¾" diameter heat shrink, but your mileage will vary)

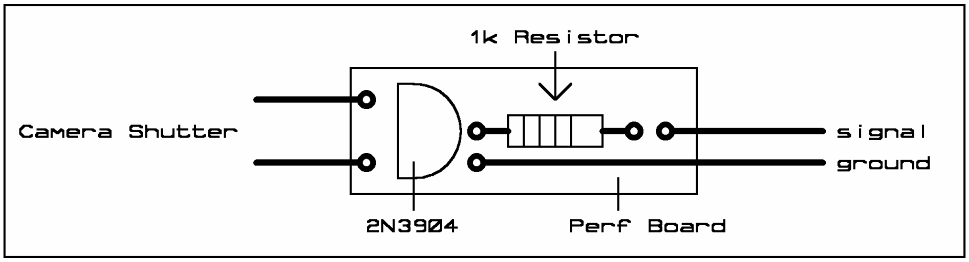
2.4.2 Procedure

The schematic of the transistor switch is shown below.



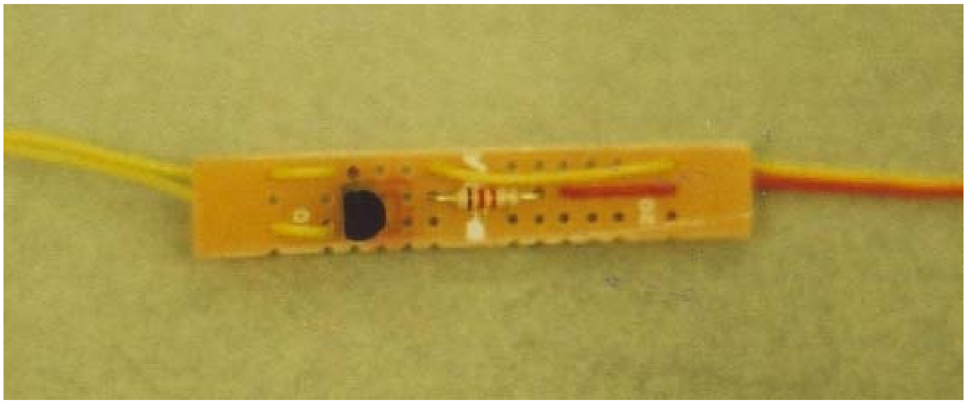
Camera Transistor Switch Schematic

Placement of components on the perf board is not critical, but try laying them out before soldering.



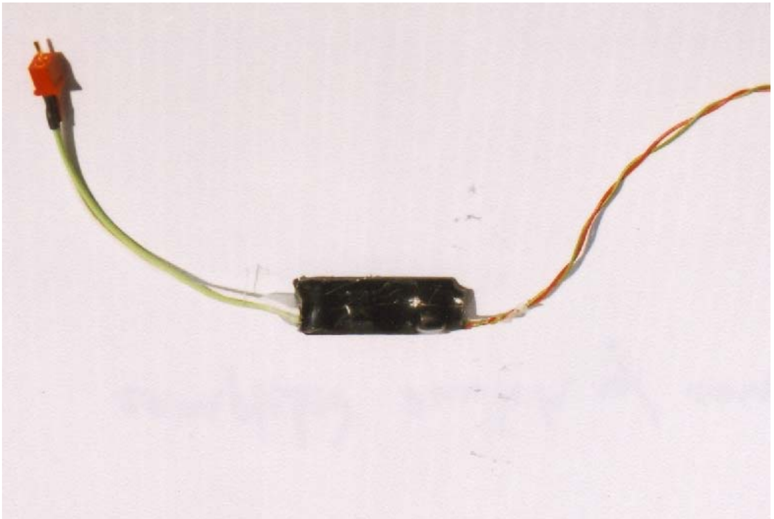
Parts Placement – *For the camera transistor switch*

- √ Connect the ground wire of the shutter switch to the emitter of the 2N3904.
- √ Connect the focus and exposure wire to the collector of a 2N3904. Note: which wire connections are made to the emitter and collector does not matter in the author's experience, but I still want to play it safe.
- √ Connect one end of a 1k resistor to the base of the transistor.
- √ Outline the size of perf board needed to fit all the components currently on the board.
- √ Cut a small piece out of the board first and sand its edges smooth.
- √ Replace the components and solder them.
- √ Cut two lengths of #24 AWG stranded wire, about 18 inches long.
- √ Solder the ground (black or green) wire to the emitter of the transistor.
- √ Solder the signal wire to the open end of the resistor.
- √ Attach connections to the open ends of the wires to interface them to your flight computer: the wire soldered to the emitter is connected to ground and the wire connected to the resistor is connected to the I/O pin.
- √ Test the transistor switch as explained in section 2.4.3.



Camera Transistor Switch – *Built on perf board*

- √ Apply a thin layer of hot glue to the perf board.
- √ Cover the perf board and its components with heat shrink tubing and shrink.



Camera Transistor Switch – *After perf board is covered with heat shrink.*

In place of a transistor, Zack Clobes (W0ZC) uses an opto-isolator to make the connection. The CC/PS controls an LED to operate the opto-isolator.

2.4.3 Operating the Modified Camera

To operate the camera, use the following code.

```
camera con 10

debug “click”, cr
high camera
pause 2000
low camera
debug “finished”, cr
end
```

The program’s constant, “camera”, is the I/O pin connected to the base resistor (which in this example is I/O pin 10). If constructed properly, the camera will take a photograph just after the Debug Terminal displays the word “click”. Experiment with the PAUSE statement to determine the minimum time the camera requires taking a photograph.

2.4.4 How it Works

When the camera I/O pin is set high, it energizes the base of the NPN transistor, saturating the transistor. A saturated transistor creates a low resistance path from the collector to the emitter where the two contacts of the switch are wired. This path acts as a closed switch when the transistor saturates allowing the two contacts of the shutter to now see each other. It’s as if you shorted the shutter’s two contacts and the camera responds as if the shutter button has been pushed (in essence, it has). See Appendix A, Lesson Nine for a lab with the transistor switch.

3.0 Camera Boxes and Camcorder Cradles

3.1 Camera Boxes

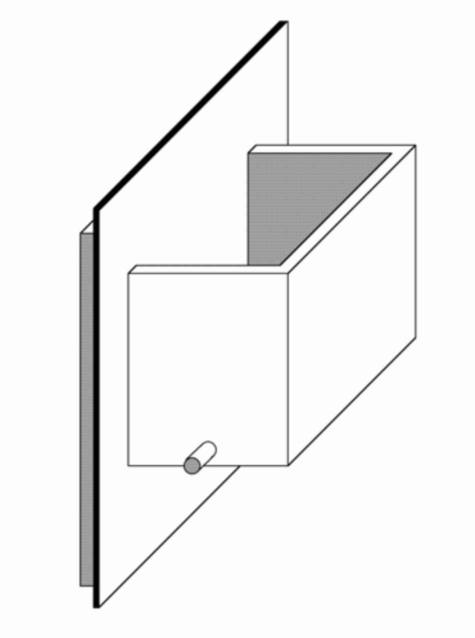
The camera boxes described here can mount a camera to the outside face of an E-Quad. Camera boxes are mounted either fixed to the E-Quad, or as a part of a scan platform. Stationary camera boxes are mounted to orient the camera either up towards the balloon and parachute, sideways to the horizon, or down towards the ground. By mounting the camera box to a scan platform, photographs of the balloon, horizon, and ground can be returned with a single camera. Whether the camera box is mounted fixed to an E-Quad or as part of a scan platform, its construction is the same. The scan platform is made to fit the camera box, ensuring that the camera box can rotate properly in the scan platform.

3.1.1 Materials

Camera Box on Quad Panel

Basic Camera Box

- Camera
- ½" thick Styrofoam[B] sheet (use the same kind of foam the airframe is constructed of)
- Hot glue
- Epoxy
- Metal straight edge
- Exacto knife
- 1/32" thick plywood
- 1/8" diameter wooden dowel (if building the basic camera box)



Camera Box on Quad Panel

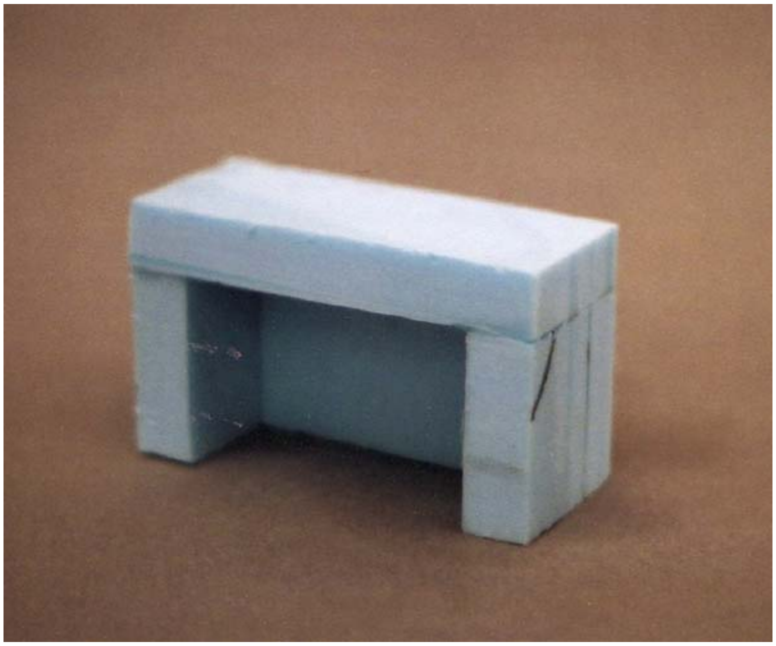
Additional Materials for Scan Platform

- 1/8” thick plywood
- ¼” diameter dowel
- Circular servo horn
- #20 solid wire, stripped
- Two Popsicle sticks

3.1.2 Procedure

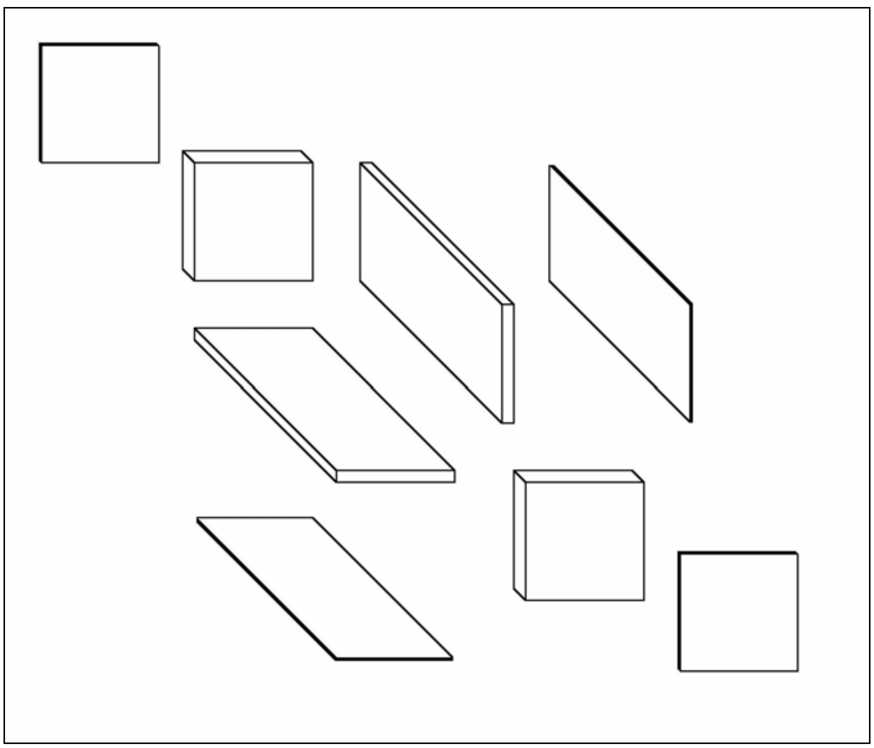
Make the Styrofoam Box

√ Measure the dimensions of the camera sides and cut two rectangles of 1/8” plywood the same size. At this time, the size of the 1/8” plywood doesn’t need to be accurate.
√ Tape the 1/8” plywood to the sides of the camera.
√ Measure the bottom footprint of the camera. Note that the camera’s footprint is now ¼” wider due to the plywood, if you are constructing a scan platform.
√ Cut a rectangle of foam just one inch larger than the camera footprint with Exacto knife and straight edge. The Styrofoam will be trimmed after construction.
√ Place the camera on the foam and determine dimensions of the box’s sides.
√ Cut out the sides of the box larger than the measured dimensions.
√ Use hot glue to glue the sides to the bottom, leaving the camera in place, but don’t glue the camera into the box.
√ Trim the box after the glue cools.



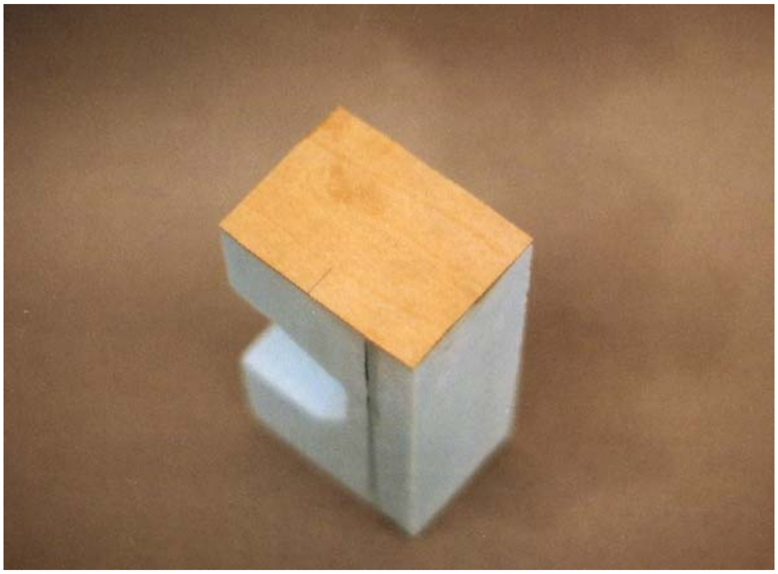
Beginnings of Camera Box –
Styrofoam Structure

Laminating the Box with Plywood



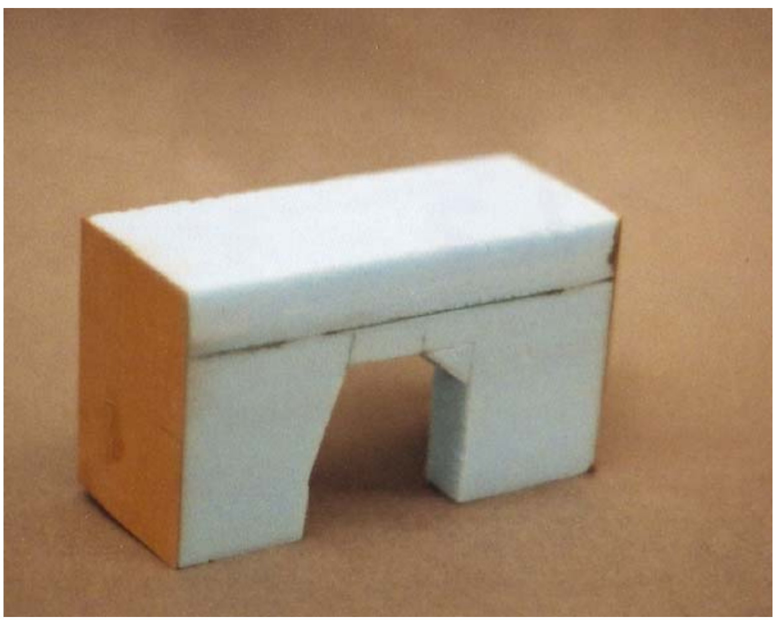
Plywood Over Box –
Exploded Diagram

- √ Laminate all sides of the box except for the surface to be mounted to the face of the E-Quad.
- √ Cut a piece of 1/32" ply slightly larger than the bottom surface of the box.
- √ Epoxy the plywood to the box.



The First Piece Epoxied in Place

- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight, such as a cast-iron muffin pan, until after the epoxy sets.
- √ Cut two rectangles of 1/32” plywood just larger than two side faces of the camera box.
- √ Epoxy the plywood on to the side faces.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.



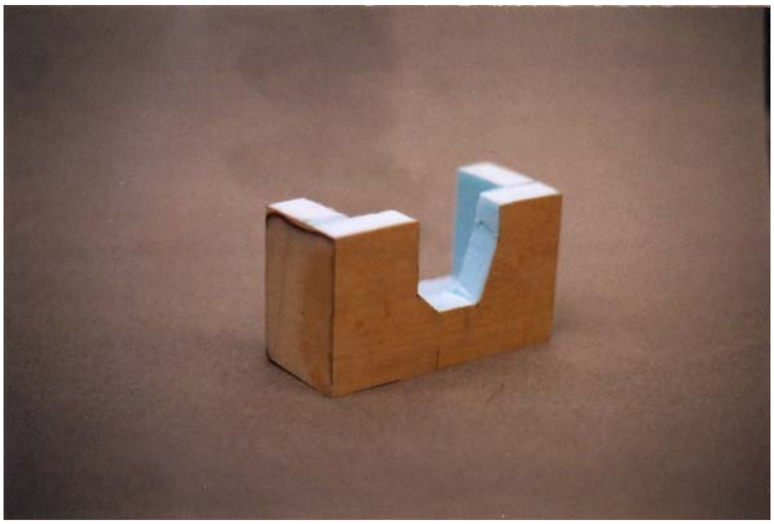
Side Faces Complete

- √ Trim the edges of the plywood to fit the Styrofoam box with a stationary sander.
- √ Cut two rectangles of 1/32” plywood just larger than the remaining two faces of the camera box.
- √ Epoxy the plywood on to the remaining faces.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.
- √ Trim the edges of the plywood to fit the Styrofoam box with a stationary sander.

- √ Fill any open gaps in the joints with epoxy and sand the joints smooth after the epoxy sets.
- √ Epoxy the 1/8” thick plywood inside the box on the side faces.
- √ Insert the camera after the sides are epoxied inside to apply force to the 1/8” ply while the epoxy sets.

Cut Lens Openings in the Camera Box

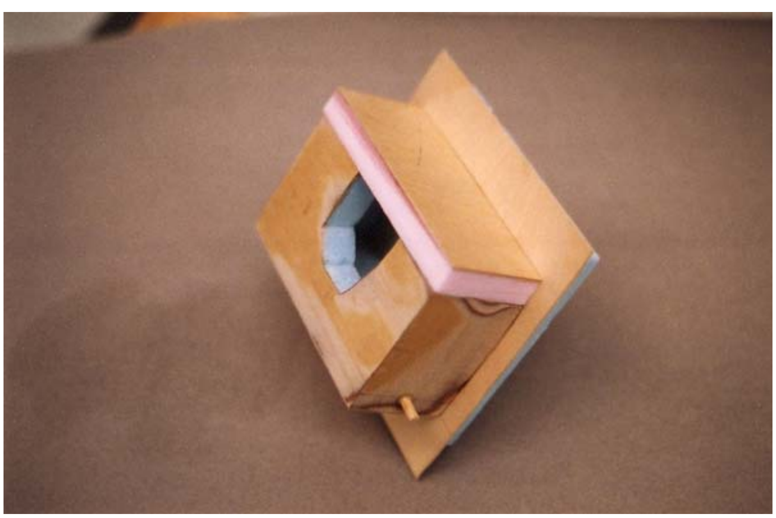
- √ Measure the dimensions and positions of the lens, light sensor, and focuser of the camera using a T-square to keep the measurements perpendicular.
- √ Transfer the measurements to the camera box, again using the T-square.
- √ Reduce the number of sharp corners by marking diagonals.
- √ Carefully cut out the openings in the camera box, as outlined by the pencil marks, with an Exacto knife.



Plywood Lamination Complete

Make the Camera Box Lid

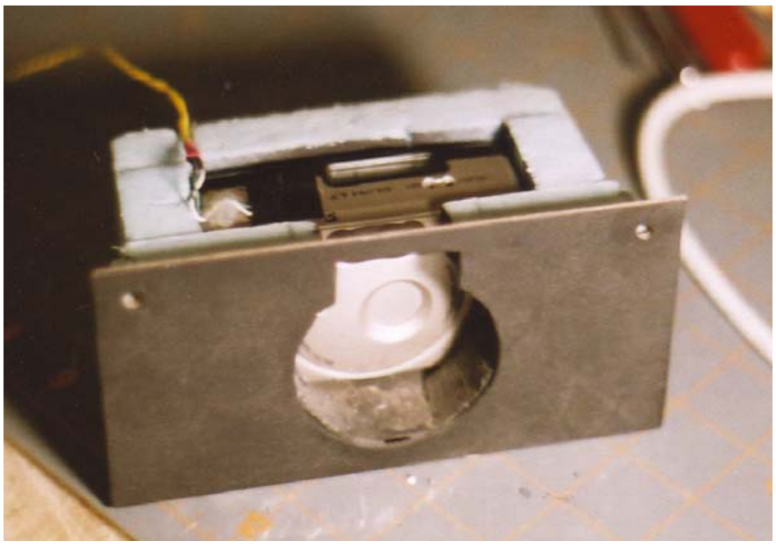
- √ Cut a rectangle of Styrofoam to cover the opened top of the camera box.
- √ Cut a sheet of 1/32” plywood to fit the cover.
- √ Epoxy the plywood to the Styrofoam lid.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.



Adding the Lid

Complete the Basic Camera Box

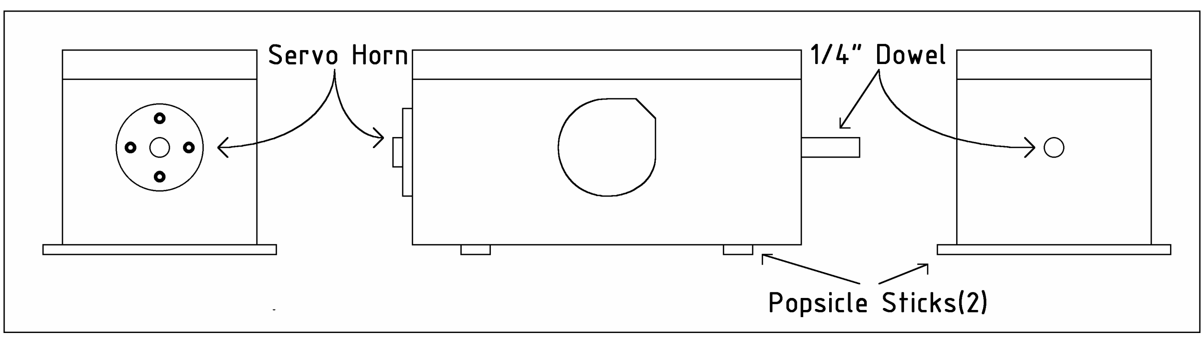
- √ Mark the center of the sides of the camera box.
- √ Drill 1/8" diameter holes in the sides.
- √ Cut two 1/8" diameters dowels to a length of one inch.
- √ Epoxy the dowels into the sides, with the dowels flush to the inside face of the camera box.
- √ After the epoxy sets, bevel the end of the dowels. The dowels are where rubber bands wrap around the camera box to hold the camera box lid in place.
- √ Epoxy the camera box to an E-Quad panel.
- √ Cut an opening in the E-Quad panel where the camera's transistor switch enters the capsule.
- √ Paint the E-Quad panel and camera box.



The Camera Box - *Painted and ready to go*

3.1.3 The Scan Platform Camera Box

The following directions convert the stationary camera box into one suitable for a scan platform.



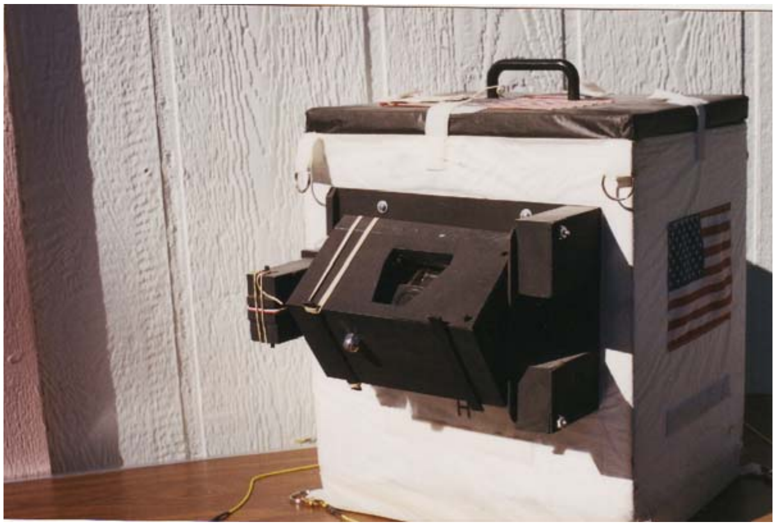
Scan Platform Camera Box

- √ Cut the Popsicle sticks to a length ½" longer than the depth of the camera box.
- √ Draw two lines parallel to the outside edges of the bottom of the camera box, one inch inside the outside edges.

- √ Epoxy and center the Popsicle sticks to the bottom of the camera box. Be sure the Popsicle sticks are positioned outside the lens openings in the camera box; the sticks protrude ¼” beyond the front and back of the box.
- √ Use strips of masking tape to keep the plywood from shifting and cover with a weight until after the epoxy sets.
- √ The Popsicle sticks are where the rubber bands wrap around to hold the camera box lid in place. Rubber band the lid to the camera box (do not place the camera inside the box at this time).
- √ Find the center of the sides of the camera box, being sure you are including the lid when determining the center.
- √ Drill a ¼” hole in one of the centers.
- √ Cut the ¼” diameter dowel to a length of two inches.
- √ Epoxy the dowel into the side, with the dowel flush to the inside face of the camera box.
- √ Epoxy the circular servo horn to the center of the other side of the camera box.
- √ Drill at least four small holes through the servo horn and camera box with small diameter drill bits, just large enough pass the wire staples you will make from the #20 wire.
- √ Cut at least four lengths of #20 AWG wire one inch long.
- √ Coat the wires with epoxy and insert through the holes in the servo horn and camera box until the wires protrude roughly equal amounts from the inside and outside surfaces.

Servo Horn on Camera Box –
Held in place with wire "staples"

- √ Fold the wire end over to form a “staple.”
- √ Coat the exposed ends of the wires with epoxy.
- √ Go to Chapter Five, Section 3.4.3 and complete the booms and servo for the scan platform.



Completed Scan Platform Camera Box

3.2 Camcorder Cradles

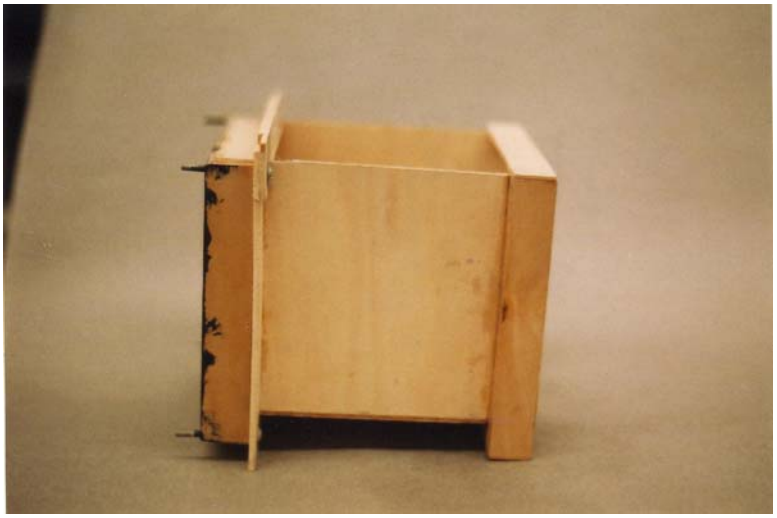
Camcorder Cradle

The camcorder cradle secures a camcorder inside an airframe. The cradle design in this chapter extends the width of the airframe and is braced on both ends by opposite E-Quad openings. One E-Quad is the opening for the camcorder lens and the opposite E-Quad is the hatch for operating the camcorder.

3.2.1 Materials

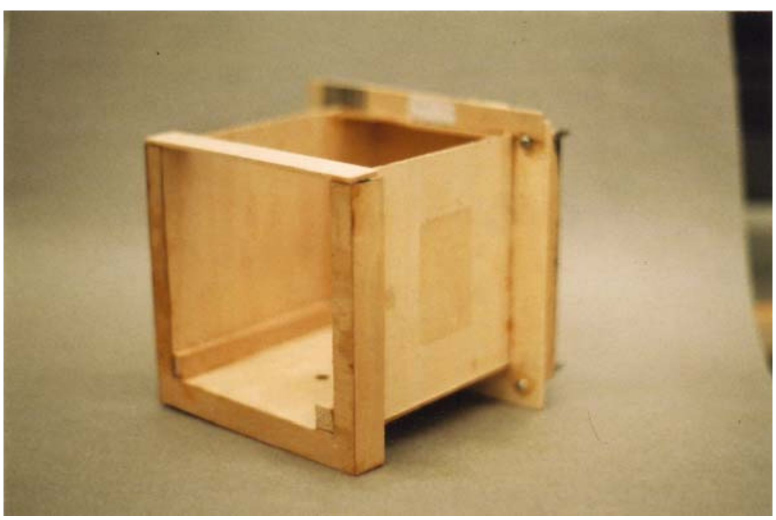
- ¾" Styrofoam sheet
- ½" Styrofoam sheet
- 1/8" thick plywood
- ¼" by ½" basswood strip
- 1/8" diameter dowel
- #6-32 threaded rod, or two inch long bolts with their heads cut off
- Epoxy
- Camcorder[C]

Procedure



Plywood Box for Camcorder Cradle

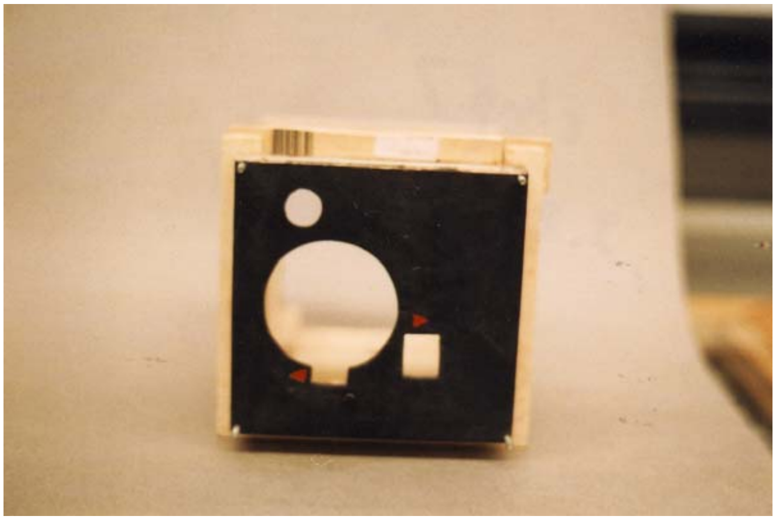
- √ Cut three pieces of 1/8” plywood to dimensions of 5.25” wide and long enough to span an airframe, usually ten or twelve inches long.
- √ Epoxy their edges together to form a “U” shaped channel capable of sliding through one E-Quad and spanning the width of the airframe. Note: This structure is fragile; treat it carefully at this point.
- √ Epoxy a 5.25” square of ¾” Styrofoam to one end of the “U” channel (this is the front panel of the camcorder cradle) and let the epoxy set.
- √ Epoxy a doubler inside the bottom of the cradle. The doubler thickens the bottom of the cradle where the ¼”-20 mounting bolt hole is drilled.
- √ Lay the camcorder inside the “U” channel and press the front of the camcorder into the Styrofoam front to form a light depression indicating where the lens is located.



Camcorder Cradle - *From another angle*

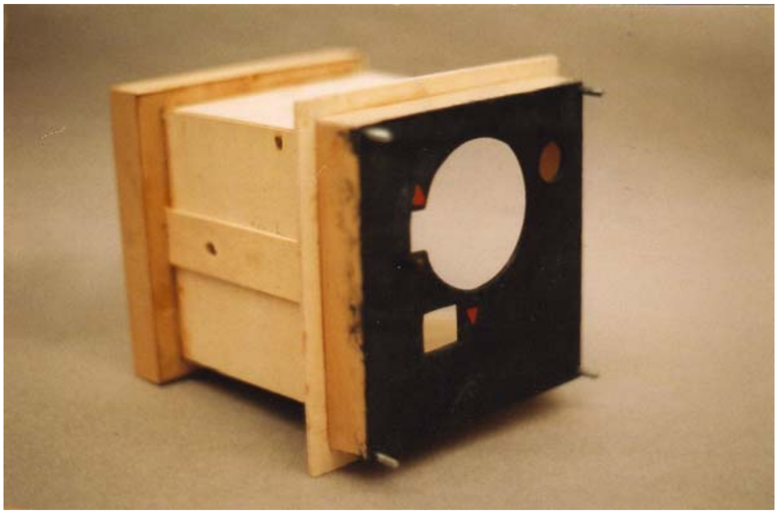
- √ Cut out an opening for the lens of the camcorder.
- √ Use the lens position to determine where to cut an opening for the camcorder’s light sensor and focuser.

√ Note: Some camcorders have controls located on the front of the camcorder. Make all necessary holes in the front plate for these controls.
√ Use a small probe to determine the location of the ¼”-20 mounting thread of the camcorder.
√ Drill out the ¼”-20 hole in the cradle and bolt the camcorder inside the cradle.
√ Cut a combination of ½” and ¾” Styrofoam to fill gaps between the camcorder and the cradle. Not all the gaps have to be filled, but use enough Styrofoam to strengthen the joints in the cradle.
√ Cut a six-inch square of 1/8” plywood and center it over the front of the cradle. This is the front plate.
√



View of the Front Plate – *Here shown painted*

√ Mark on the front plate the location of the openings in the front Styrofoam face of the cradle.
√ Cut out the openings in the front plate.
√ Epoxy the six-inch square front plate to the front of the cradle.



Another View of Front Plate

√ Cut a 5.25” square of ¾” Styrofoam to fit the back end of the cradle as a rear panel.
√ Assuming the camcorder record button is located in the back of the camcorder, cut a large enough opening in the back plate so that fingers can reach in and start the camcorder.
√ Cut another opening to make the viewfinder visible.
√ Epoxy the back Styrofoam plate into place.

- √ Cut a 5.25" square of 1/8" thick plywood for the back plate.
- √ Mark the location of the openings on the plywood back plate.
- √ Cut out the openings in the back plate.

The camcorder sits next to the cradle – *next step, the test fitting.*

- √ Test fit the cradle by sliding it into one open E-Quad port and making sure the back end of the cradle with the plywood back plate does not extend beyond the face of the airframe.

Cradle in the Airframe

- √ Epoxy the plywood back plate in place.
- √ Cut four pieces of #6-32 threaded rod to a length of two inches for the rear bolts.
- √ Drill 1/8" diameter holes 1.5 inches deep into the corners of the rear panel and back plate.
- √ Fill the holes with epoxy and thread the threaded rod into the epoxy-filled holes
- √ Cut a six-inch square sheet of 1/8" thick plywood for the back locking plate.
- √ Drill four holes in the back locking plate to match those protruding from the back plate of the cradle.
- √ Cut a rectangle of ¾" thick Styrofoam for the access cover. This will cover the openings in the back locking plate of the cradle.
- √ Cut a rectangle of 1/32" thick plywood to cover the face of the access cover.
- √ Epoxy the 1/32" plywood onto one face (this will be the outside face) of the access cover.

√ Lay the back cover over the opening in the back plate and mark its outline.
√ Cut ¼” by ½” basswood strips to form a border around the back cover.
√ Epoxy the ½” by ¼” basswood strips to the back plate, ½” face down.
√ Test fit the back cover to be sure it fits within the boundary created by the basswood strips.

Test Fitting the Covers

√ Find the center of the vertical sides of the basswood boundary.
√ Cut notches through the center deep enough to lay a 1/8” diameter dowel in.
√ Cut the 1/8” diameter dowels to a length of ¾” long and sand the cut ends smooth.
√ Epoxy the dowels inside the cut notches.
√ Trim the corner bolts of the cradle and the ¼”-20 camcorder mounting bolt.
Note: Use a Dremel with a sanding disk to make the bolts just long enough to do their job.
√ Mount the camcorder inside the cradle and test fit the cradle by sliding it into one E-Quad port and bolting the back plate to the bolts, securing the cradle inside the airframe.
√ Note: It may be necessary to trim the top of the cradle over the ¼”-20 bolt to be able to lift the cradle high enough to clear the bolt head at the bottom of the cradle.

If your camcorder has function buttons on its top face, then follow the next steps to construct a top hatch that prevents Styrofoam peanuts inside the airframe from changing camcorder settings.

√ Load camcorder into the cradle.
√ Insert the cradle into an airframe.
√ Cut a sheet of ½” thick Styrofoam large enough to cover the exposed open top of the cradle. This will be the top hatch. Note: The top hatch must be supported on its sides by the cradle, but do not create a significant overhang.
√ Cut ¾” wide strips of 1/8” plywood to the same length as the top hatch.
√ Epoxy the 1/8” strips to the sides of the top hatch, flush with the top edge and extending ¼” below the bottom edge.
√ Use masking tape to hold the 1/8” plywood strips into place while the epoxy sets.
√ Test fit the top hatch after the epoxy sets. The fit can be loose, as the top hatch just prevents Styrofoam peanuts from getting into the cradle.
√ Paint the cradle.

3.2.2 Using the Camcorder Cradle

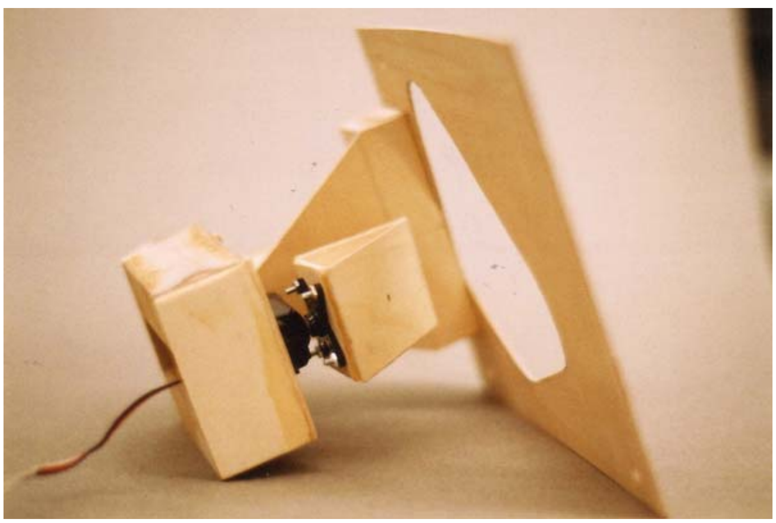
During assembly of the capsule, perform the following steps:

- √ Recharge the camcorder battery and load videotape into the camcorder.
- √ Bolt the camcorder into the cradle.
- √ Slide the back end of the cradle into one E-Quad port opening of the airframe.
- √ Push the cradle through the E-Quad until the back end is sitting on the opposite E-Quad port.
- √ Bolt the back locking plate to the back of the cradle.
- √ Attach the access cover into the opening in the back locking plate by wrapping rubber bands around the dowels and over the back cover.

Shortly before launch, perform the following steps:

- √ Remove the access cover.
- √ Start the camcorder.
- √ If the camcorder has function buttons on its top, then open the airframe hatch to operate the camcorder.
- √ Press any necessary buttons on the front of the camcorder.
- √ Ensure the camcorder is functioning properly by looking through its viewfinder.
- √ Close the access cover and rubber band into place.
- √ Close the top hatch, if needed.

4.0 Mirror Rotator



Completed Mirror Rotator

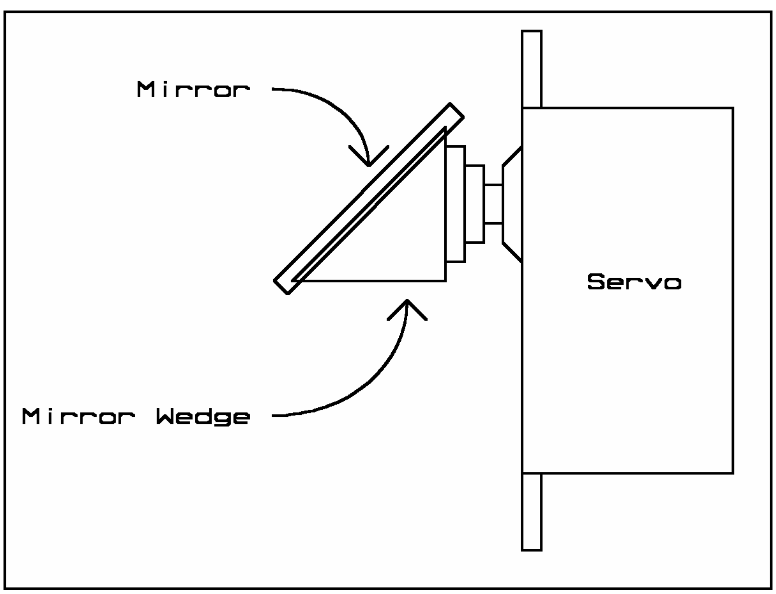
Camcorders are large enough that it’s best to leave them fixed in place. This situation is fine if you are content with viewing only the horizon. For those times you are not, use a rotating mirror mounted outside the airframe to change the view of the camera. It is easier to rotate a lightweight mirror than a heavy camcorder. On the negative side, the mirror produces a reversed image. A second reflection can correct this (this is one of those few times where two wrongs make a right). However, the field of view of most camcorders is large enough that the second mirror must be at least six inches across. So, I'd recommend against using a second mirror. Instead of using a second mirror, video from the camcorder can be captured on a PC and rotated in software.

A mirror mounted at a 45-degree angle in front of the camcorder lens creates a view 90-degrees away from the original optical axis of the camcorder. When the mirror is rotated along the axis between the center of the mirror and the camcorder lens, the view from the camcorder also changes. Rotating the mirror though an arc of 180 degrees lets the camcorder see the ground, the horizon, and the balloon. This section describes the construction of a rotating mirror mount for a camcorder. A simpler version of this device was used on KNSP's 1997 ATV near space missions.

4.1 Materials

- First surface mirror (size to be determined)
- Glasscutter
- Fine tip felt tip marker
- Metal straight edge
- 2" thick Styrofoam
- ½" thick Styrofoam
- ¾" thick Styrofoam
- Epoxy
- 1/32" thick plywood
- 1/8" thick plywood
- Popsicle sticks
- Servo
- Servo horn
- #24 AWG stranded wire, preferably three different colors
- Two diameters of heat shrink tubing to cover individual servo wires and a second larger diameter to cover all three of the servo cables
- #2-56 hardware, ½" long
- Nylon cable zip tie mounting plates
- #6-32 hardware (bolts lengths to be determined later)

4.2 Procedure

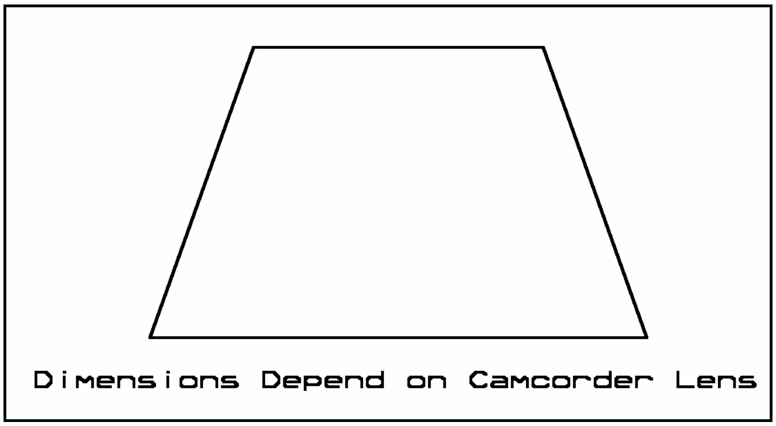


Mirror Rotator Diagram

The mirror rotator is a unit designed as an optional attachment for the camcorder cradle. Near space flights in which the camcorder only records the horizon do not carry the mirror rotator. However, those flights carrying a camcorder to record images within an arc from the ground to the balloon carry the mirror rotator mounted to the front face of the camcorder cradle. Alternatively, the mirror rotator can be permanently mounted to the face of camcorder cradle, like KNSP's first camcorder cradle.

Cut the Mirror

- √ Place the camcorder within the cradle.
- √ Hold an index card in front of the camcorder lens at a 45 degree angle.
- √ Look through the viewfinder and draw the field of view of the camcorder on the index card. The result should be an oval.
- √ Since it's difficult to cut circles in glass, draw a trapezoid (keystone-shape) around the oval field of view.
- √ Cut out the shape on the card.



Trapezoid-shaped Mirror – *The dimensions depend on the camcorder lens.*

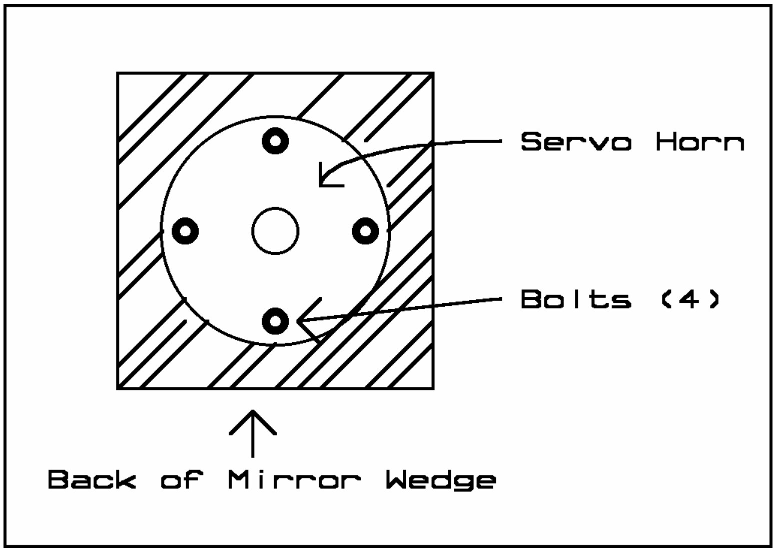
- √ Transfer the cardboard shape to the mirror with a marker.
- √ Cut out the mirror with a straight edge and glasscutter.
- √ Clean the glass of cutting oil and set the mirror aside.

Alternative Mirror Shape

An alternative to a truncated triangle shaped mirror is to cut the mirror to a rectangle shape. This shape wastes weight, but may be easier to cut.

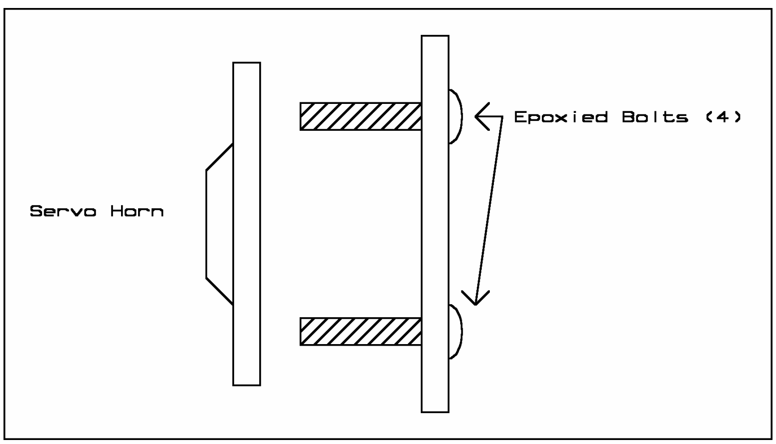
Making the Mirror Wedge

- √ Make a square in 1/8" plywood with each side equal to the smallest dimension of the mirror trapezoid. This square forms the base of the mirror wedge.
- √ Draw diagonal lines from opposite corners of the mirror wedge base.
- √ Place a servo horn on the mirror wedge base, centered on the drawn cross.



Servo Horn on Mirror Wedge Base

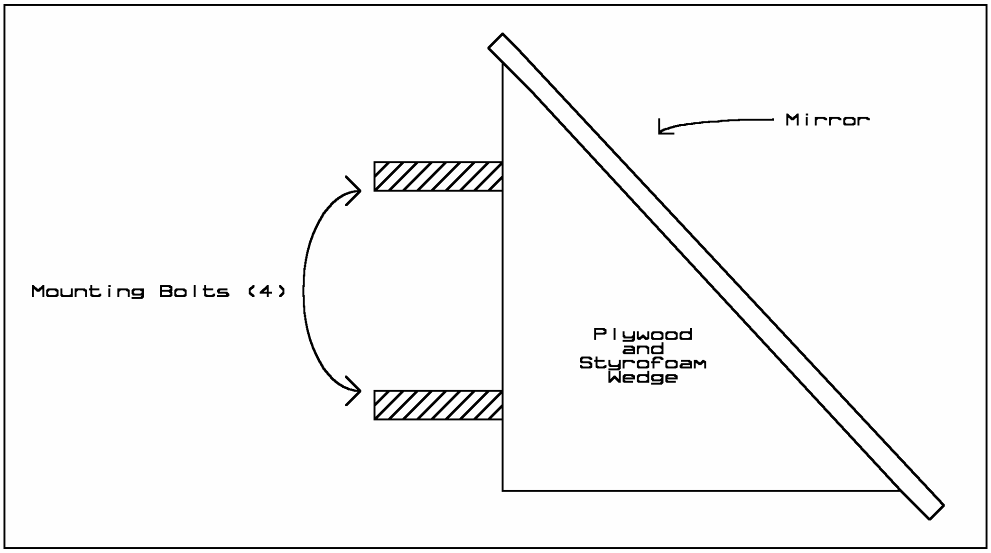
- √ Mark the location of the outer hole in each servo horn.
- √ Enlarge the outer hole in each arm of the servo horn (the hole has to be large enough for #2-56 bolts).
- √ Drill four holes in the 1/8” plywood mirror wedge base just undersized for the #2-56 bolts.
- √ Epoxy and thread the bolts into the plywood mirror wedge base and let the epoxy set.



Mirror Wedge Base

- √ Test fit the servo horn; it needs to slip on and off the bolts in the mirror base.
- √ Cut a cube out of Styrofoam with sides equal to the sides of the mirror base.
- √ Press the cube on the bolt head side of the mirror base, making impressions in the Styrofoam at the location of the bolt heads.
- √ Cut small pits into the cube at the location of the bolt heads.
- √ Test fit the cube; it should sit flush on the mirror base.
- √ Epoxy the cube to the mirror base, trapping the bolt heads between the mirror base and the cube.
- √ Measure the dimension and corners of the cube; insure the cube is as close as possible to a perfect cube.
- √ Cut 1/32” plywood to fit the sides of the cube.
- √ Epoxy the plywood to the sides of the cube. Do not epoxy plywood to the top of the cube.
- √ Mark a 45-degree diagonal line on two side of the cube.
- √ Carefully cut the cube in half along the line, creating a wedge attached to the mirror base.

√ Trim the 45-degree face of the former cube to make it flat and smooth, with a stationary belt sander if possible.



Side View of Epoxied Mirror on Wedge

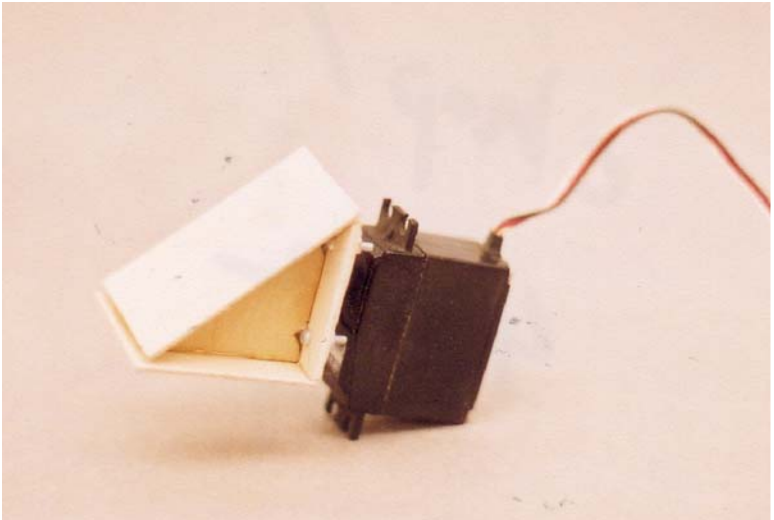
Center and epoxy the mirror to the diagonal face of the wedge with the aluminized face up.

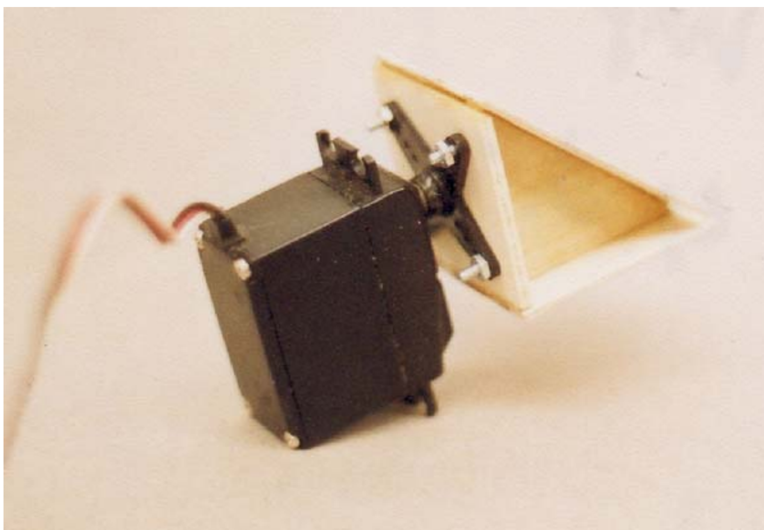
Note: When the mirror is epoxied with the aluminized side facing the wedge the mirror still reflects, but the images are slightly doubled and less crisp and bright. This is why a second surface mirror is not used.

Making the Servo Holder
The servo holder positions the mirror directly in front of the camcorder lens. Since every camcorder model has different dimensions, these directions cannot give the dimensions for your particular camcorder. However, from the procedure outlined below, you can design and build a servo holder.

The servo holder is designed as an "L" shaped bracket that is bolted onto the face of the camcorder cradle. The servo holder is optional; not every flight carrying a camcorder must carry it. The servo holder positions the mirror wedge as close to the camcorder lens as possible. The servo rotates the mirror through a 180-degree arc, letting the camcorder see everything within that arc.

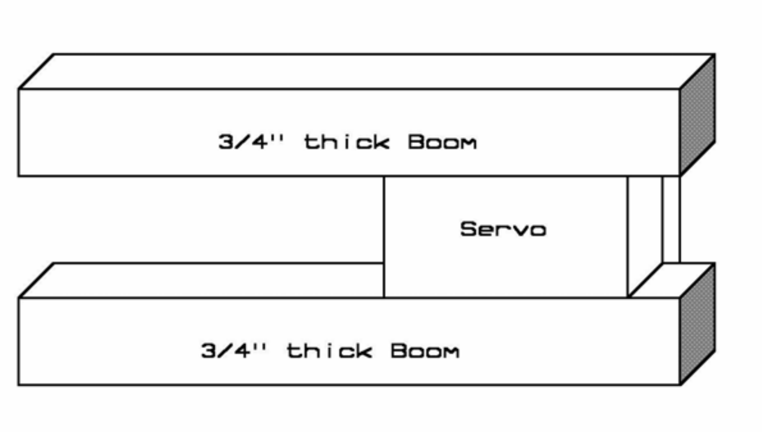
√ Place the camcorder inside the camcorder cradle.
√ Rotate the servo to its mid-position.
√ Bolt the servo horn to the servo.
√ Bolt the mirror wedge to the servo horn so that the narrow end of the mirror wedge points to the far end of the servo.





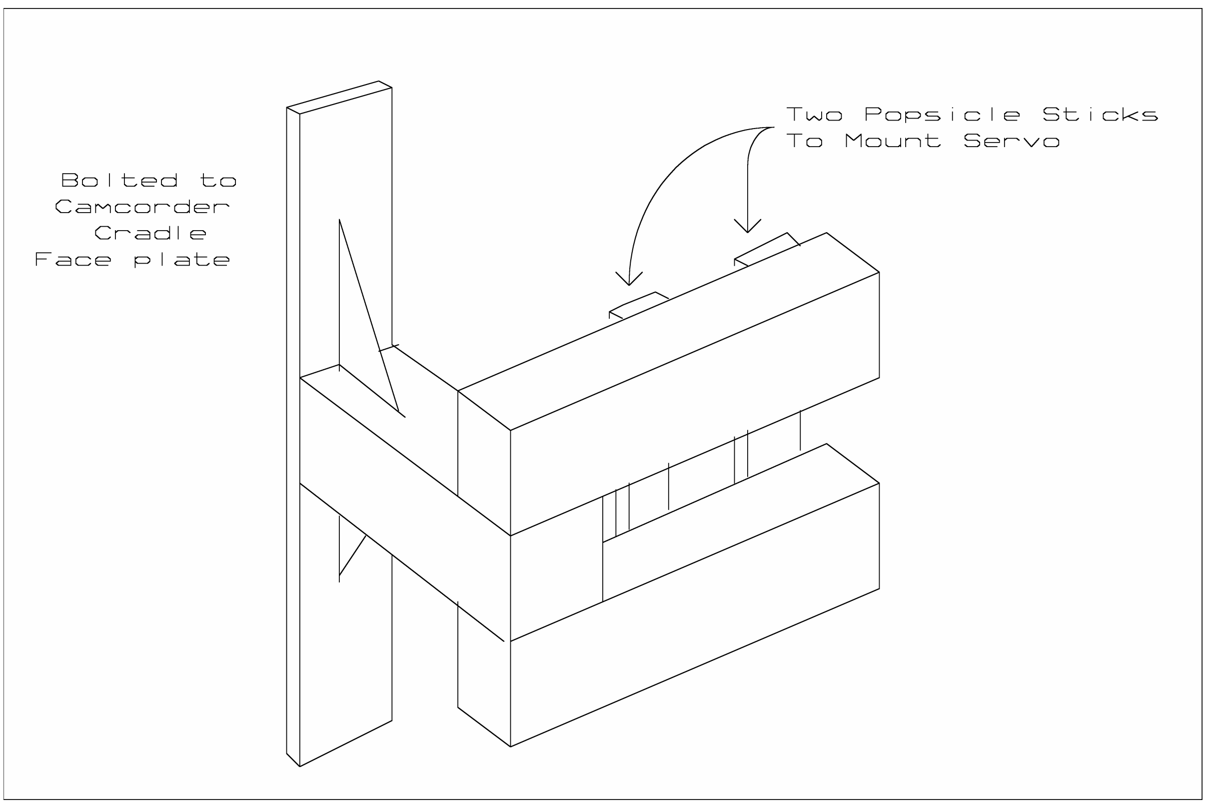
Mirror Wedge Attached to the Servo

- √ Prop the mirror wedge centered and in front of the camcorder lens.
- √ Measure the distance from the front of the servo to the far edge of the cradle; this distance is the length of the mirror rotator arm.
- √ Make two booms from ¾" thick Styrofoam and 1/32" plywood that is one inch wide and as long as the length of the mirror rotator arm. Note: Do not cover the small ends of the boom with 1/32" plywood or trim the booms at this time.



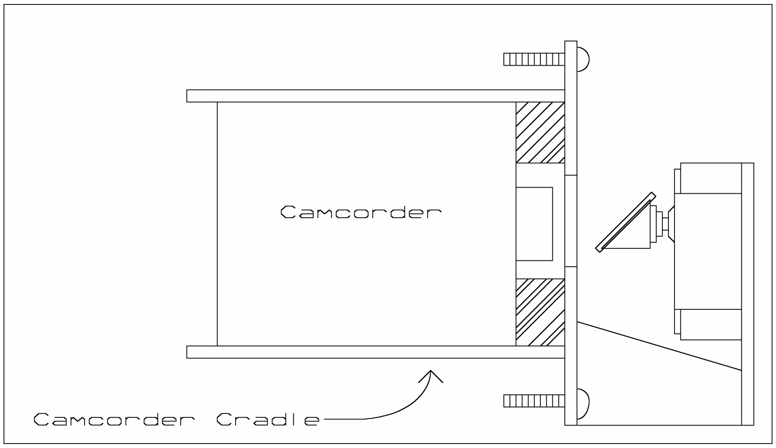
Booms Holding Servo – *Two ¾" thick Styrofoam booms support the servo.*

- √ Tape or rubber band the booms to both sides of a servo.
- √ Cut two Popsicle sticks to length, so they extend across the booms and servo.
- √ Slide the servo away from the booms slightly, so that the Popsicle sticks slide beneath the servo-mounting tabs.
- √ Epoxy the Popsicle sticks into place so that they and the booms form a box around the servo.
- √ Clamp the Popsicle sticks to the booms as the epoxy sets.
- √ Drill one hole in each Popsicle stick that matches a hole in the servo-mounting tab.
- √ Cut and epoxy a piece of 1/8" thick plywood to cover the exposed end of the booms closest to the servo.

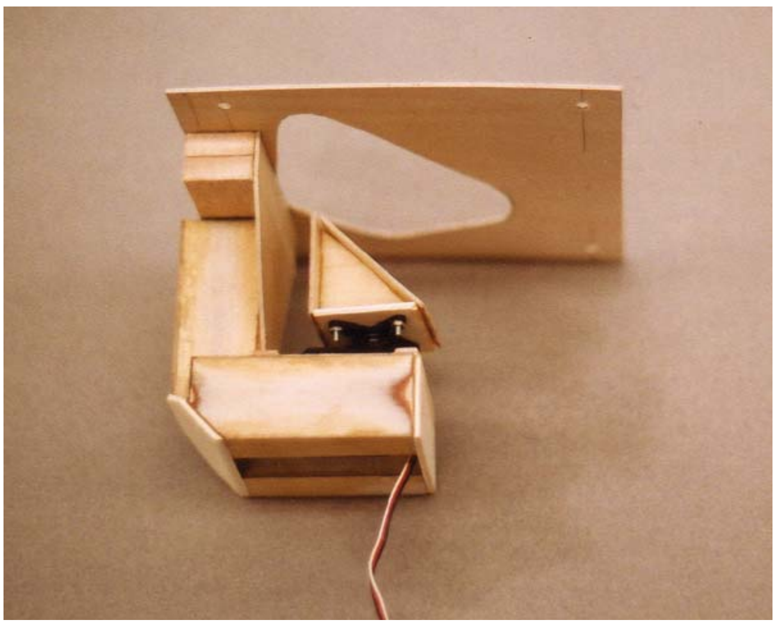


Positioning the Popsicle Sticks

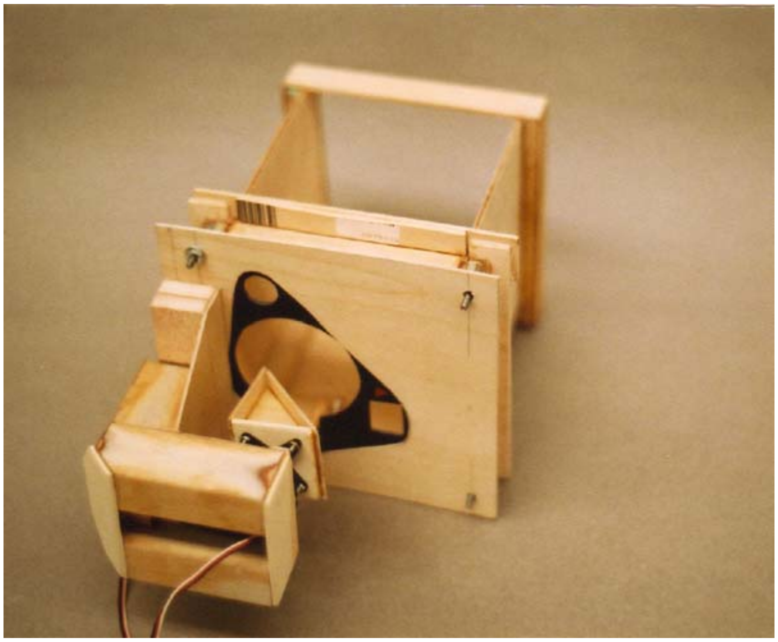
- √ Bolt the servo into the end of the booms.
- √ Position the booms in front of the camcorder cradle such that the mirror is centered in front of the camcorder lens (the camcorder is still inside the cradle).



Mirror and Wedge in front of Camcorder



Photograph of Mirror Assembly – *Before Mounting to Cradle*



Mirror and Wedge mounted to Cradle

- √ Measure the distance from the front of the mirror rotator arm to the front face of the camcorder cradle; this distance is the depth of the mirror rotator arm.
- √ Make one boom from ¾" thick Styrofoam and 1/32" plywood that is one inch wide and as long as the depth of the mirror rotator arm. This arm is called the mirror rotator stand-off.
- √ Check the fit of the new boom to the spacing between the servo arm; you may need to trim the foam thickness or add a doubler to the boom to make a tight fit. Note: Do not cover the small ends of the mirror rotator standoff with 1/32" plywood or trim the boom at this time.
- √ Epoxy the mirror rotator standoff between and perpendicular to the mirror rotator arm.
- √ Cut a rectangle of 1/8" plywood that is one inch wide and two inches long.
- √ Epoxy the rectangle over the end of the standoff and the rotator arm.

- √ Remove the servo and mirror from the rotator arm.
- √ Sand the rotator and standoff arms with a stationary belt sander to remove any blemishes or rough edges.
- √ Replace the servo back into the end of the rotator arm.
- √ Cut a rectangle of 1/8" plywood to measure six inches long and two inches wide. This is the mounting plate of the rotator.
- √ Place the plywood on the cradle and along either the left or right edge of the cradle.
- √ Place the standoff mirror rotator arm on the rotator mounting plate.
- √ Check the fit and the gap between the mirror and cradle face, making sure the standoff is perpendicular to the mounting plate and the mirror is free to rotate.
- √ Trim the standoff arm as necessary.
- √ Double check the fit again and mark the proper location for the standoff arm.
- √ Remove the mirror wedge and set it aside.
- √ Epoxy the standoff arm to the mounting plate.

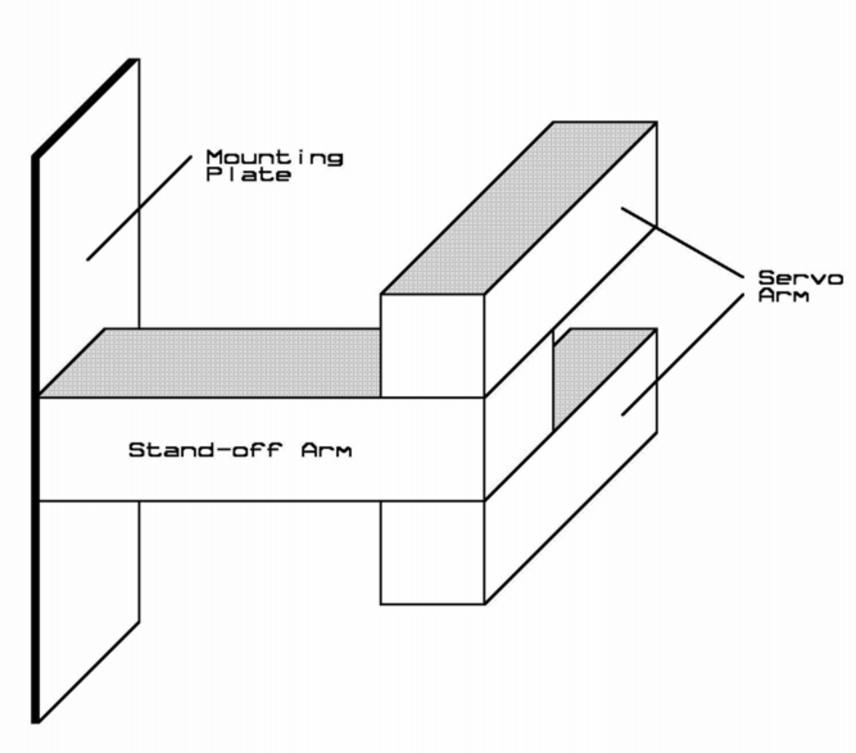


Diagram of Mounting Plate on Arm

- √ Cut two triangles of 1/8” plywood to brace the standoff arm to the mounting plate.
- √ Epoxy the plywood braces to the standoff arm and mounting plate.
- √ Remount the mirror wedge to the rotator arm.
- √ Place the rotator arm back onto the cradle and center the mirror over the camcorder lens.
- √ Determine two locations to drill two holes for 6-32 bolts. The bolts are bolted inside the cradle, with threads sticking out. The mirror rotator is attached to these bolts.

- √ Mark the location of two holes to mount the plate on the face of the cradle.
- √ Mark the location of a third hole to pass the servo cable through.
- √ Remove the mirror wedge.
- √ Align the rotator arm with the cradle face.
- √ Drill two 1/8” diameter holes through the cradle face and the mounting plate.
- √ Remove the cradle from the airframe.
- √ Insert bolts from the inside, sticking out.
- √ Determine the length of bolts needed (about ¼” beyond edge of the cradle face).
- √ Insert the proper length of bolts and epoxy inside the cradle face.
- √ Drill and cut a slot to pass the servo connector through.

Servo

- √ Cut the servo cable in half.
- √ Split the servo cables back one inch.
- √ Strip insulation from the ends of all the wires.
- √ Cut three lengths of #24 AWG wire, at least 24 inches long.
- √ Strip insulation from both ends of all three wires.
- √ Solder the wires to the ends of the wires on the servo.
- √ Slide thin heat shrink tubing onto the #24 AWG wires and cover the exposed solder joint.
- √ Slide the large diameter heat shrink tubing over the solder wires and shrink.

- √ Slide one more piece of large diameter heat shrink tubing over the #24 AWG wires.
- √ Slide three more pieces of thin heat shrink tubing over the individual #24 AWG wires.
- √ Solder the end of the servo wire to the new extension.
- √ Cover the exposed soldered wires with thin heat shrink tubing.
- √ Cover the soldered joint with the large diameter heat shrink tubing.
- √ Stick a couple of nylon zip tie mounting plates to the mirror rotator arm so that the servo cable will stay out of the way of the camcorder.
- √ Zip tie the servo cable to the arm.
- √ Paint the mirror rotator

Directions to Use the Mirror Rotator

- √ Bolt the mirror rotator to the face of the cradle.
- √ Mount the camcorder inside the cradle.
- √ Insert the cradle into the airframe.
- √ Bolt the back plate onto the cradle.

Connect the servo cable to a flight computer and write test code to determine what values command the SSC II to position the servo-controlled mirror into the desired positions.

Good to Know

The Distance To and Depression Of the Horizon From Near Space

Near Space Horizon

The higher a near space capsule ascends, the greater the distance to its horizon. A simple rule of thumb is that the distance to the horizon in miles equals the square root of one and a half times the altitude in feet. In other words:

$$D = \sqrt{1.5 \times A}$$

where D is distance in miles

A is altitude in feet

Not only does the distance to the horizon get greater as the capsule ascends, it also depresses. That is to say that the horizon gets lower as the capsule climbs higher. At the Earth's surface the horizon is 90 degrees from the zenith (the point straight overhead) in all directions. So the Earth and sky each occupy equal amounts (50% each) of your total view. As the capsule ascends, the horizon appears lower, allowing the sky to occupy more than 50% of the total viewing area of the capsule.

The angular radius occupied by the Earth is calculated by taking the arcsine of the ratio of the radius of the Earth divided by the sum of the Earth's radius and the capsule's altitude. The Earth's radius and the balloon's altitude must be in the same units so the ratio is a dimensionless number before taking the arcsine.

Angular Diameter of the Earth (at altitude H) = arcsine[Re/(Re+H)]

Where: Re is the radius of the Earth (3963 miles or 6378 km)
H is the altitude of the capsule (in same units as Re)

So while standing at the Earth's surface, with negligible altitude, we have:

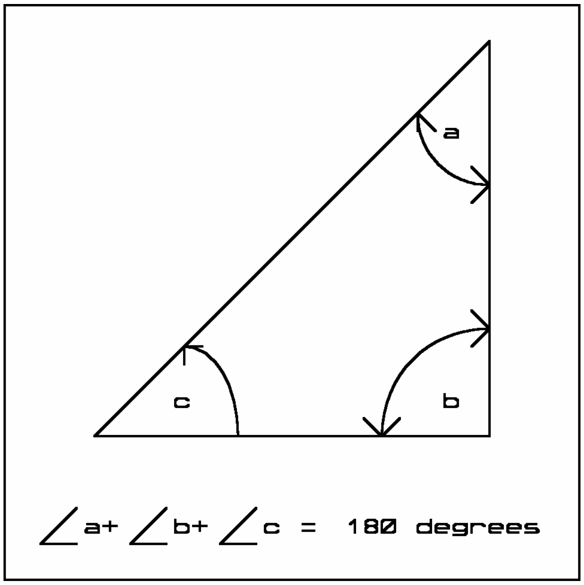
Diameter (angular)	=	arcsine [3963/(3963+0)]
	=	arcsine (3963/3963)
	=	arcsine (1)
	=	90 degrees (as expected)

At a flight reaching 100,320 feet (19 miles) though, the angular radius of the Earth changes significantly.

Diameter (angular)	=	arcsine [3963/(3963+19)]
	=	arcsine (3963/3982)
	=	arcsine (0.9952)
	=	84.4 degrees

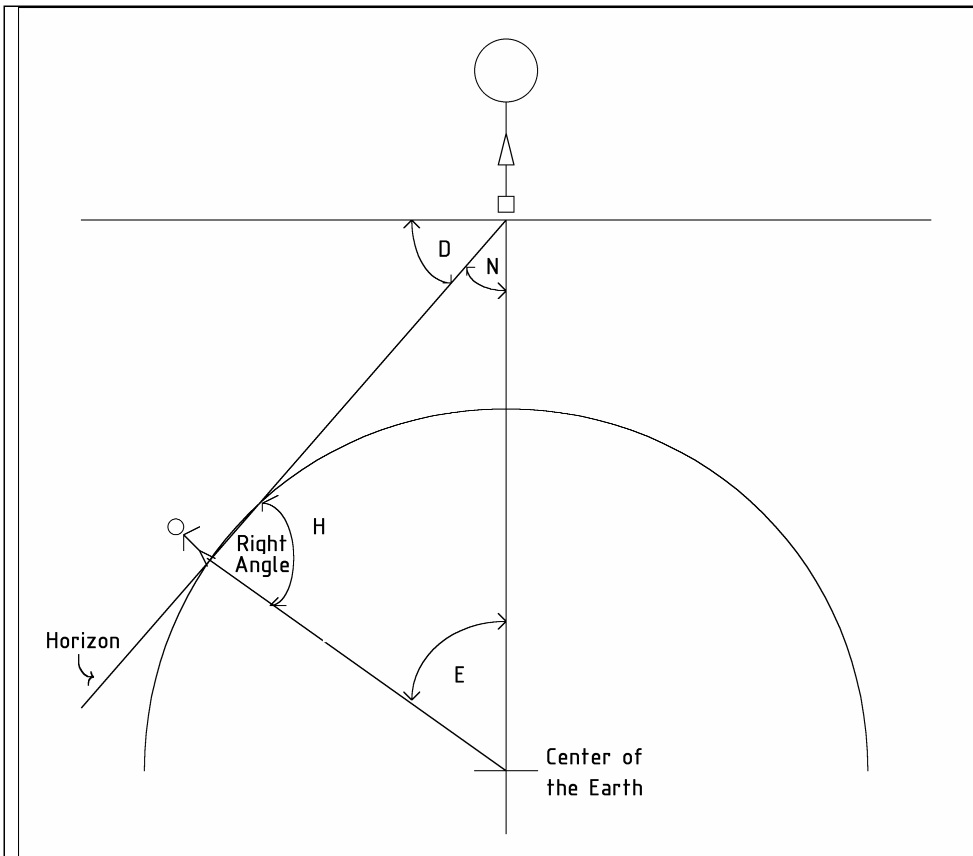
So at 100,320 feet the horizon is depressed 5.6 degrees and the sky extends 95.6 degrees from zenith to horizon in all directions.

Why is horizontal depression related to the distance to the horizon? Recall from geometry that the sum of interior angles of a triangle is equal to 180 degrees.



Triangle *- Sum of interior angles*

So, in the diagram below, the sums of the angles, E (the angular distance to the horizon), N (the angle between the capsule's nadir to horizon), and H (angle between horizon and Earth's center – always equal to 90 degrees) must equal 180 degrees. If angle H (90 degrees) is subtracted, then we find that the sum of angles N and E equal 90 degrees. At the balloon's location, the sum of angles D (horizontal depression) and N also equals 90 degrees. Setting the two sums of angles equal to each other, we have



Angle of Depression *– As seen from the balloon, depicted at top of diagram. (Not to Scale)*

N + E = N + D = 90 degrees

Subtracting N, we have E = D

The angle of horizontal depression (D) is equal to the angular radius occupied by the Earth, as seen from the balloon (N). From the earlier example, at an altitude of 100,300 feet a near space capsule views an area within a radius of 5.6 degrees of the Earth beneath it.

In the north-south direction, the distance covered by a degree doesn't change as a factor of latitude. In latitude a degree is about 69.12 miles. In the east-west direction, however, the distance covered by a degree of longitude does change as a function of latitude. The distance covered by one degree of longitude is greatest at the equator, where it is equal to the length of a degree in latitude (69.12 miles). The length of a degree in longitude approaches zero as you approach the poles. But since we're only interested in the distance to the horizon in miles, we can still use 69.12 miles per degree. At 100,300 feet then, the horizon is equal to 387.0 miles (5.6 degrees times 69.12 miles per degree). Our rule of thumb gives us 387.9 miles, or an error of less than one mile. That's not bad for a rule of thumb.

Space Mission Analysis and Design 2nd Edition, 1992 Wiley J. Larsen and James R. Wertz.

Near Space Humor - Six Things NOT to Photograph During a Near Space Mission

1. Area 51.
2. A foreign embassy building.
3. Airborne military aircraft, especially those flying higher than 100,000 feet.
   If you do photograph one, be sure Aviation Week and Space Technology pays enough for the photograph to pay your court costs.
4. Your crotch, while waiting to launch the stack (you'd be surprised how often this happens).[D]
5. A chrome-plated bulldog during landing.[E]
6. The inside of your lens cap.[F]

[A] Ken Tromburg, Photek, 3075 N. Cole, Boise, ID 83704, (208) 323-7568, photek@micron.net
[B] STYROFOAM Brand Foam is a trademark of The Dow Chemical Company.
[C] The camcorder body must be small enough to be able to enter an airframe through an E-Quad with its viewfinder folded down.
[D] Suggested by Mark Conner (N9XTN) of NSTAR.
[E] Suggested by Mike Manes (W5VSI) of EOSS.
[F] Suggested by Stephanie Lindsay of Parallax, Inc.

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)

Chapter Objectives

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

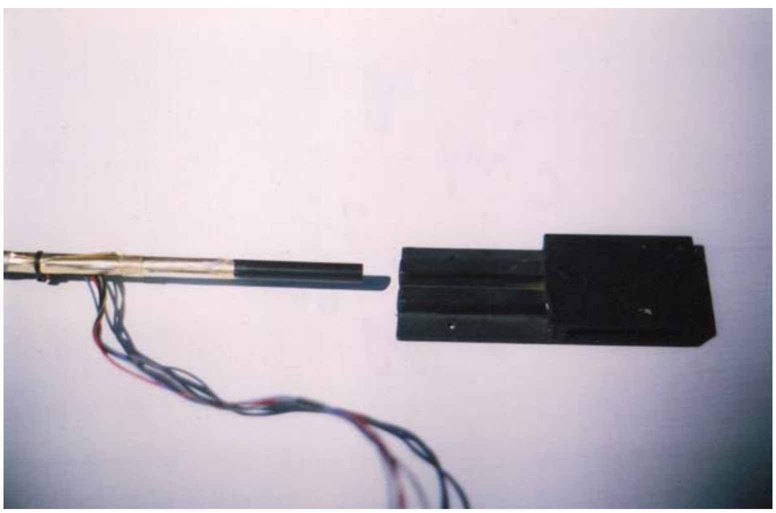
Here are additional suggestions on designing near space experiments.

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.

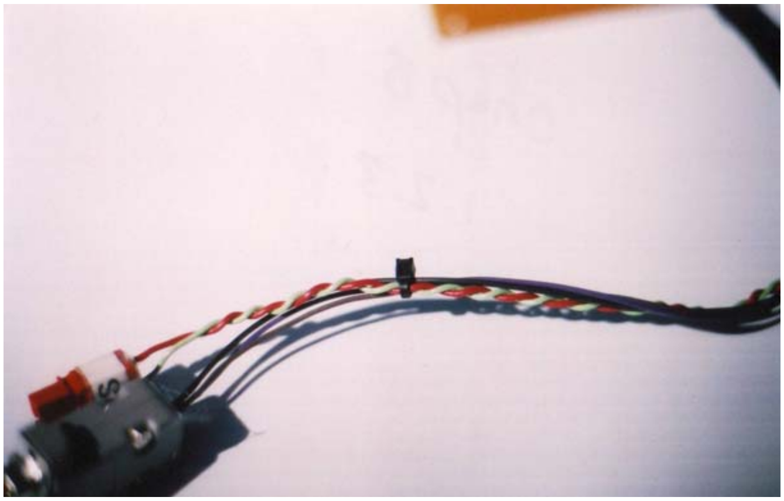
The Isaac Asimov - *My first near spacecraft. Note the truss structure of the booms.*

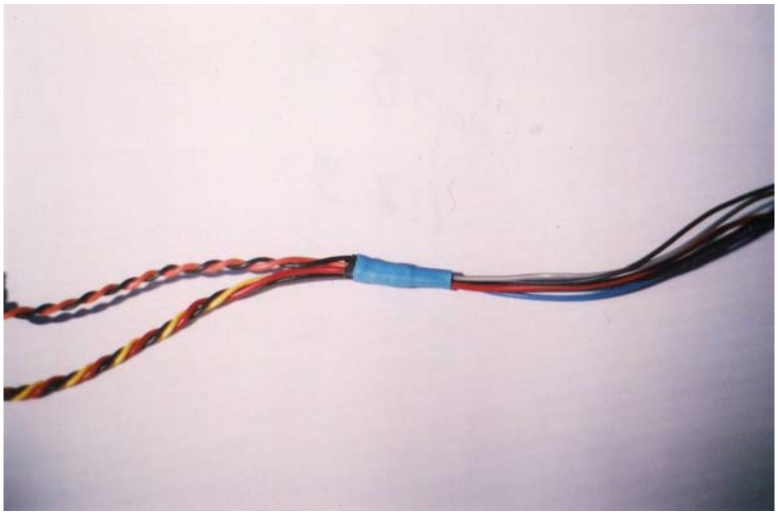
1.2.3 Organizing Cables

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 tires 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

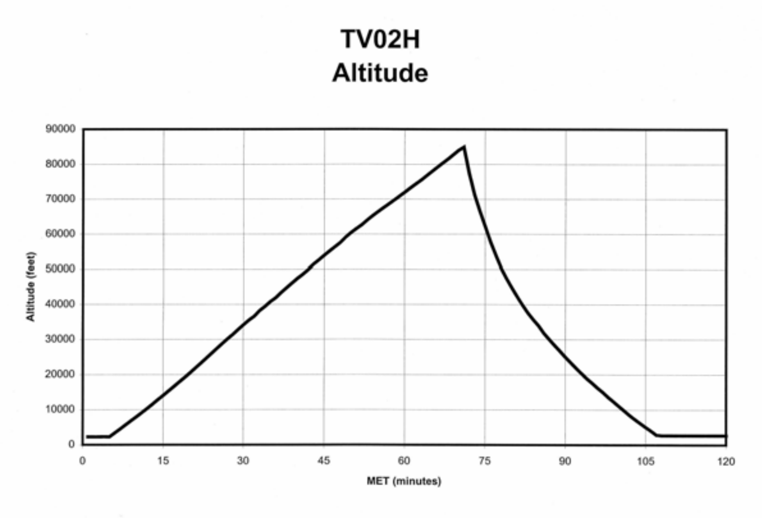
In most cases, the sensor values measured during a near space mission are graphed in relationship to the altitude. The GPS $GPGGA sentence is commonly used to determine the altitude. There are proprietary sentences indicating altitude, but these change from GPS manufacturer to manufacturer, so they will 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.

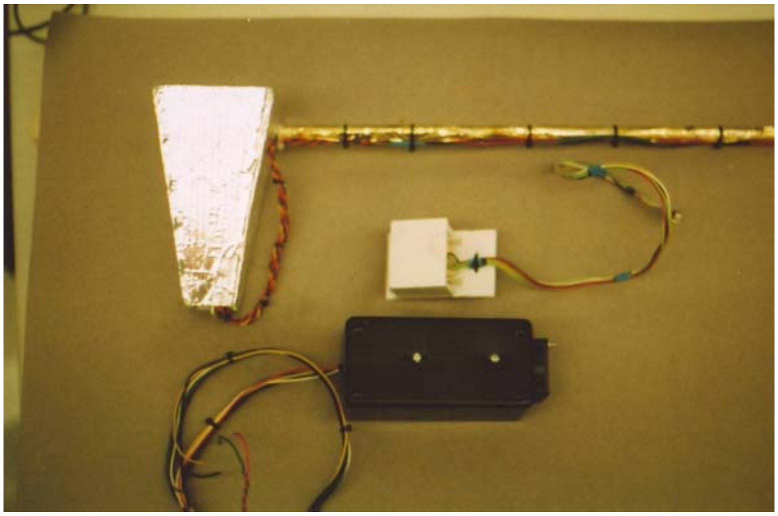


Altitude vs MET Chart

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 corroplast 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.

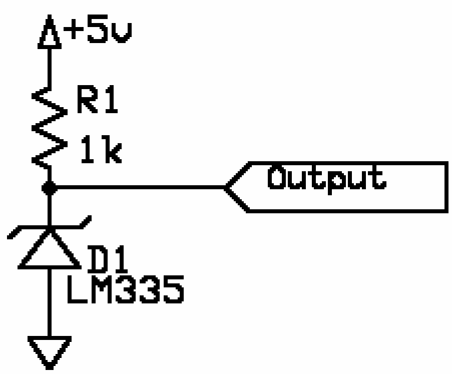
3.1 The Simple Sounder

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.

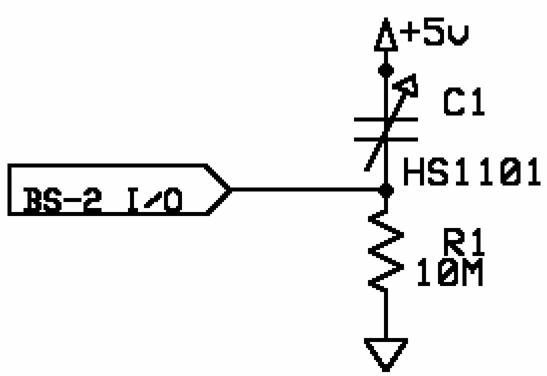


LM335 Schematic

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

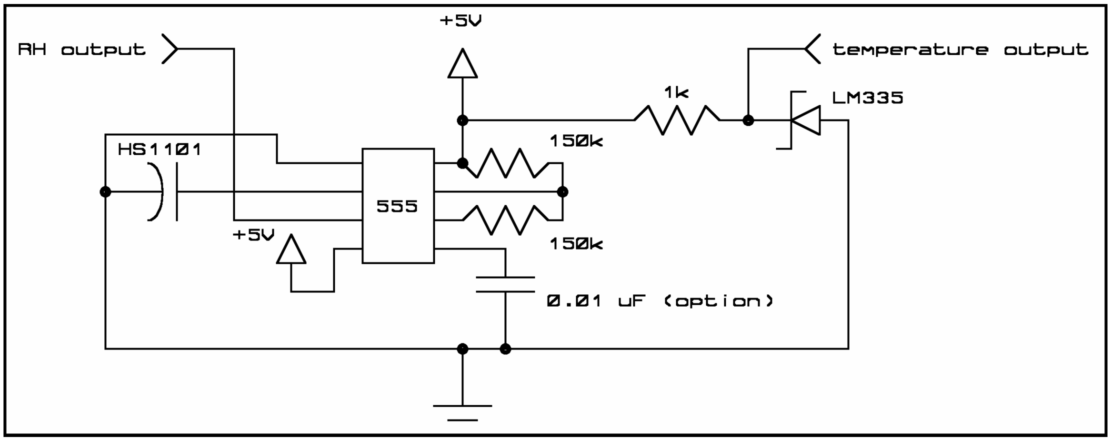
In the HS1101, the capacitance of the RH sensor is varies linearly with the change in the relative humidity. The capacitance of the HS1101 is determined by how long it takes for the sensor to charge through a 10M resistor connected to ground. This procedure works because the other side of the HS1101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



Schematic – *Capacitor in RCTIME circuit*

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.

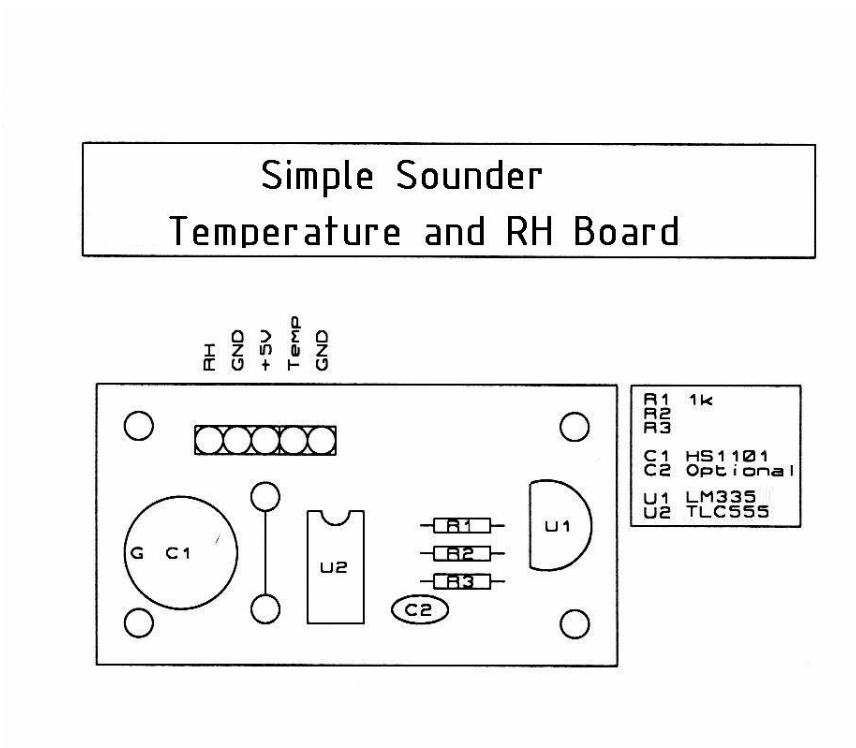


Simple Sounder Schematic - *Measures relative humidity with the HS1101 and temperature with the LM335.*

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 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 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

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 Correplast tube mounted on a boom next to the N/C
2. In a Correplast ram cup mounted away from the N/C
3. In a Correplast 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.

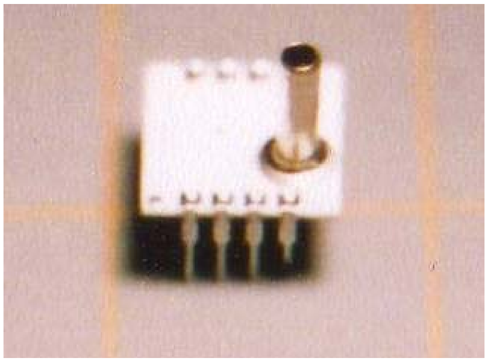
3.2.1 Mini Weather Station Theory Of Operations

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-Vs(0.16)]/(Vs*0.0062)
```

Where Vs = supply voltage

Which simplifies to

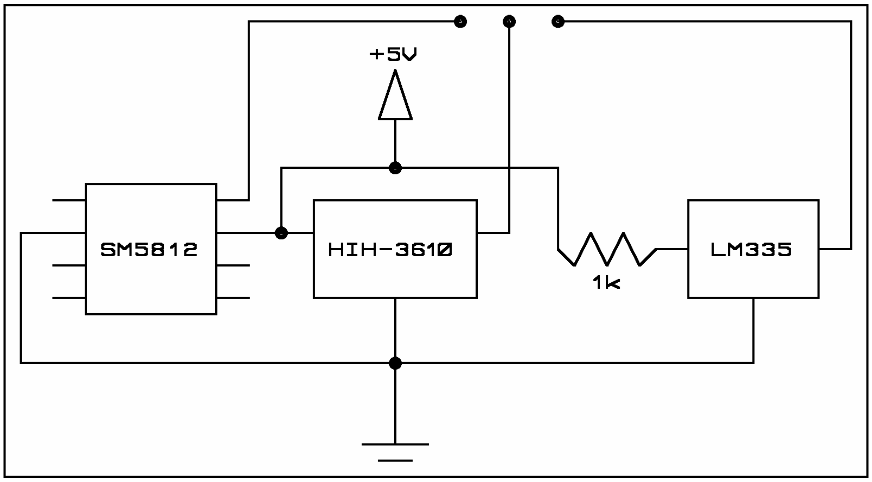
```
% RH = (V-0.8)/(0.031)
```

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

Temperature compensation is provided with the following equation

```
True RH = (%RH)/(1.0546-0.0216T)
```

Where %RH was calculated above
And T is the temperature in degrees F



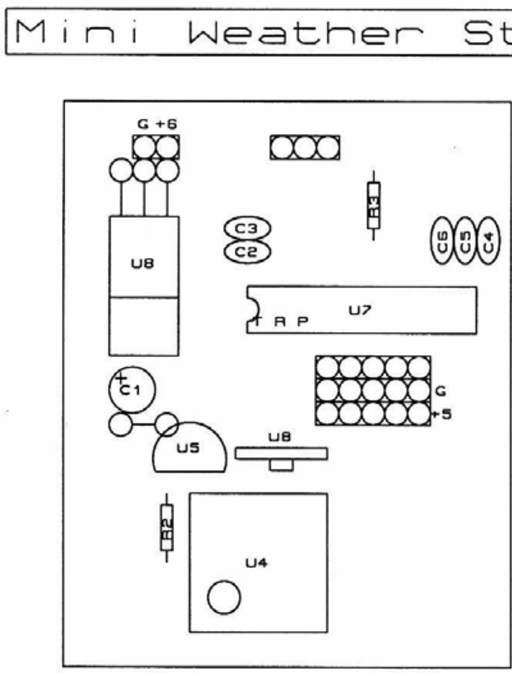
Mini Weather Station Schematic – *Pressure (SM5812), humidity (HIH-3610), and temperature sensors (LM335) in one circuit.*

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.



C6	0.01 uF
C2, C5	0.1 uF
C3, C4	4.7 uF
C1	22 uF
R1, R2, R3	1 kOhm
U5	LM335
U4	SM5812
U8	HIH-3610
U6	LM2940T-5
U7	MAX186

Mini Weather Station Parts Layout *– LM335 for temperature, SM5812 for pressure, HIH-3610 for humidity.*

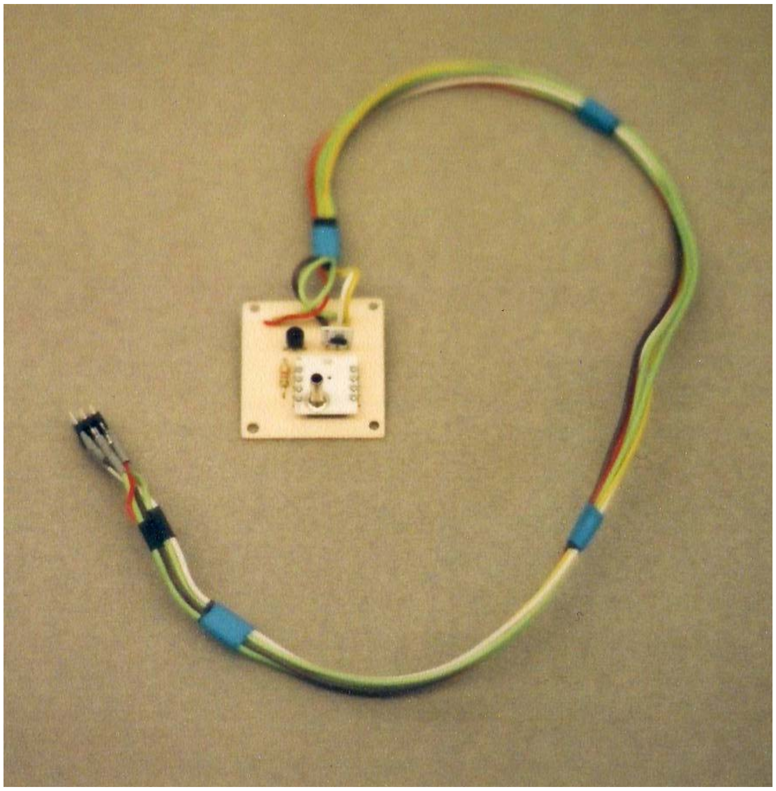
Soldering The PCB

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

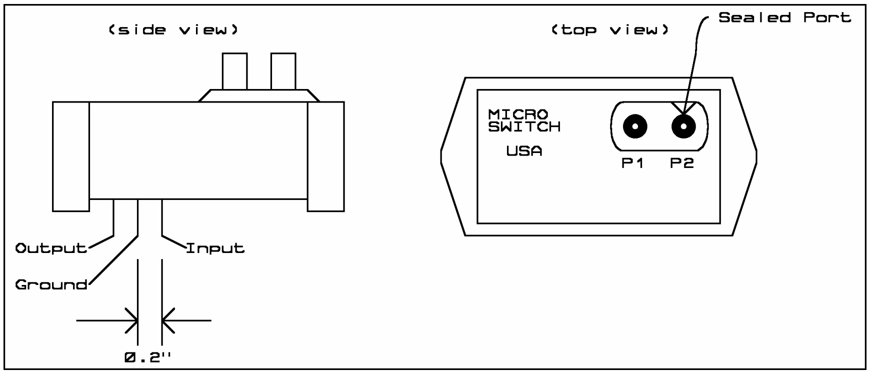
Pressure sensors that are accurate over the range of pressures experienced in a near space flight are neither readily available nor inexpensive. So instead, fly multiple pressure sensors, each geared to a particular pressure region.

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 it’s 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

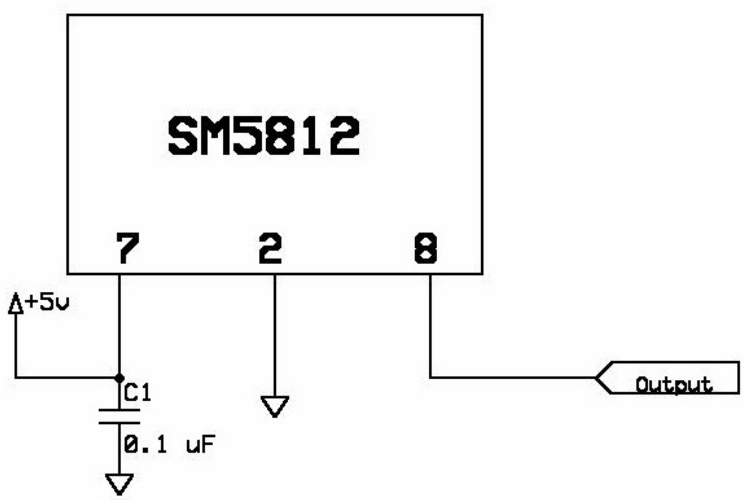


The 140PC - *The proper model contains a sealed tube that is just visible in Port P2.*

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.

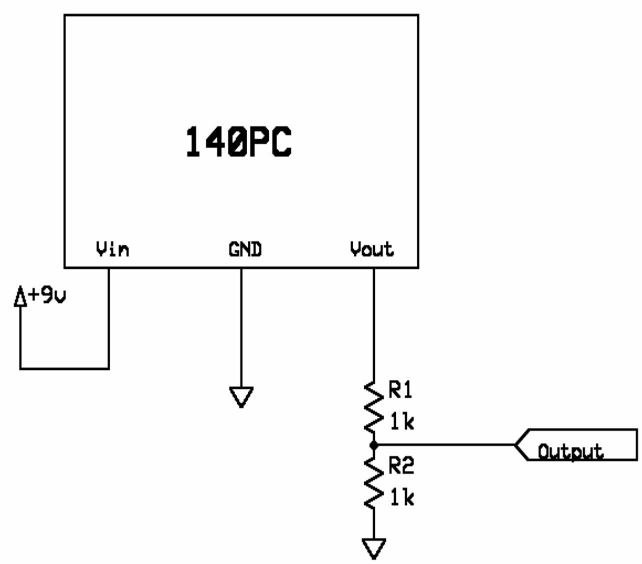


Schematic – *SM5812*

3.3.2 Stand-alone Sensor Materials

- SM5812 or 140PC Pressure Transducer
- Two 1k resistors[A]
- #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 form 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 Correplast to make a strain relief for the cables

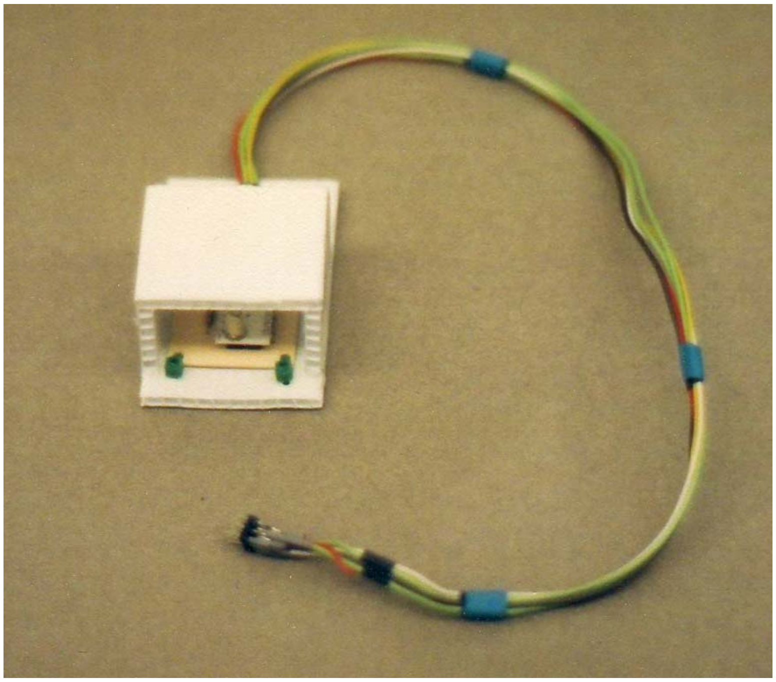
3.4 Mounting Environmental Sounders

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 Correplast Box

There are several styles of correplast boxes suitable for Sounders. The good points of correplast include: it's lightweight, quite strong, cuts easily with an Exacto knife, and glues together well with hot glue. Building the correplast 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 correplast to shape and punch PCB mounting holes in it.
- √ Glue the correplast 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 correplast box and tie them down with nylon zip ties.



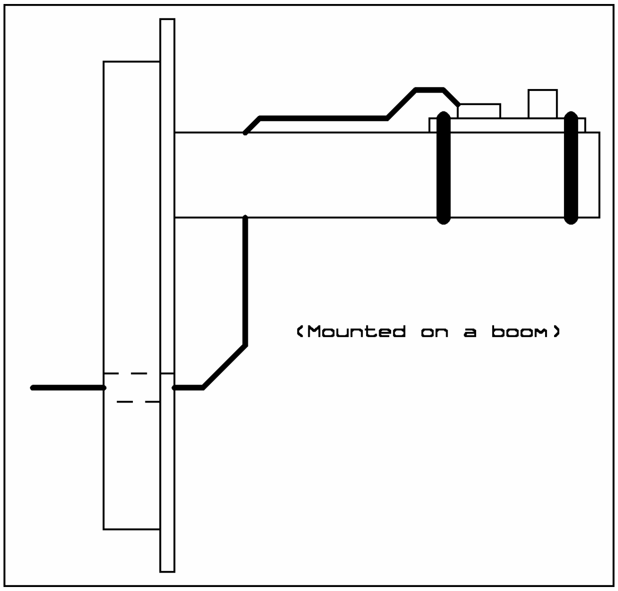
The Mini Weather Station – *Housed in a protective corroplast box.*

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

3.4.2 The Simple Mount

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



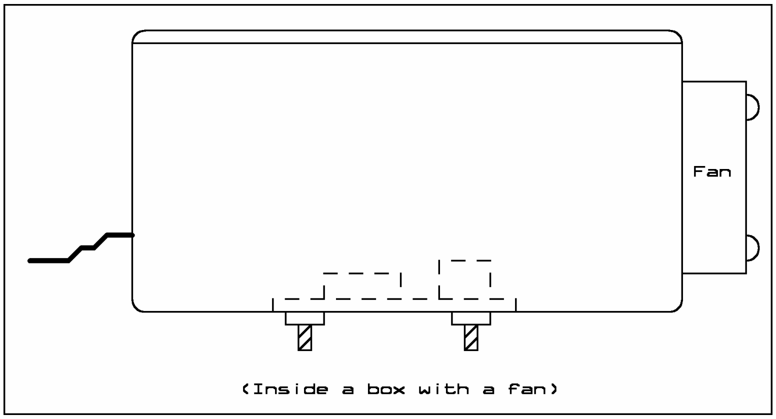
Sounder Mounted on a Boom -
Make a housing to protect the circuit.

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

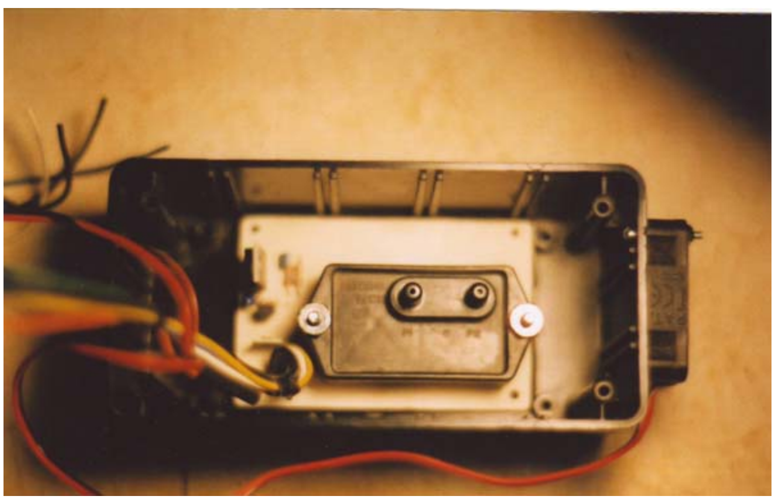
Temperate sensors like the LM335 (that generate their own heat) depend on the air around them to prevent self-heating from effecting the measurement. As the altitude increases during a mission, the amount of air around the LM335 decreases, reducing the air's effectiveness at removing generated heat. 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 Correplast tube, then the Correplast 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).



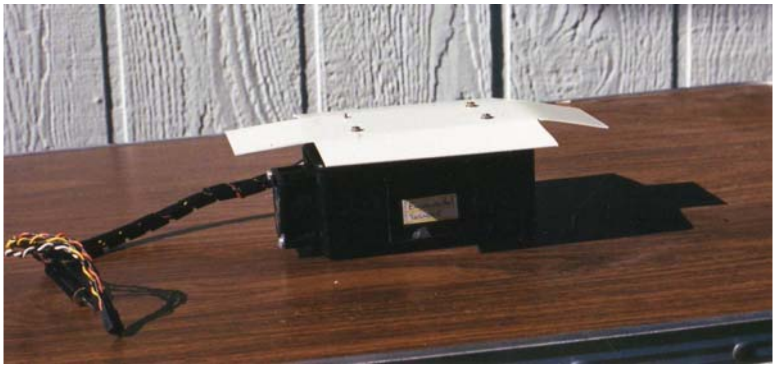
Fan Mount - *If using a fan, use a separate battery for the fan, as it may draw a lot of current.*

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.*

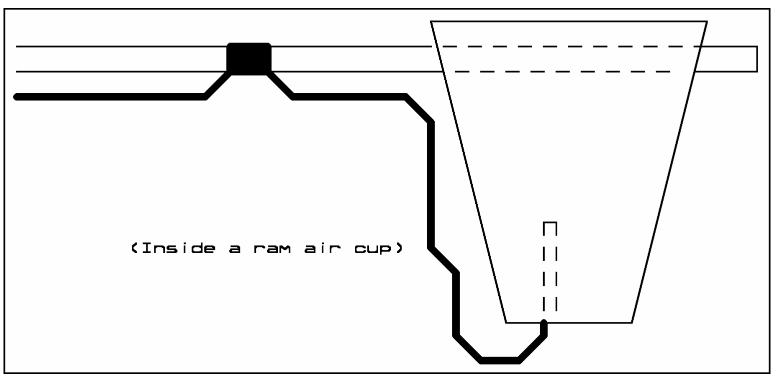
Solder the fan wires together, matching their colors. Extend the lengths of the wires so they reach the interior of the near spacecraft, where their battery is located. Terminate the wires in the appropriate connector for your near space program (like using Anderson Power Poles). Wire a toggle switch 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 Correplast box can have dimensions as outlined below



Mounting the Sounder Inside a Ram Air Cup

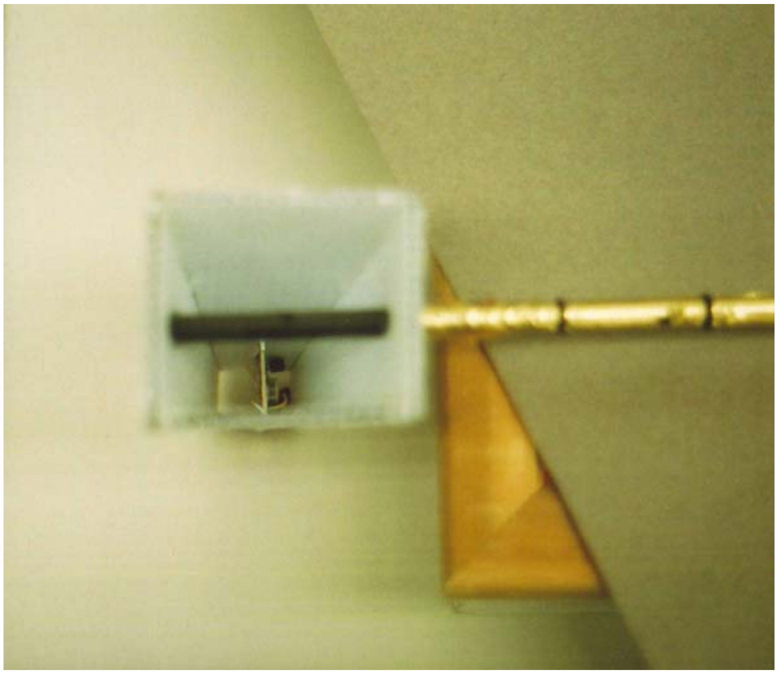
This design requires a fiberglass boom to mount the ram air cup away from the near spacecraft and into faster flowing air. In the ram air cup design, the Sounder PCB is glued into two narrow slits cut into the base of the ram air cup. Very little hot glue is needed to secure the Sounder PCB to the ram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

Mounting The Ram Air Cup To The Fiberglass Boom

For lightweight, but a strong boom, use a ¼” 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 ¼” 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 Correplast 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.



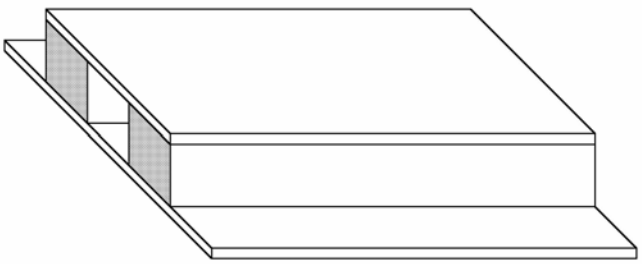
***Inside a Ram Air Cup -** The temperature and RH sensor PBC is mounted at the small end of the ram air cup.*

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

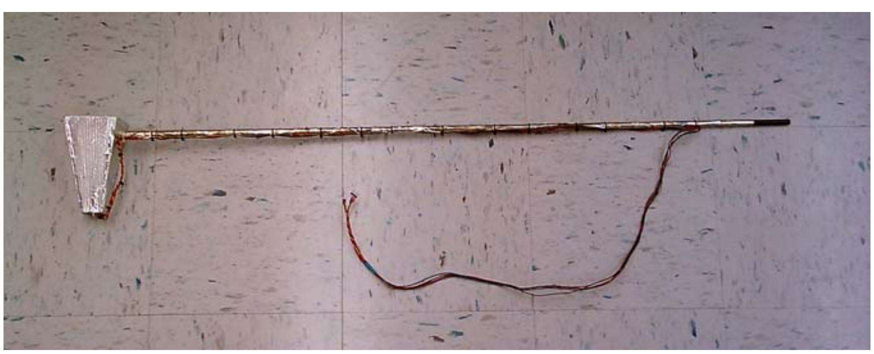
- 1/8" thick plywood
- Two feet length of ¼" square basswood
- Epoxy
- 6-32 mounting hardware
- Experiment boom



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 ¼" 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 ¼" 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 ¼" 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
  `Reading * 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
Multiple 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 Rg and the pressure as Pg. Monitor the air pressure inside the vacuum pump and the 140PC as you begin to pump it down. Taker 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,
  - o Altitude (A Column)
  - o Standard Pressure (B Column)
  - o 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).[B]

- √ 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
```

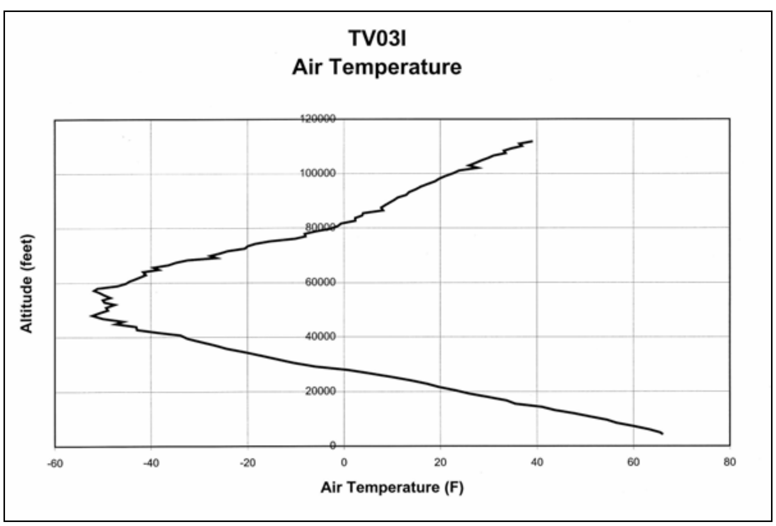
Where
A column is assumed to be the temperature column
B column is assumed to be the altitude column
Change the references as needed for your spreadsheet

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

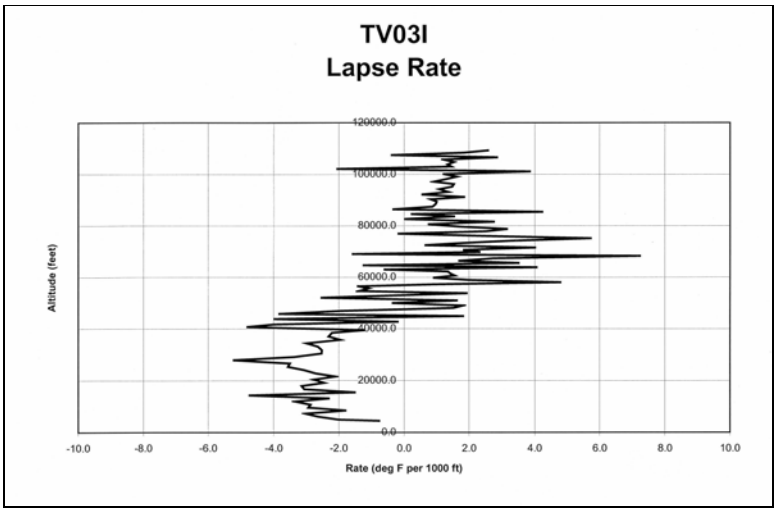
√ Left click the series on the chart
√ Right click
√ Click Format Data Series…..
√ Under Patterns tab

- √ 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

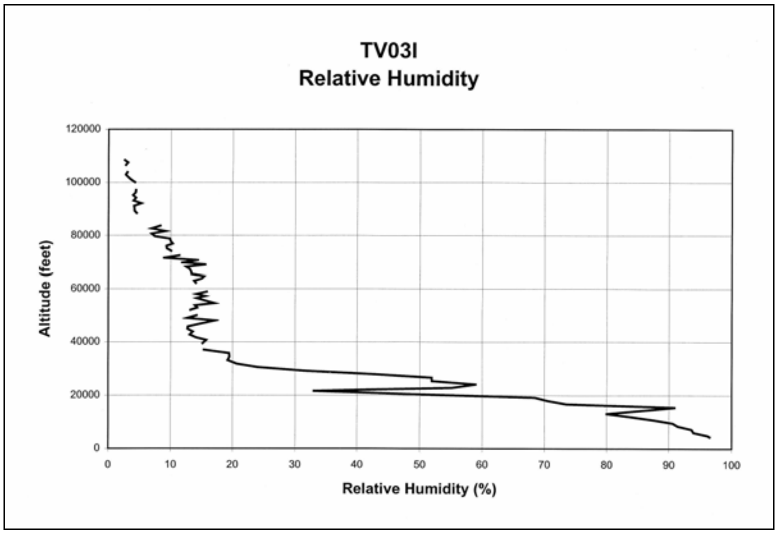
In the first cell, enter the equation

```
= ((+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

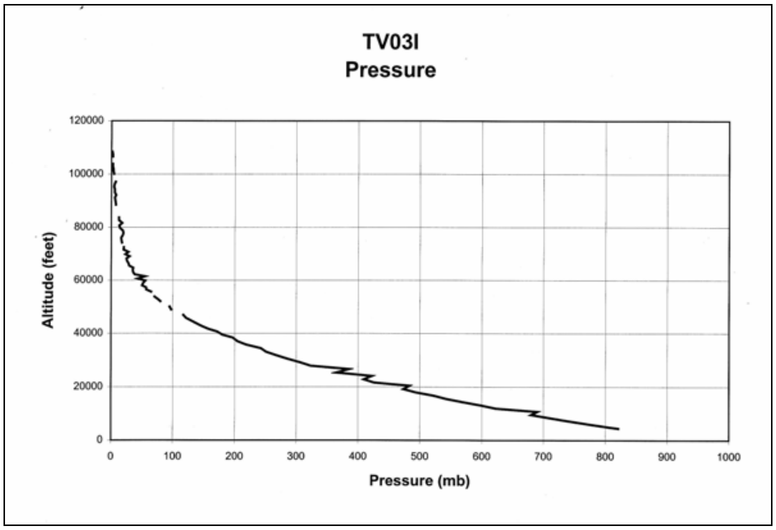
- √ Enter the following equation for millibars (mB)
  `= ((+A3/1000)-0.5)*253.25`
- √ or the following equation for pounds per square inch (PSI)
  `= ((+A3/1000)-0.5)*3.675`

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,K0YG-7:!3934.12N/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

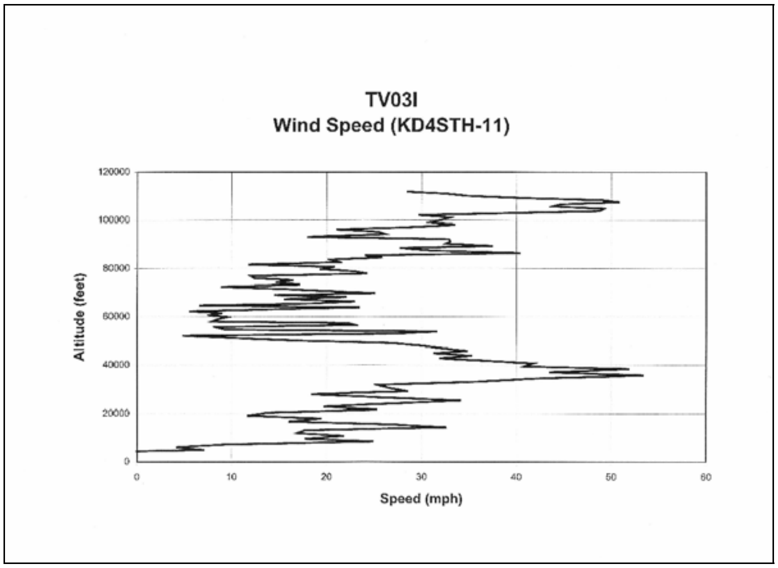
```
=IF(+A3<180,+A3+180,+A3-180)
```

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

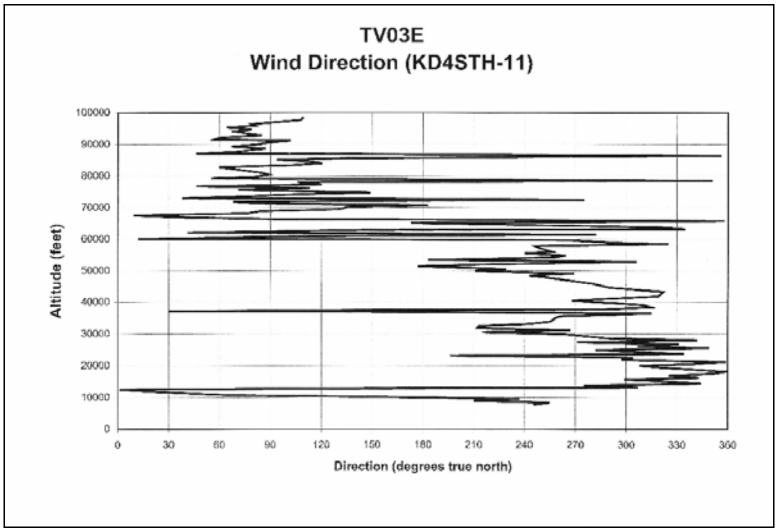
Typically the wind speed aloft increases with altitude until the near spacecraft is at the same altitude of the jet stream. If the balloon passes through the center of the jet stream, its speed can exceed a 100 mph! The jet stream is a thin river of high-speed winds aloft. The jet stream controls the 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

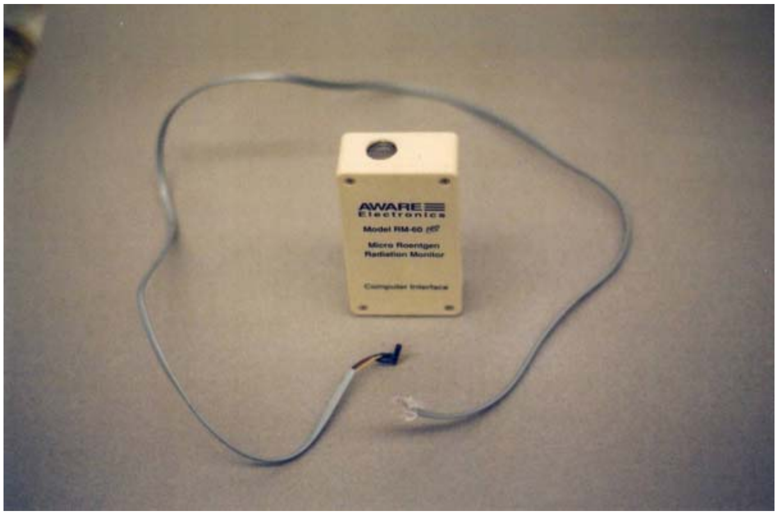
Cosmic rays are primarily high energy nuclei and most of those nuclei are protons, or hydrogen atom nuclei. Some cosmic rays travel from the depths of space to the surface of Earth while others originate in the Sun. Before they reach us on the ground, though, cosmic rays must first traverse the upper 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 exits 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

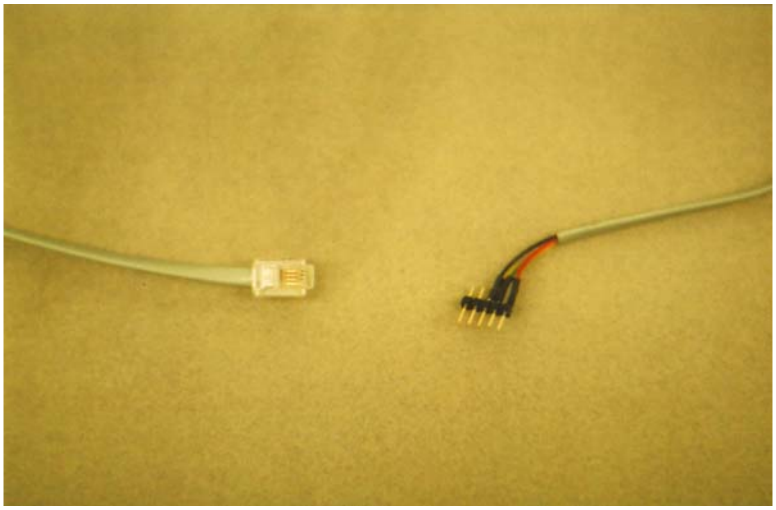
- RM-60 Geiger Counter
- Phone cable
- Header to connect to flight computer

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 is green, 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 X 10 E9 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 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)      (with horizontal tube)
        or
= (+A3 * 6) / 1.57         (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

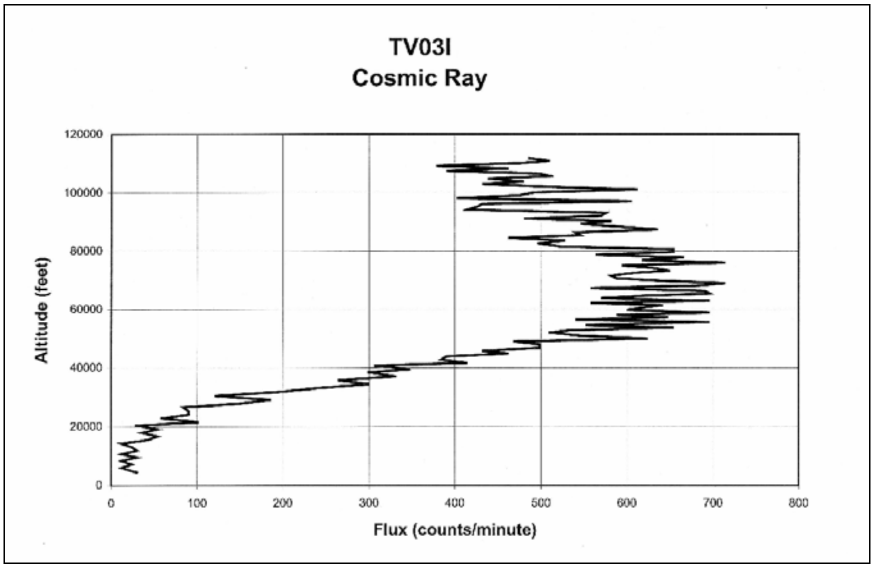
In the Penetrating Cosmic Ray Flux, enter the following equation

```
= +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 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 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.[C]

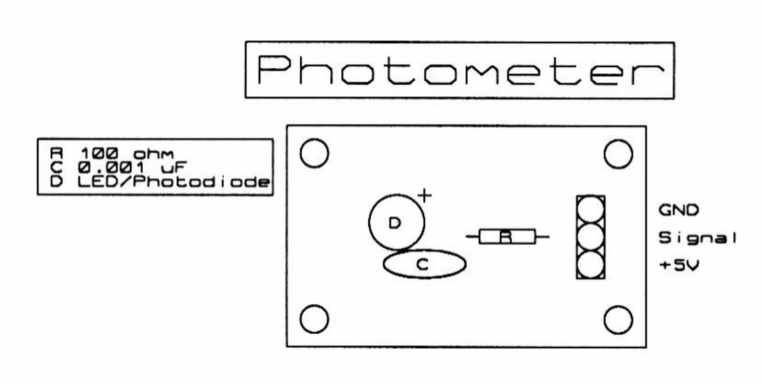
In the circuit described below, light striking the photodiode or LED creates a small current, like an inefficient solar cell. The current from the photodiode or LED changes the charge on one of the plates of a capacitor. The capacitor begins with equal charges on both of its plates. The voltage across 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 though 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

- T1¾ 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

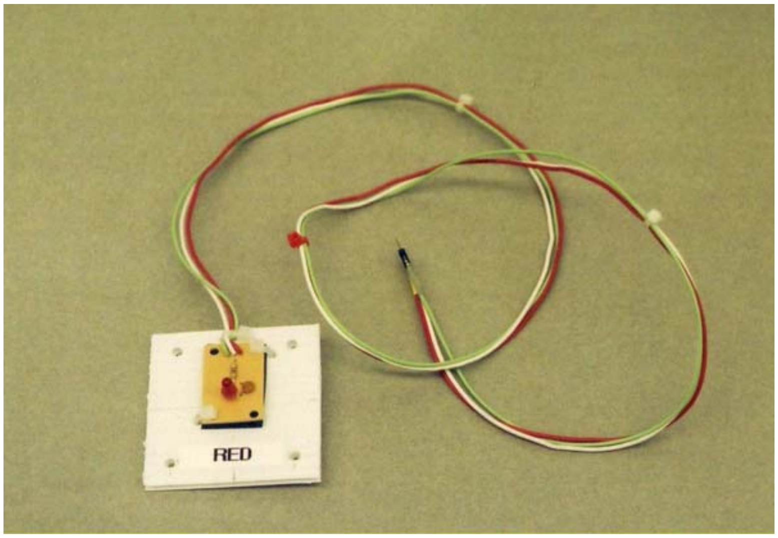


Photometer Parts Layout

√ Solder the following components into the PCB
  - o C
  - o R

√ If using the photodiode, fold the leads back so that the bubble on the photodiodes case points up.
  - o D[D]

√ 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 corroplast/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.

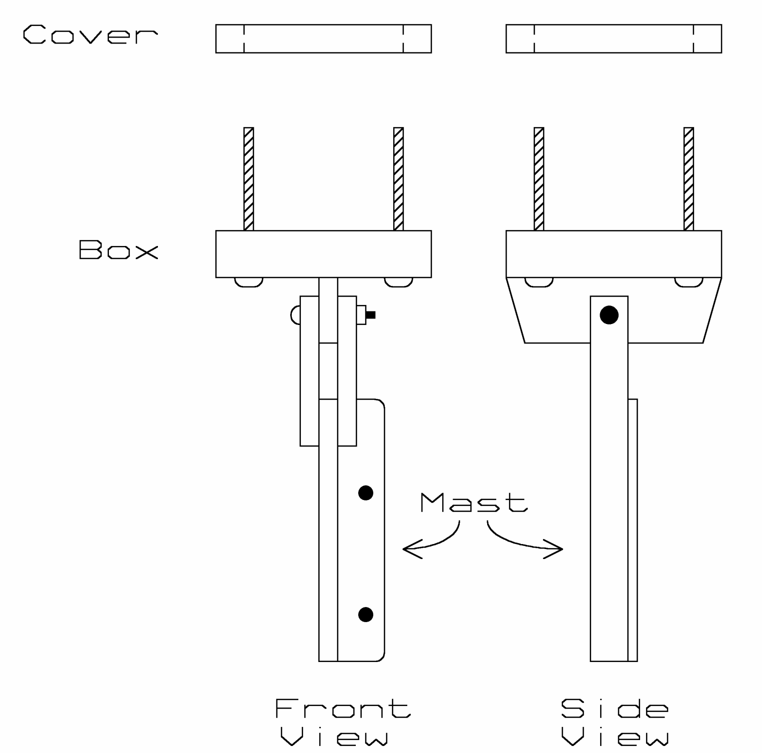
6.3 Completing The Photometer

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

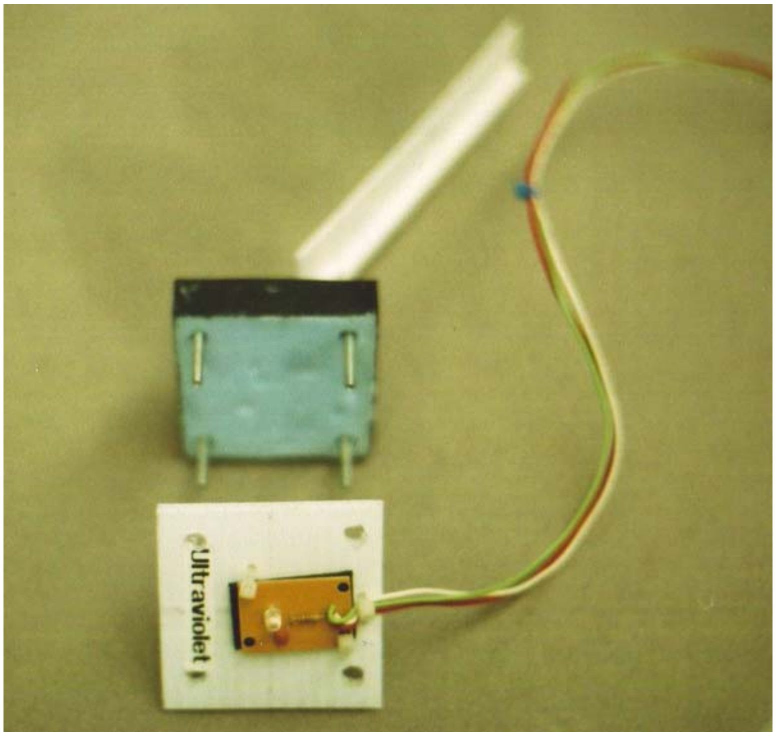
- ½" thick Styrofoam
- 1/16" plywood
- 1/4" square basswood strip
- ¼" X ½" basswood strip
- Wood glue
- Black paint
- Drill and 1/8" drill bit
- Clamps and an Exacto knife or saw
- Correplast
- ¼" square plastic tubing
- 0.04" thick plastic sheet, at least six inches long and one inch wide
- Plastic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

- Thin Styrofoam or foam core
- Hot glue



Photometer Diagram

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 ¼" 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

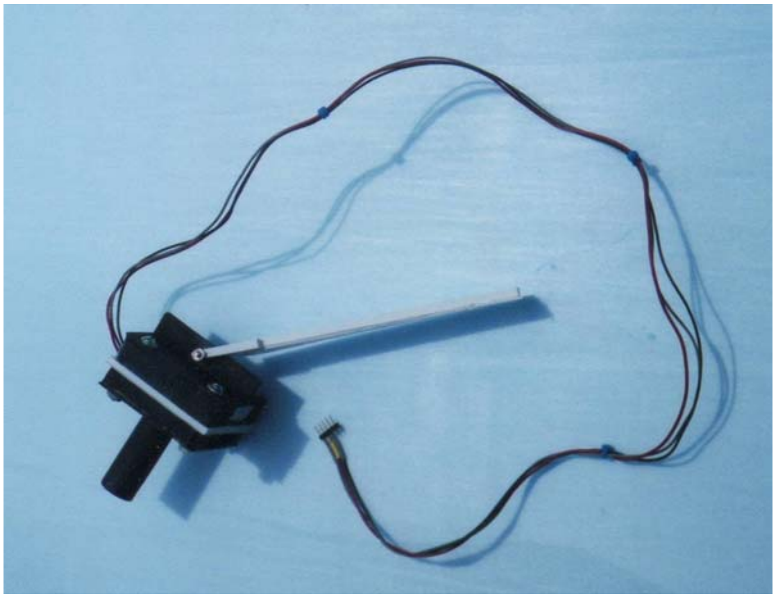
Make Photometer Bottom

- √ Cut the ¼" by ½" 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 ½" Styrofoam
- √ Epoxy the 1/16" thick plywood to one face of the ½" Styrofoam
- √ After the epoxy sets, on the underside of the plywood, mark the middle of two opposite sides
- √ Glue the ¼" by ½" 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 ¼” 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.

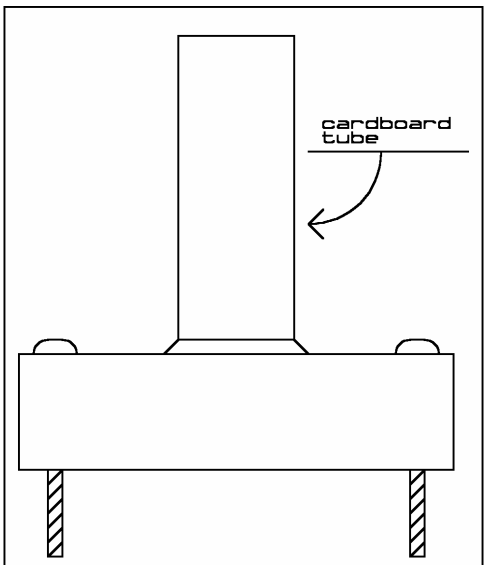
Filters And Polarizers to Control Light

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.

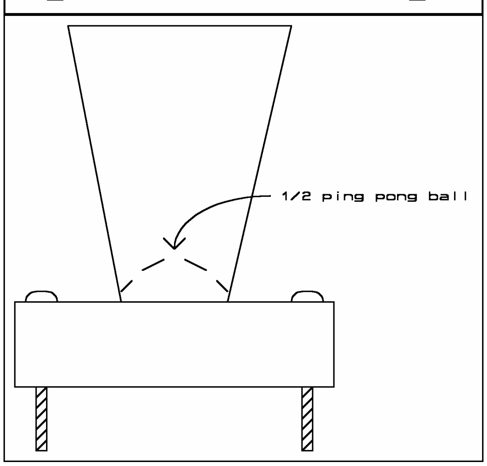
If an LED is used in the photometer, then color filters are not needed (they would be a waste of weight and time). Since the LED sticks up above the photometer cover, a polarizing filter must be placed on the topside of the photometer cover.

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

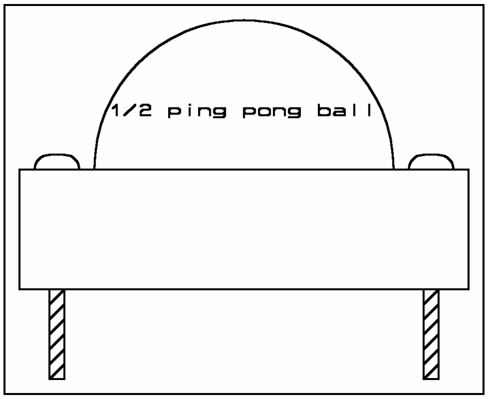
If the field of view of the photometer needs to be restricted, attach a tube or horn (cone) to the top surface of the photometer cover. The easiest tube is a length of rocket tube glued centered over the photometer cover. Plastic horns can be made from a plastic cup or constructed from scratch from thin 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 a part 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 band 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
`= +$D$3/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

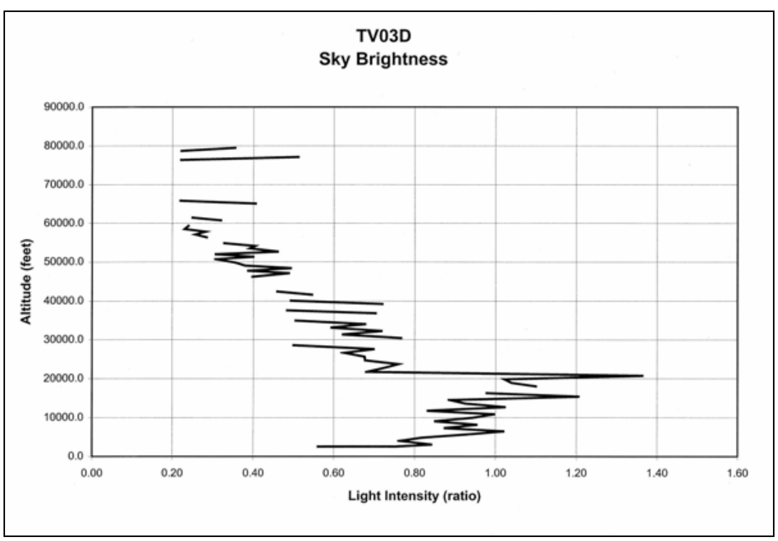
TSL230-based Photometer
In the spreadsheet there must be columns for the altitude and the photometer's measurement at that altitude. The photometer column is called Photometer Reading and its unit is counts (counts are for a specific period of time).

- √ 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

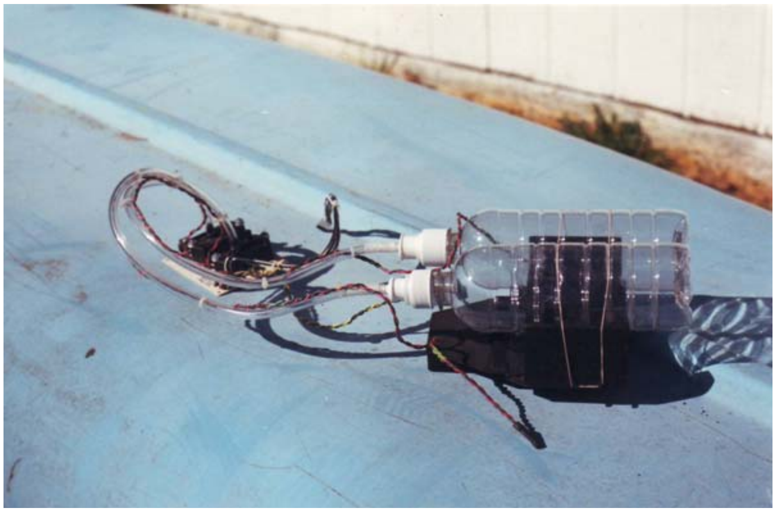
7.0 Simple Near Space Life Sciences

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.

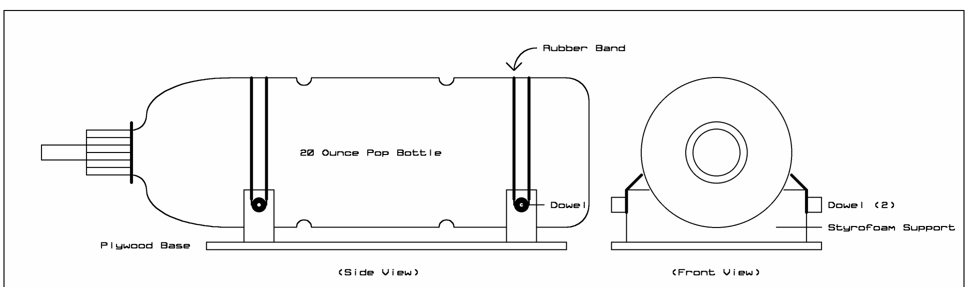
Try covering habitats with different types of insulation to monitor the effects of near space temperatures on the crew. A second habitat can be left uninsulated for a comparison. Use the temperature sensor array or Thermochron in Section 9.0 to monitor the temperature inside of habitats.

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.

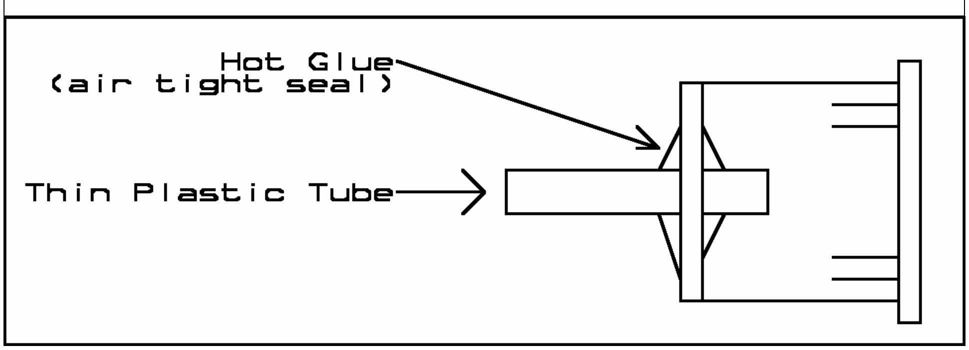
Remember your experimental controls. The crew making the trip into near space must be compared to the controls left on the ground. In addition, just as there are variations in the physical attributes of humans, there are no doubt the same types of variations in roaches. Send up several roaches in each 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
  - o Leaving a crew of roaches on the ground
  - o Using different forms of insulation on cabins
  - o Using different UV blockers on the cabin walls
  - o 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[E]

- 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
  - o Petri dishes left on the ground and others sent on a mission
  - o Include some sterile petri dishes on ground and near space samples
    Note: This is to test for contamination before launch
  - o Petri dishes inside and outside the airframe
  - o Petri dishes covered in different types of thermal insulation
  - o 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?[F]

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.

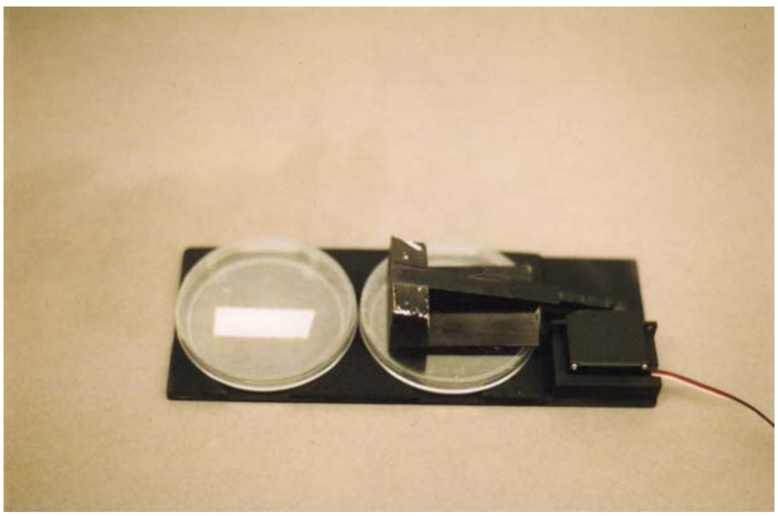
Aside from the seeds, give the kids a cleaned up flight log. Let them pull the temperatures of their experiment out of the data along with time and altitude. These represent other graphing activities for the students. In addition, give the class a copy of the photographs taken during the flight. If the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

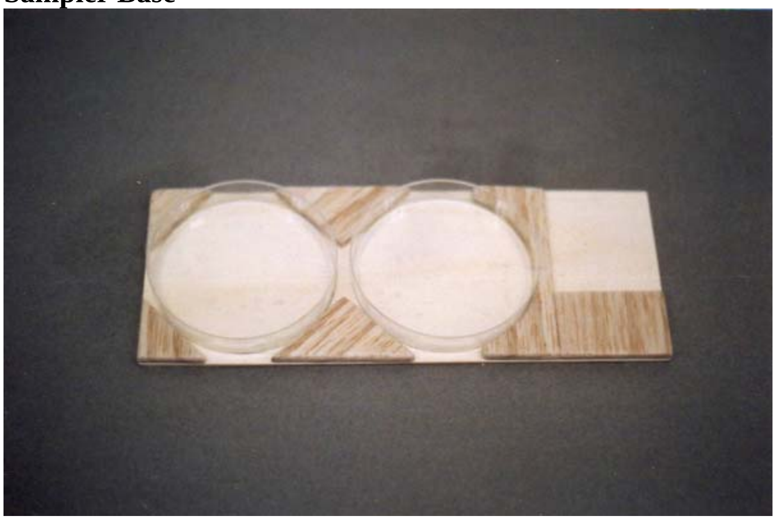
8.2 Materials

- Two non-sterile petri dishes[G]
- 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, ¼" by ¼"
- ½" thick Styrofoam
- ¼" by ½" 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)[H]
- Thin heat shrink tubing to cover the #24 AWG wire

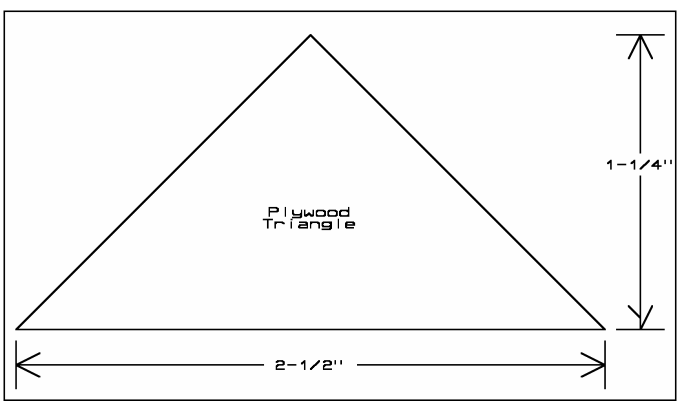
8.3 Procedure

Sampler Base



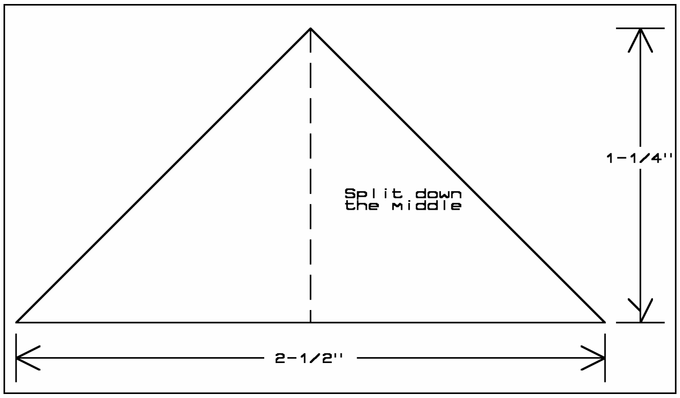
Completed Sampler Base

- 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



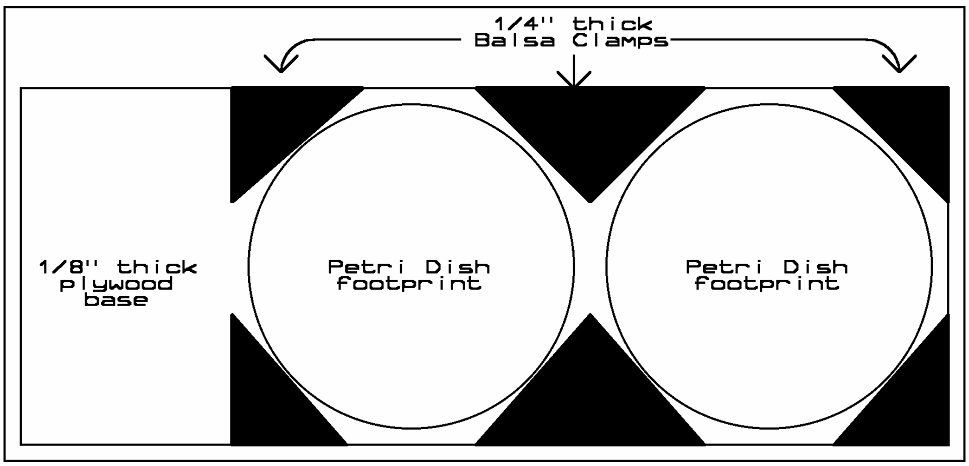
***Triangles -** Cut four of these*

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



Split Triangle

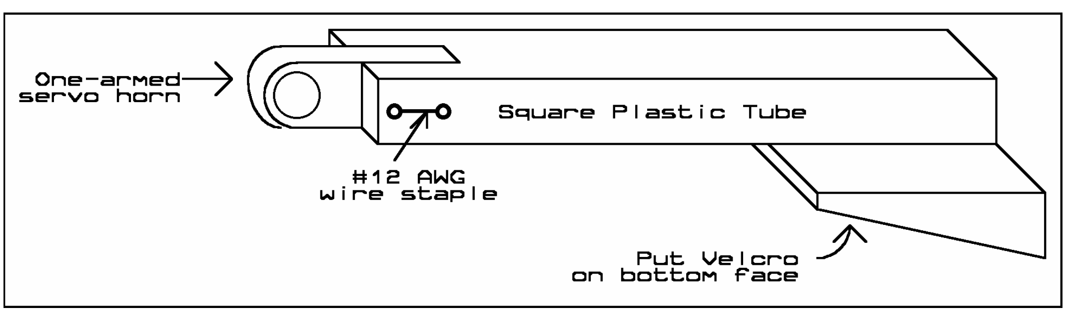
√ Glue the triangles to the sampler base as illustrated to form "clamps" for the petri dishes



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

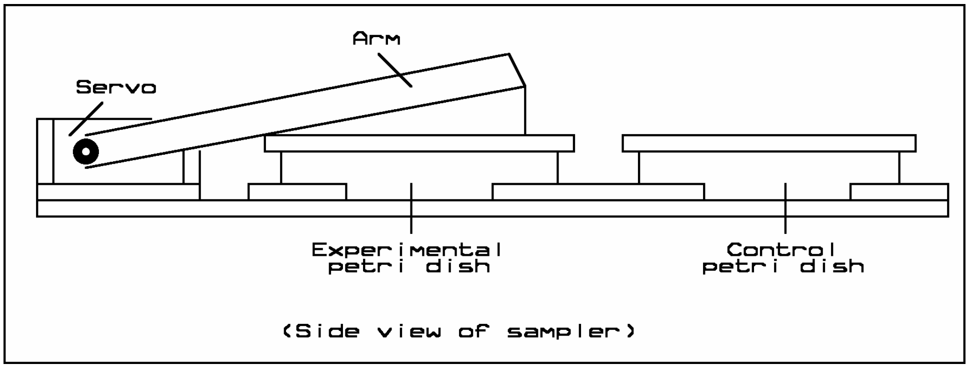
Sampler Arm

√ 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 ½" 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



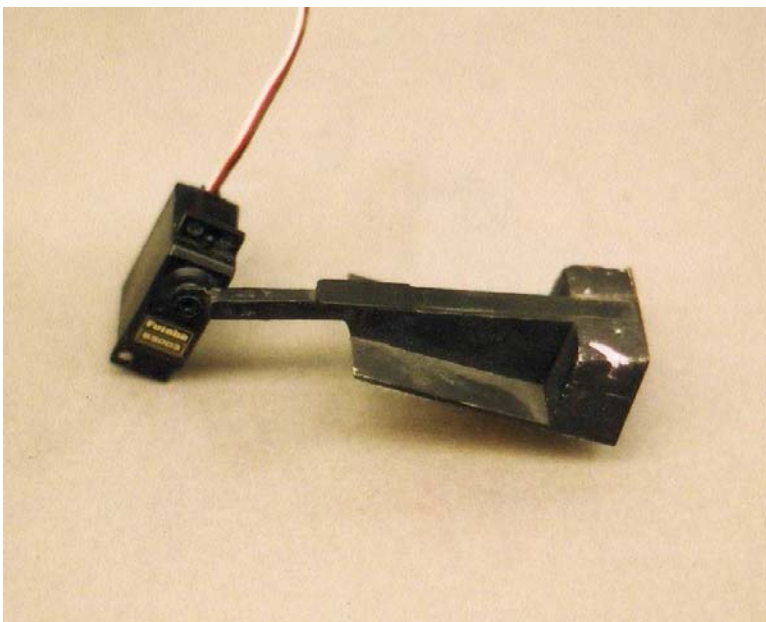
Sampler Arm Diagram

√ 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



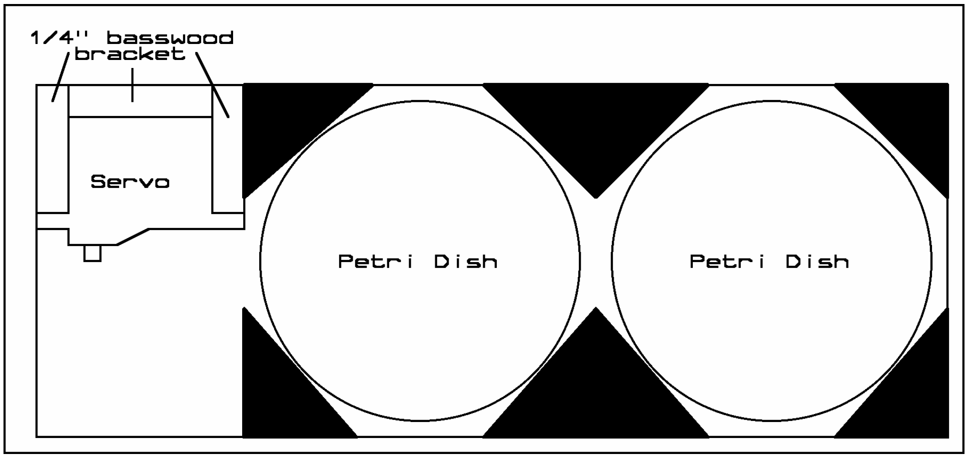
Sampler Arm on Petri Dish – *Side view of the sampler when it's complete*

√ 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 ½” by ¼” wood to form a bracket for the servo

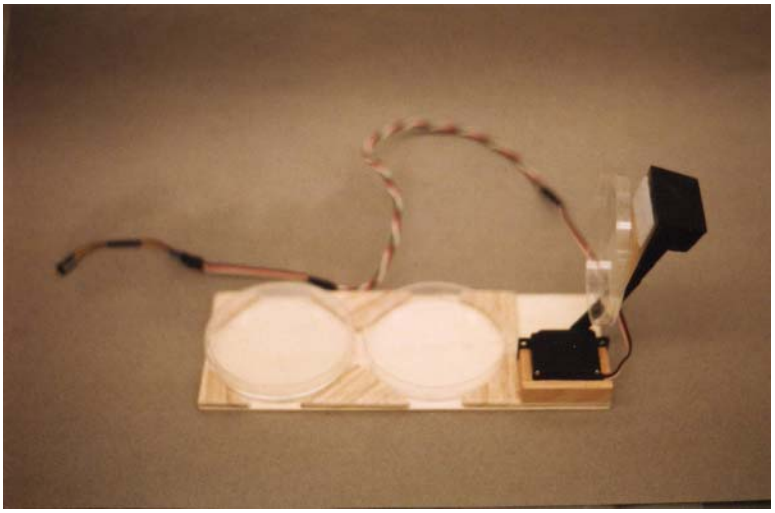


Bracket Diagram - *The wood forms a bracket for the servo*

- √ 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+).

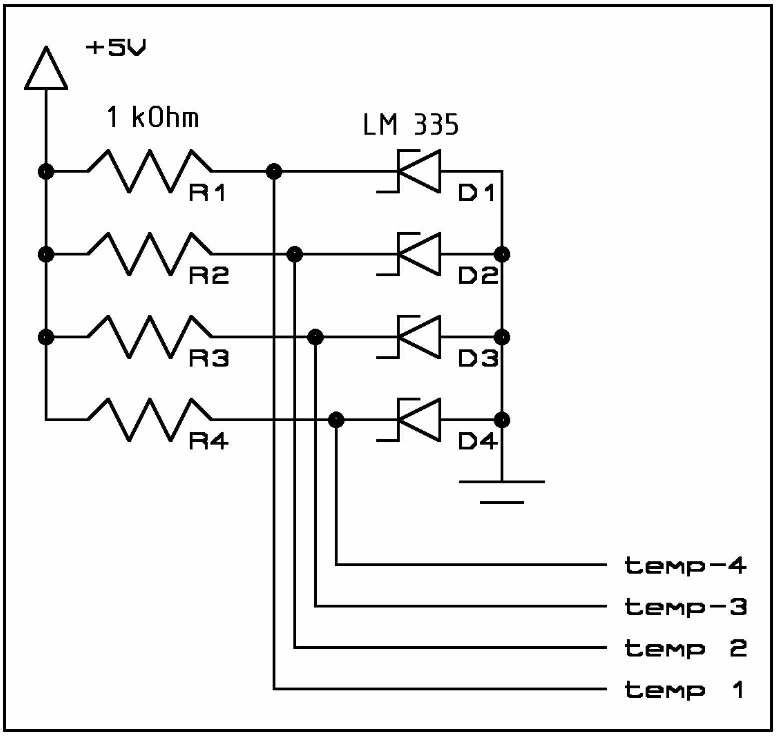
9.0 Temperature Sensors

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 though R4 are 1kΩ 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.

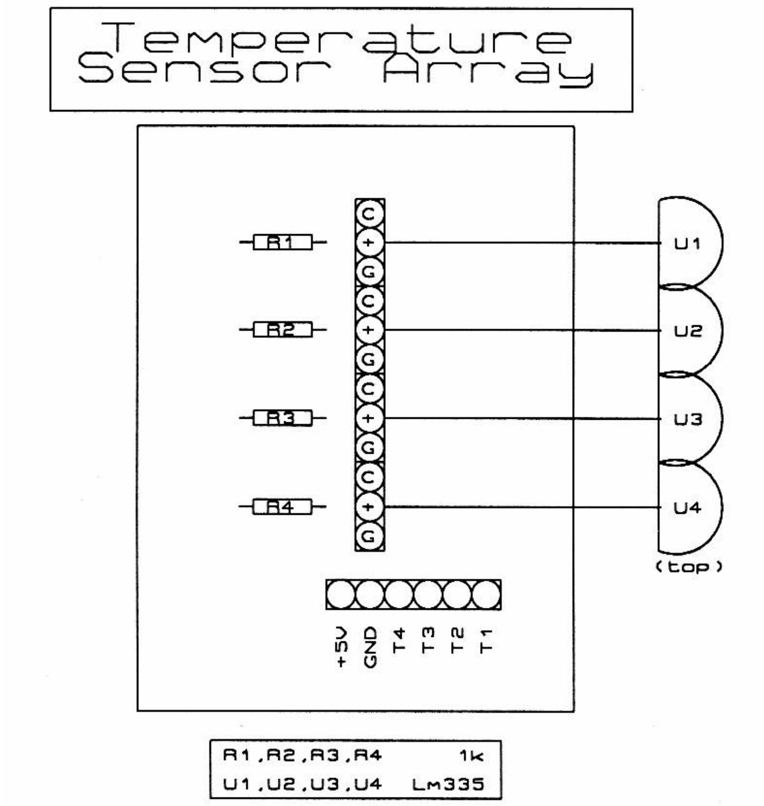
In the temperature sensor array, all three wires are connected to the LM335, but only two are used. The third lead is used to calibrate each LM335, but it's easier to do this calibration in software after the mission.

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



Temperature Sensor Array Parts Layout

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

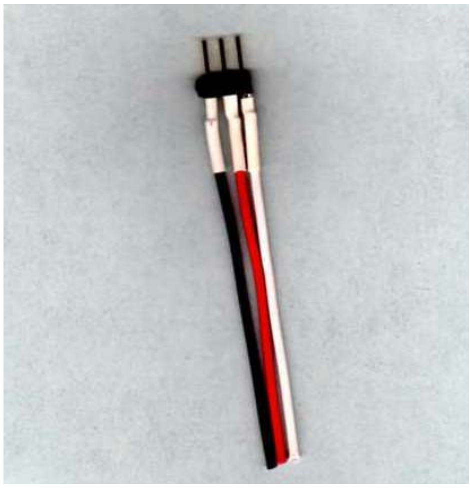
1. Male headers on the interface cable and female receptacles on the ADC ports

- √ 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

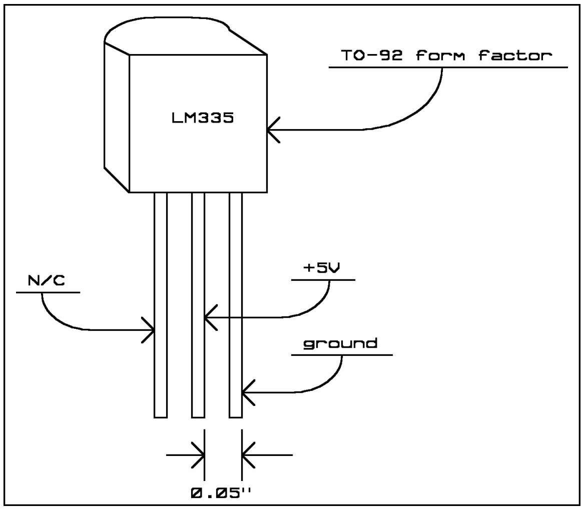
Label the ADC connector so you can keep track of which cable is for which sensor
Cover the label in clear heat shrink



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

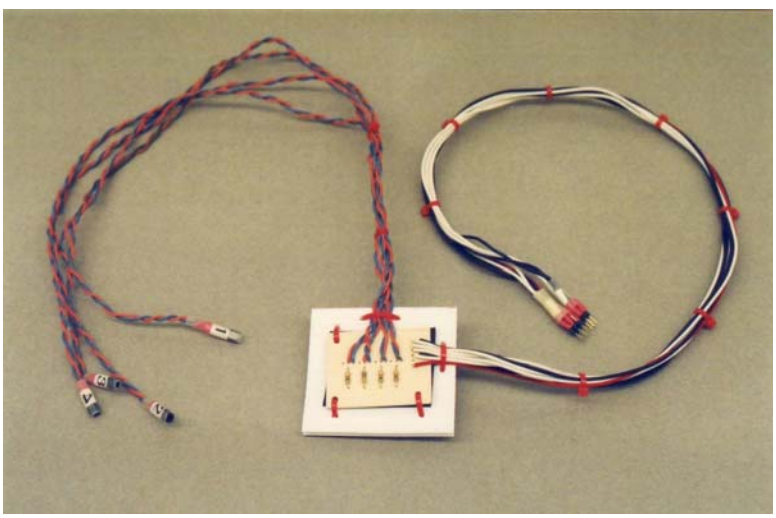


LM335 Pin-out Diagram

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
```

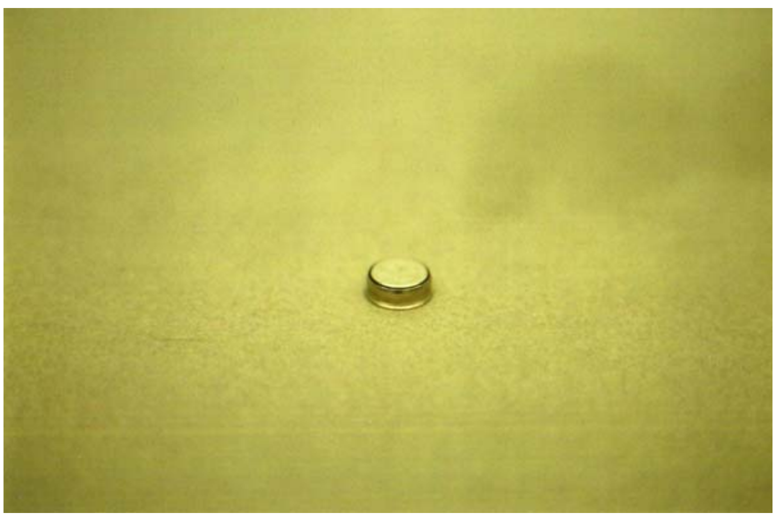
To convert to degrees Fahrenheit

```
((((+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.

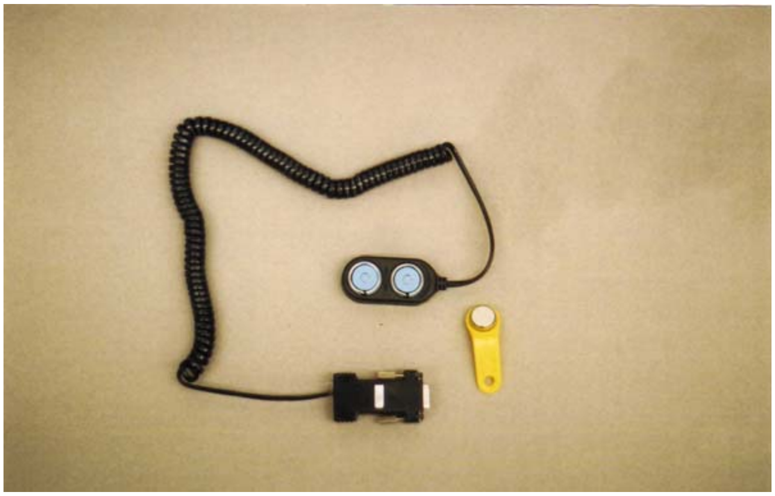
9.2.2 Source For Thermochrons And Software

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.*

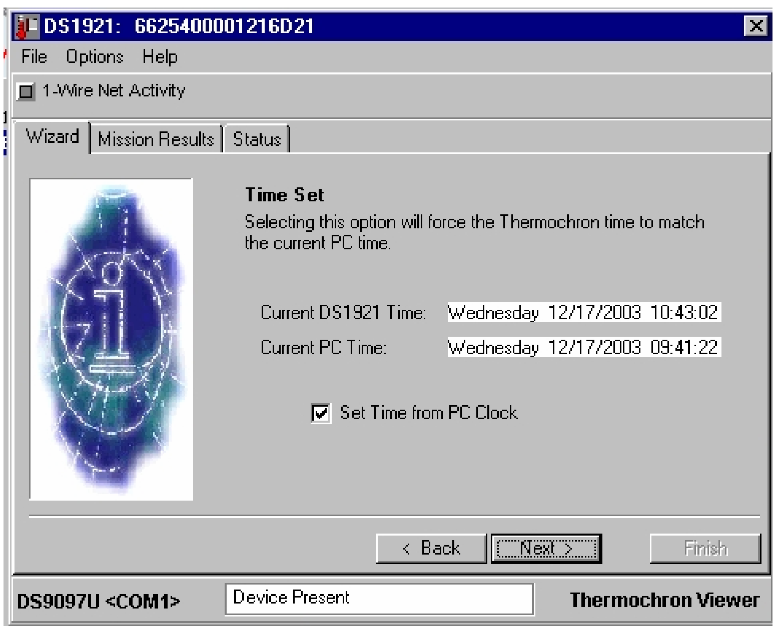
- √ Install the iButton Viewer (TMEX) software on a PC or laptop
- √ The night before a mission plug the Reader into a PC or laptop with the TMEX software (the FRR is an excellent time to do this)
- √ Start the PC or laptop and open the TMEX-iButton group
- √ Start the iButton Viewer
- √ Record the ID (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.*

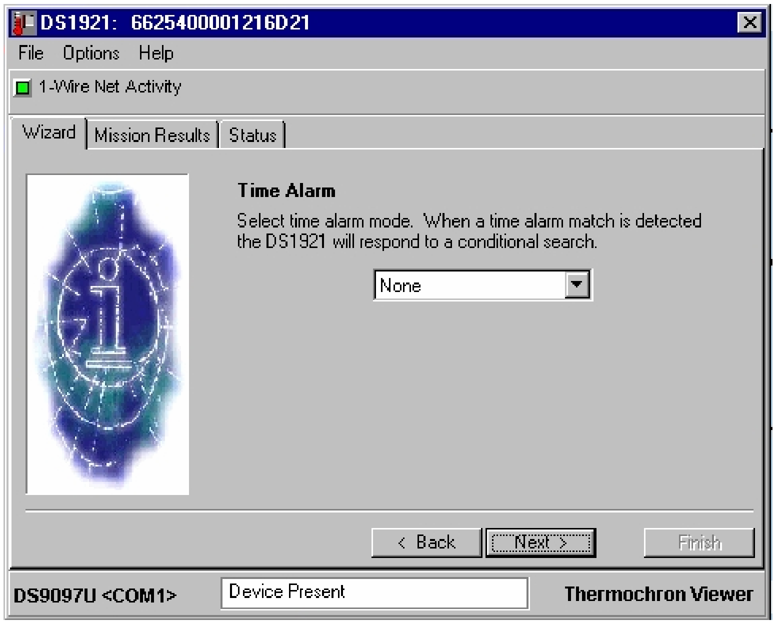
- √ The iButton Viewer reads the iButton detected in the Reader and informs you that it cannot read the directory in the Thermochron memory

- √ 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



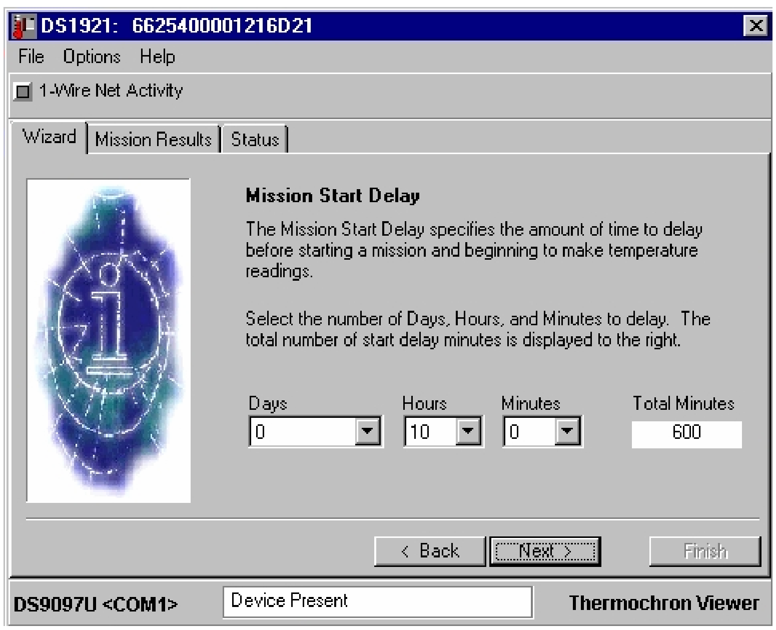
Time Set

- √ 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

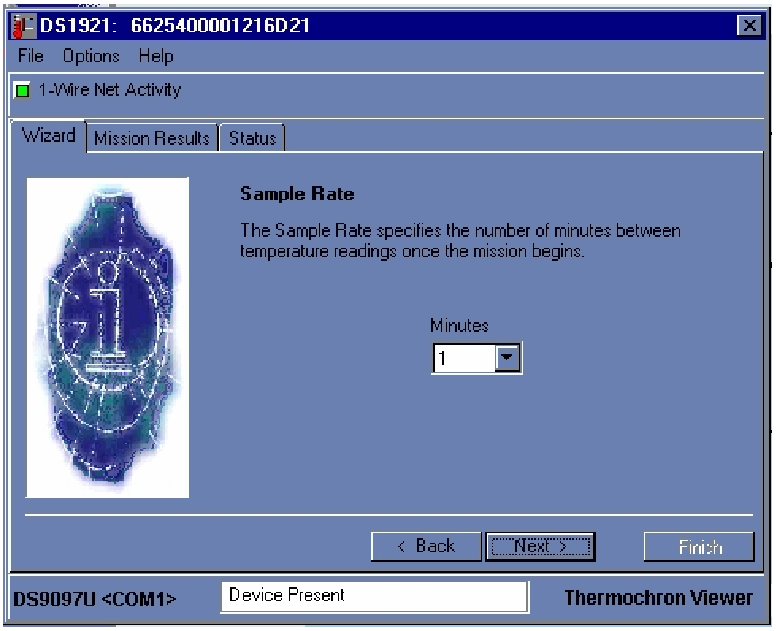
√ Set the Mission Start Delay in Days, Hours, and Minutes



Mission Start Delay

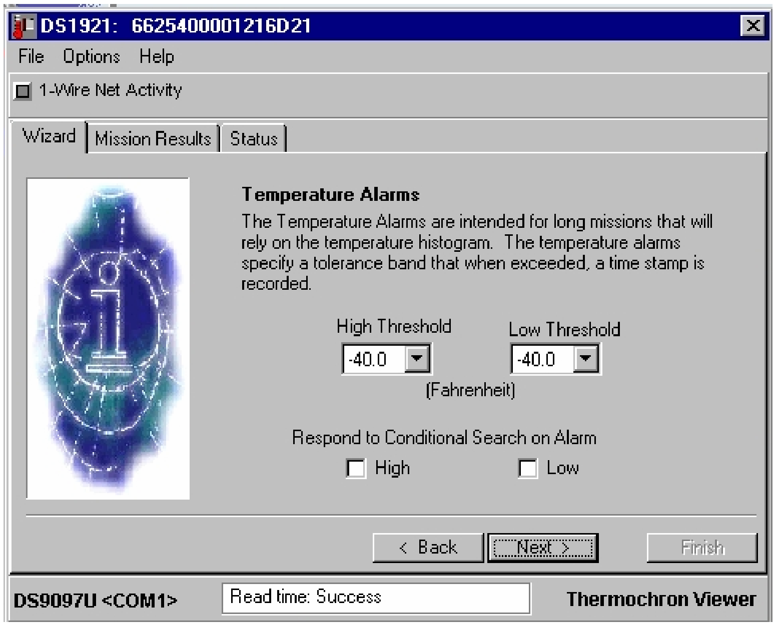
Note: The Thermochron does not start recording time and temperature until after the Mission Start Delay. Be sure to start recording data a little before the expected time of launch.

√ Select one minute for the Sample Rate

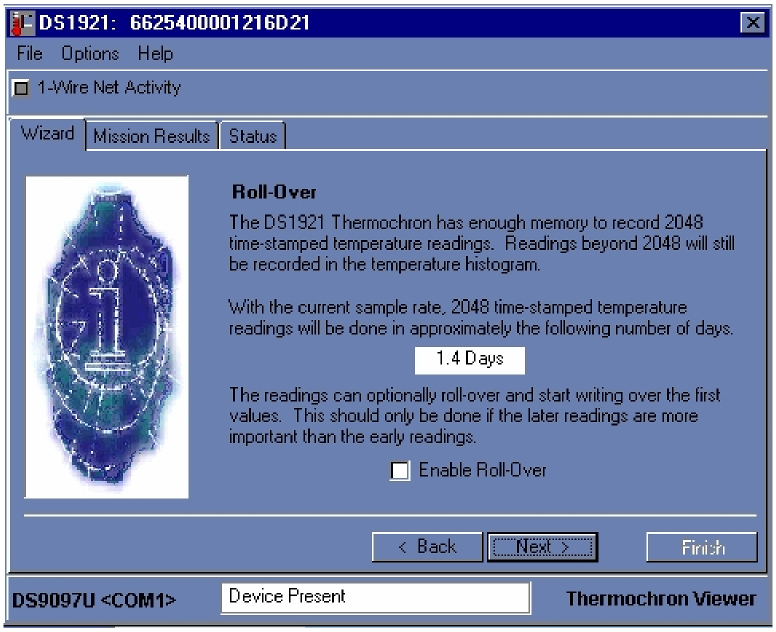


Sample Rate

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



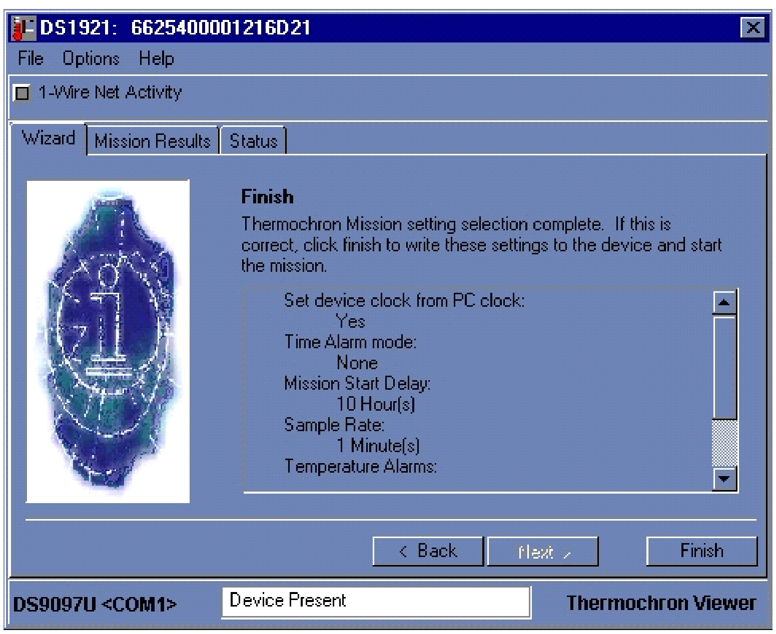
Temperature Alarm



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

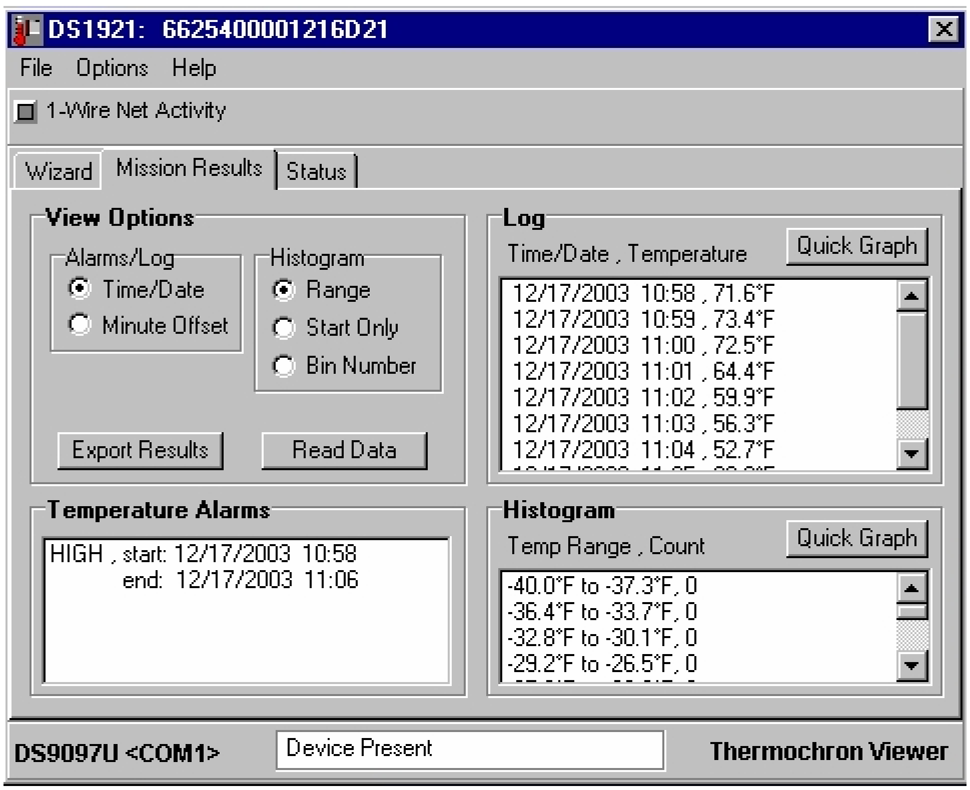
If you order extra Thermochrons, test them together and compare their recorded temperatures. This indicates the corrections you may have to add to Thermochron data. You want to compare like temperature sensors during a near space experiment.

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

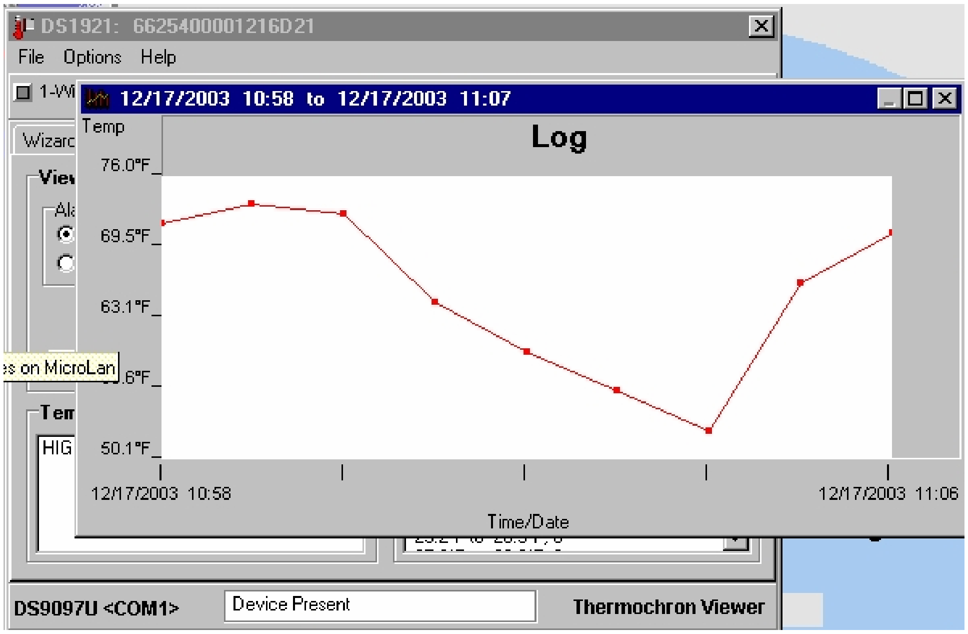


Mission Results

- √ 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

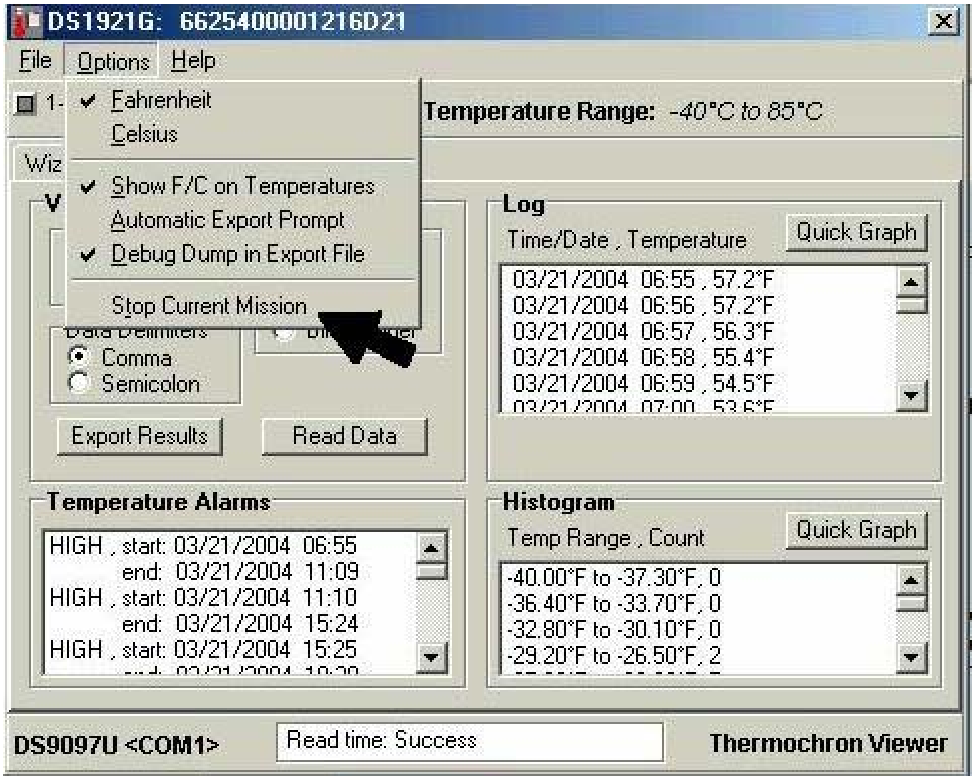


Log Quick Graph

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.



Stop Current Mission

√ 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

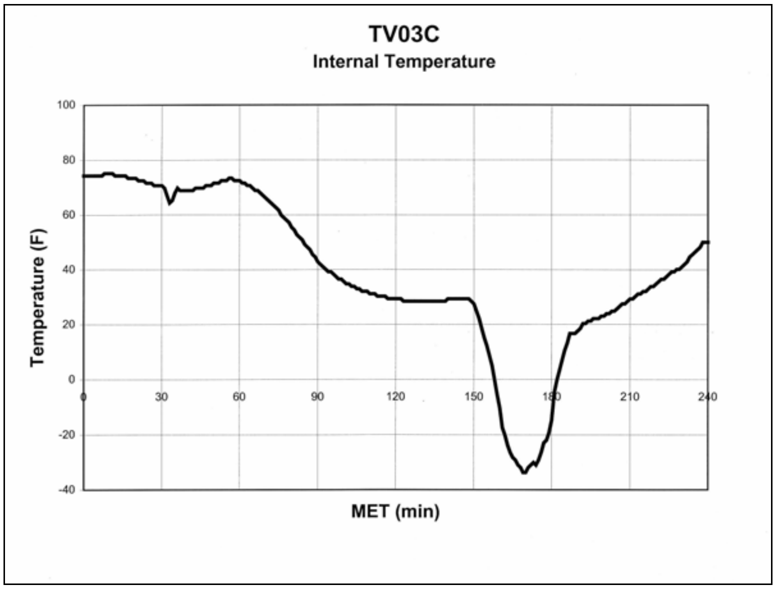
```
(+A3*60)+B3-nnn
```

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.

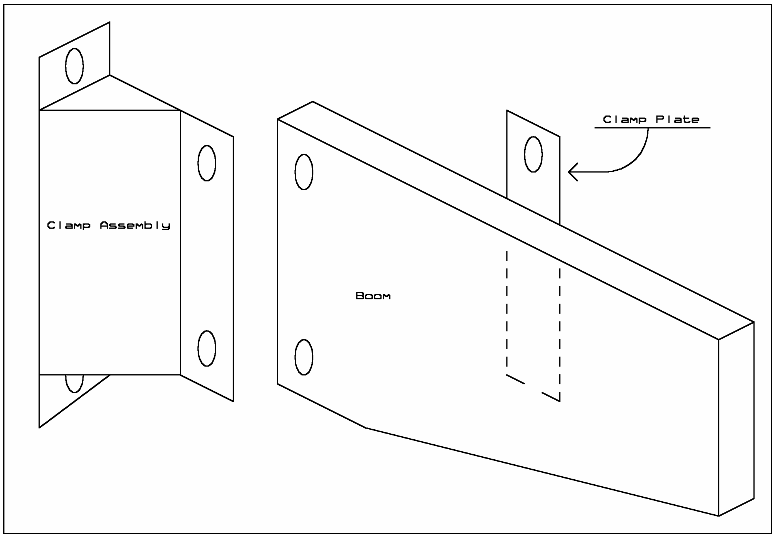
Ultraviolet Sensitive Materials
Send fluorescent papers and plastics into near space and photograph them during the flight. If the materials and camera are sealed inside of a UV passing filter, then visible light cannot contribute to the observed brightness of the materials.

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_2 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
- ¾" 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 ¾" thick (you're creating a square cylinder four inches tall and ¾" 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, ½" from the far edge of the plate and washer and ¾" 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

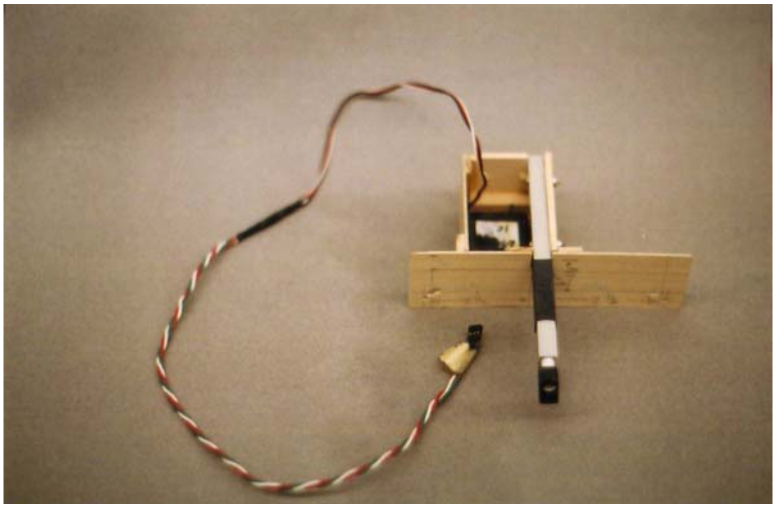
Students may want to design their experiment into a LEGO® Technics structure. Consult a LEGO book for information on building strong structures. If you deem the structure is safe enough to launch (safe enough that parts won't fall off during the flight), then use nylon wire ties to secure the LEGO Technics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

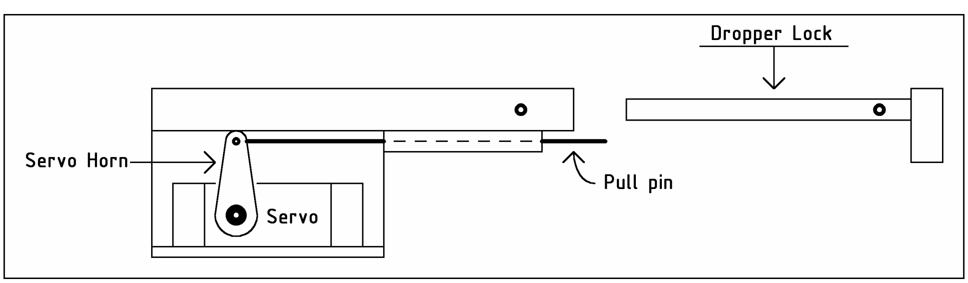


***A Dropper -** Mounted behind a quad panel.*

10.2.1 Materials

- Parallax Standard Servo (P/N 900-00005) (Equivalent to Futaba S-148)
- 1/8" diameter plastic tubing
- ¼” diameter plastic tubing
- ¼" 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
- ½” by ½” basswood
- Epoxy
- Plastic glue
- Four servo-mounting screws
- Two #2-72 mounting hardware, ¾” 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 ½" by ½" 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 ¾" long pieces of ½" by ½" 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 ½" by ½" 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

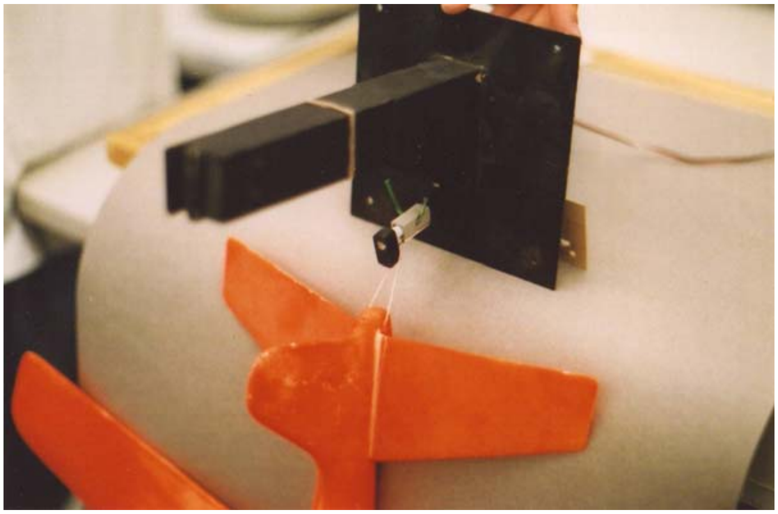
- √ Leave square and round tube in place and line up left side flush to Servo Box and Dropper Arm
- √ Clamp Servo Arm to left side
- √ Remove left side and Dropper Arm (keeping them clamped together)
- √ Drill two small holes for #2-72 bolts so that the square tube can be bolted to left side
- √ Use 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 ¼" plastic tubing to a length of five inches
  Note: This tubing will be shortened later
- √ Cut ½" square basswood to a length of ¾"
- √ Drill a ¼" diameter hole near the end of the basswood block
- √ Epoxy the basswood block top end of ¼" tubing (Locking Pin)
- √ Slide Locking Pin into 3/8" square tube until ¼" 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 ¼" 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 ¼" 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 ½"
- √ 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.

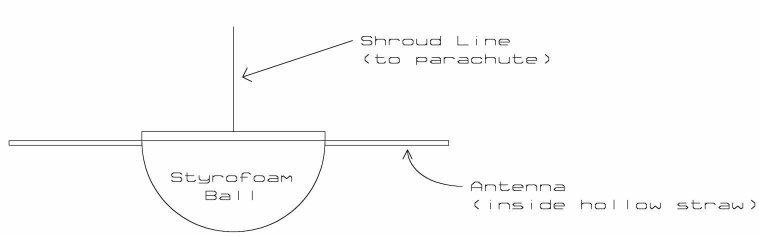


Diagram of Dropzond

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

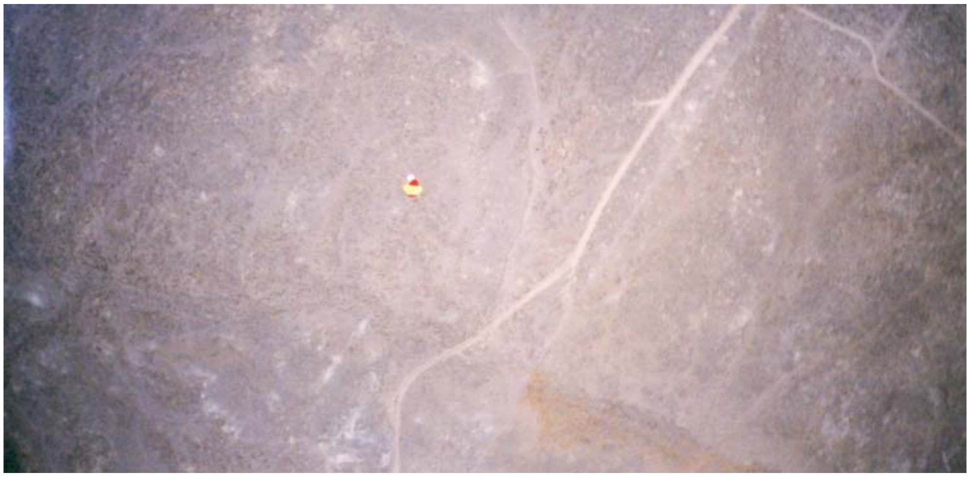
√ Cut a six-inch diameter Styrofoam ball in half
√ Cut wedge-shaped pieces out of the fiberglass, where the length of the wedge is one-quarter the circumference of the dropzond body and the width of the wedge is slightly larger than 1/8th the wedges length *
√ Apply epoxy to Styrofoam surface and layer 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 ½" 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.

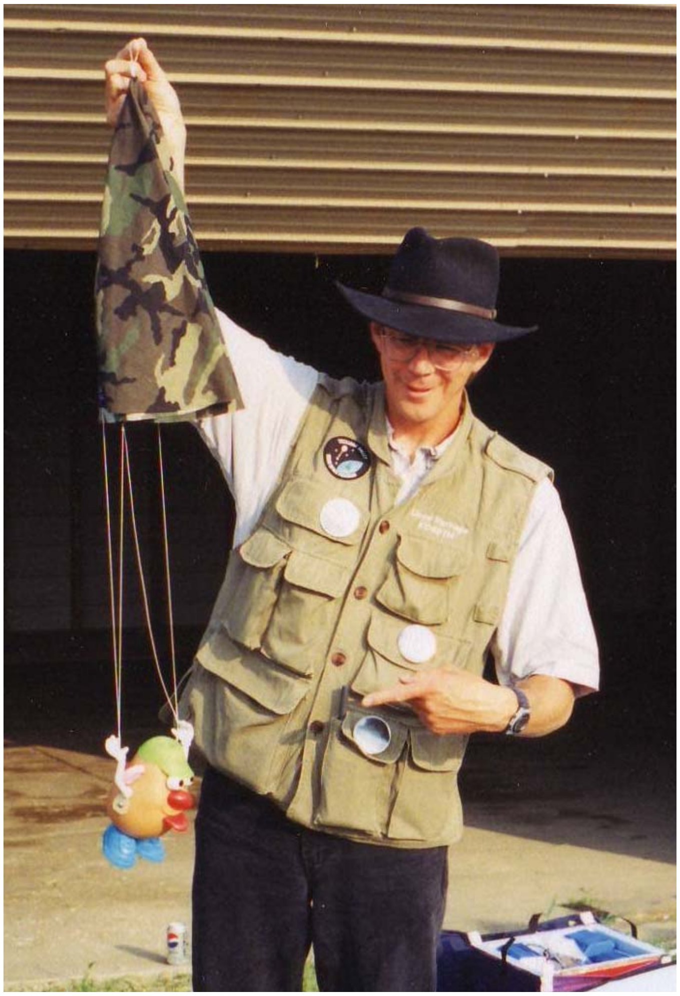
Recovery System

√ 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.*

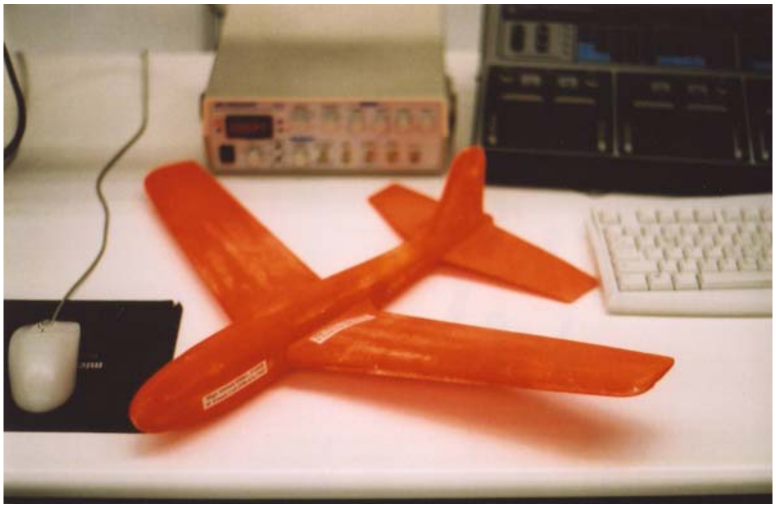
The second dropzond carried by TVNSP was a Mr. Potatohead figure with his own camo parachute (Idaho air assult). Mr. Potatohead was released at 50,000 feet over Herrington, KS, as a part of the GPSL 2002 launches. Mr. Potatohead was recovered by a rancher who turned him over to the local sheriff.



Mr. Potatohead - *This character (the one on the left!) took a ride into near space during GPSL 2002. His airborne assult 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 it’s 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,K0YG-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,K0UT-
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,K0YG-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.

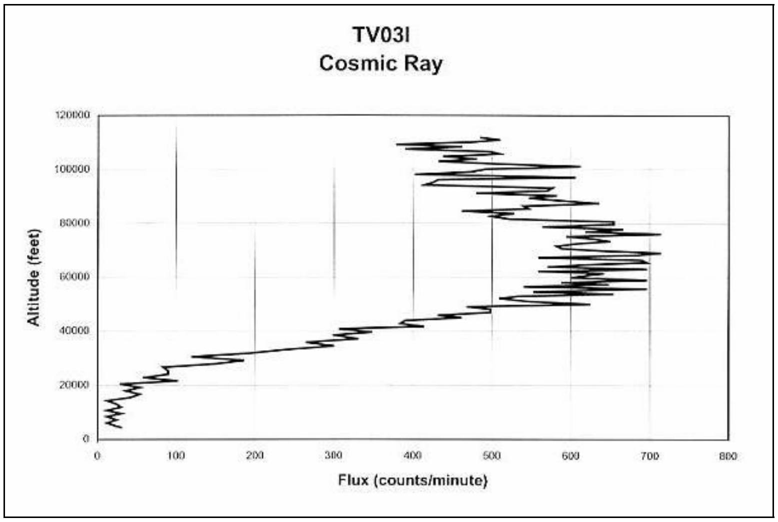
The flux of cosmic rays is at least as great as one cosmic ray per square centimeter per second, or about the same flux as raindrops during a rain shower. When these energetic nuclei slam into Earth's atmosphere they collide with air molecules (mostly nitrogen and oxygen) high in the atmosphere. Upon 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?[I]

[A] 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).
[B] 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.

[C] 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.
[D] 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.
[E] Scientific Wizardry carries petri dishes and agar. Contact Scientific Wizardry at: 2404 S Orchard St # 500, Boise, ID, 83705, ph. (208) 336-4958
[F] 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).
[G] Non-sterile petri dishes are used in testing
[H] 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.
[I] 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 my 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 your 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 where 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 lose during the flight. Due to the nature of near space flight, the riskiest time is early in the decent, 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 require 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 sees 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 amazing 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 a 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 1/10th 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 1/10th 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 names 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 easy 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 planets 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 where 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 where 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 where 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 where 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?

CHAPTER NINE

Launch Support Equipment

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

Chapter Objectives

1.0 Support Equipment To Collect

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

Items For Balloon Filling

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

Items For Stack Assembly

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

- Bag of Styrofoam peanuts
- Laundry bag

Launch Equipment

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

Items For Capsule Closeout

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

Items For Organizing Equipment

- Boxes for small parts
- Several large gym bags or plastic tubs with lids
- Labels for bags or tubs

1.1. 1.0.1 Ground Support Equipment

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

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

1.2. <u>1.0.2 Balloon Filling Equipment</u>

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

1.3. <u>1.0.3 Stack Assembly Equipment</u>

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

Styrofoam Peanuts - *in mesh laundry bag*

1.4. 1.0.4 Miscellaneous Tools

Miscellaneous Tools

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

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

Balloon and Bag

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

1.5. 1.0.5 Hauling Helium Bottles

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

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

2.0 Support Equipment To Be Built

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

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

2.1. Weighing Frame

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

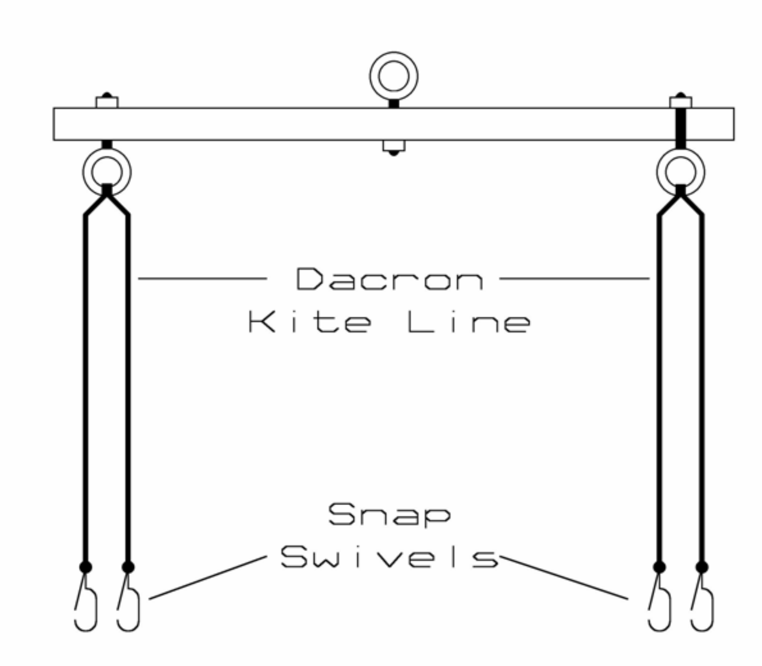
Weighing Frame - *Mark Conner (N9XTN) and Dan Miller (KC7SLC) weighing a module of a near spacecraft*

2.1.1. Materials

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

2.1.2. Procedure

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



Eyebolts in Weighing Frame

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

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

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

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

2.1.3. Using The Weighing Frame

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

2.2. Balloon Filler

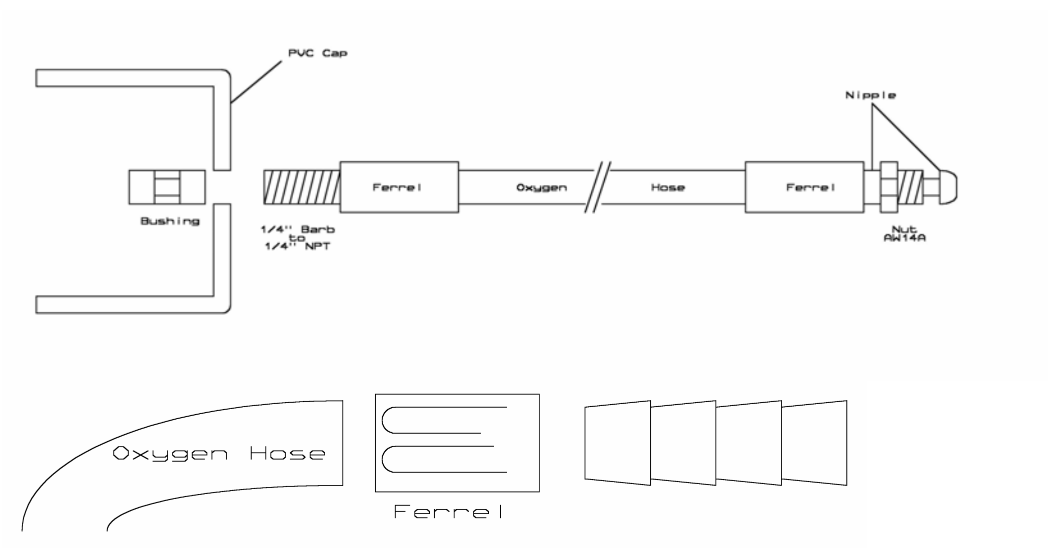
A weather balloon requires on the order of 300 cubic feet of helium, an amount that a toy balloon filler is incapable of providing in a reasonable amount of time. There is no known commercially available filler capable of handling a 300 cubic foot balloon. The filler described here is design specifically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

Balloon Filler

2.2.1. Materials

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

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



Oxygen Hose *– Diagram of Parts*

The remaining items are available at your local hardware store

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

2.2.2. Procedure

Regulator Modification

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

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

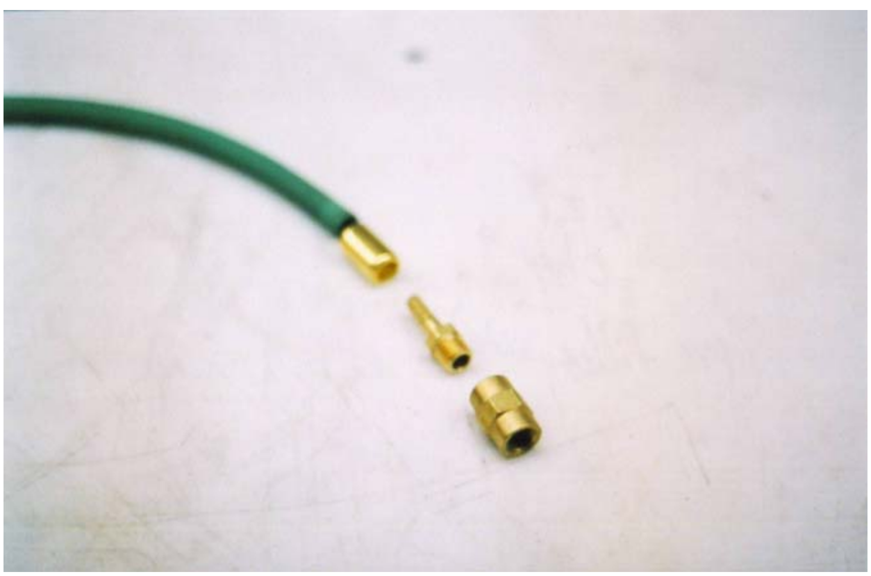
Oxygen Hose

Ask a Welding Shop to do the following

On one end of the hose, install the following:

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

This end of the hose connects to the PVC pipe



PVC Filler Side of oxygen hose

On the other end of the hose, install the following

- 7325 Ferrule
- AW17 Nipple
- AW14A Nut

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

Regulator Side of oxygen hose

PVC Filler

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

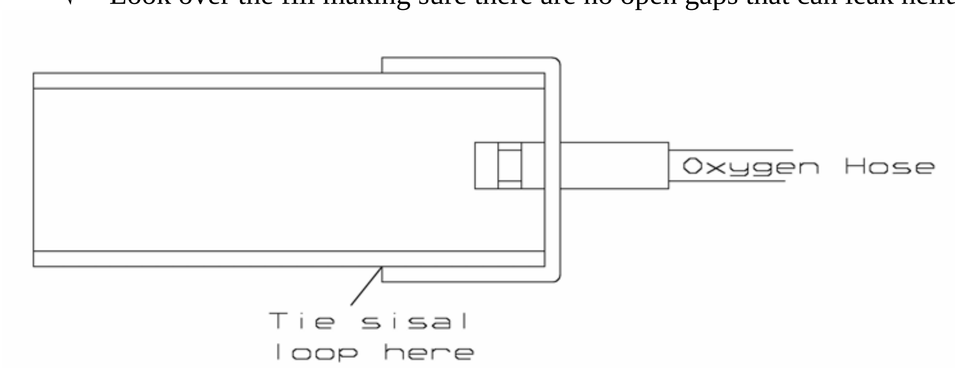


Diagram of PVC End of hose

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

Close-up of filler end

2.2.3. Using The Filler

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

2.2.4. Additional Optional Modifications

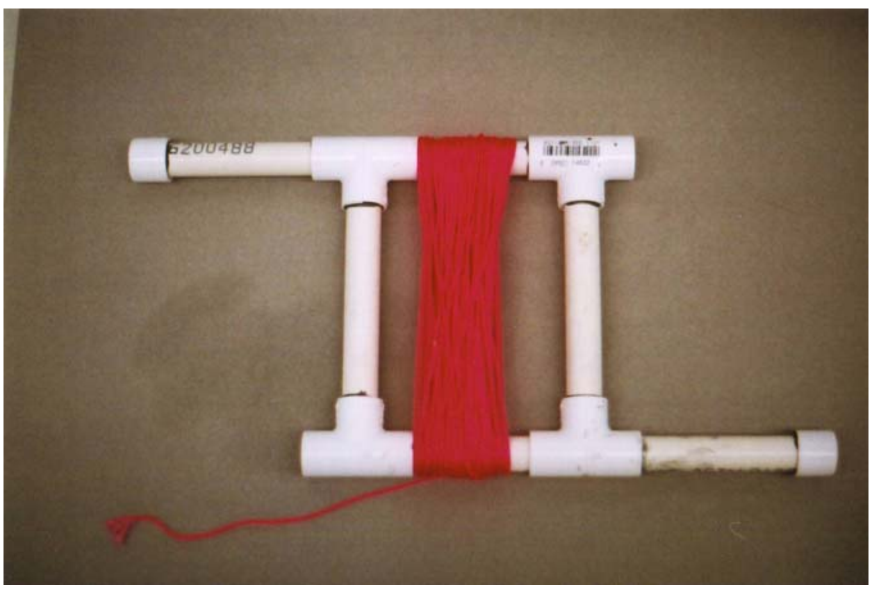
Large balloons like 2000 and 3000-gram balloons have larger nozzles than the balloons most commonly used. The author has not found it necessary to change the diameter of the PVC pipe of the filler for these larger balloons. The excess nozzle is wrapped around the pipe and the entire nozzle tapped down.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

2.3. Launch Lanyards And Lanyard Release

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

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

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



PVC Winder

2.3.1. Materials

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

- Two enclosed blade letter openers or seat belt cutters

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

2.3.2. Procedure

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

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

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

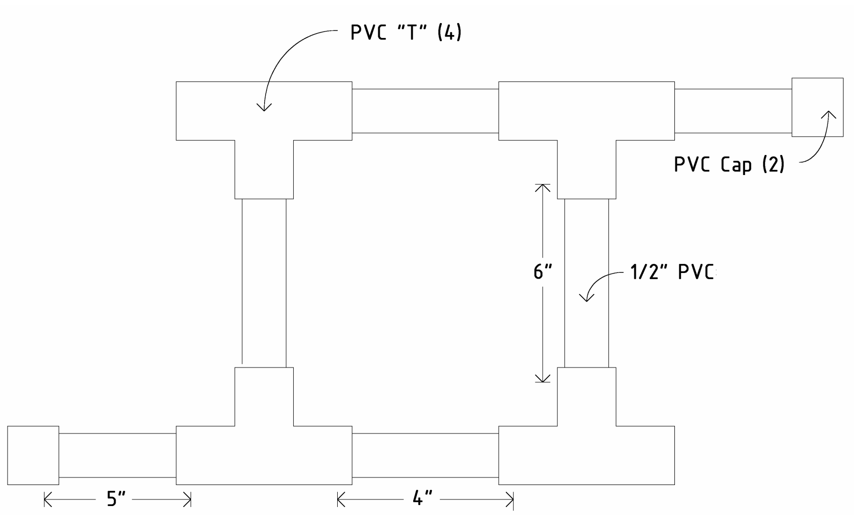
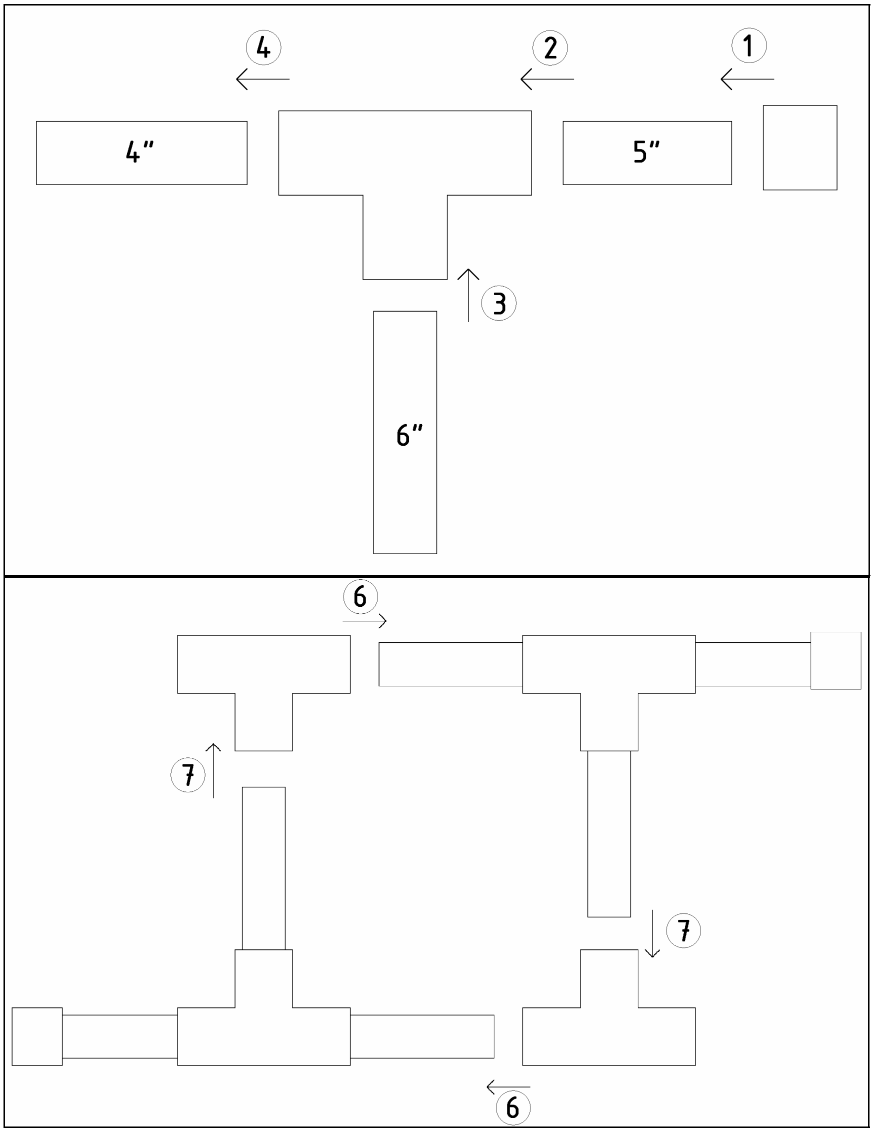


Diagram of PVC Winder

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



PVC Winder Assembly Steps

In Rapid Succession

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

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

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

Winding String On The Kite Winders

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

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

An option to think about

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

Finishing the winders by adding the emergency cutaways

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

Finished Winder

2.3.3. Using The Launch Lanyards

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

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

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

2.4. Launch Tower

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

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

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

2.4.1. Materials

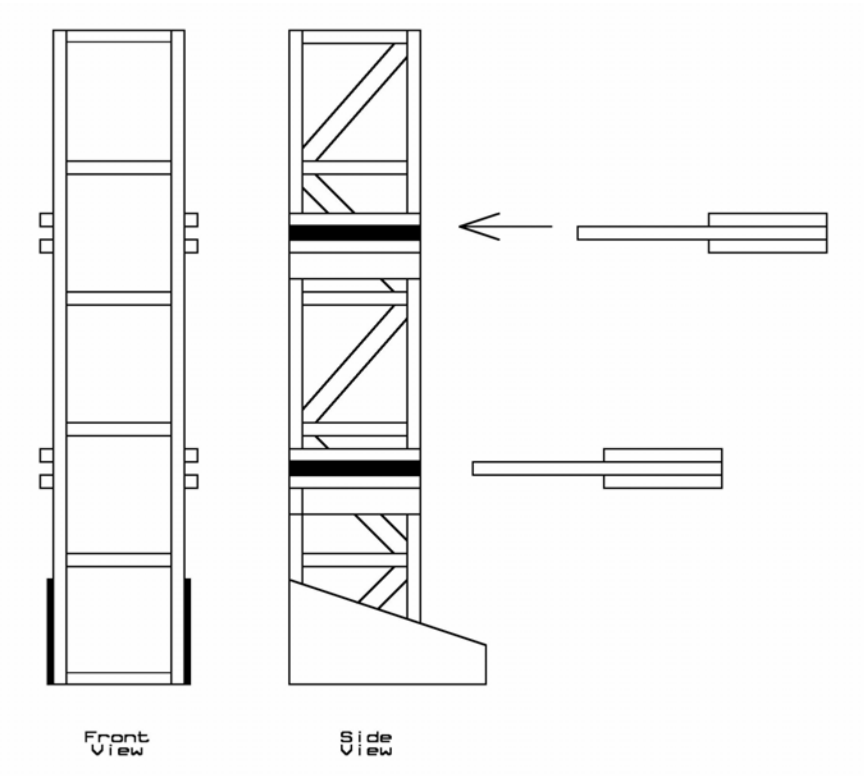
- ¾” square pine trim
- 1/8” plywood door skin
- ¾” thick Styrofoam
- At least twelve feet of one-inch wide Velcro tape (non-sticky back variety)
- Assorted fasteners like screws and finishing nails
- Wood glue
- Paint (red and white is traditional)

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

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

2.4.2. Procedure

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



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

Tower

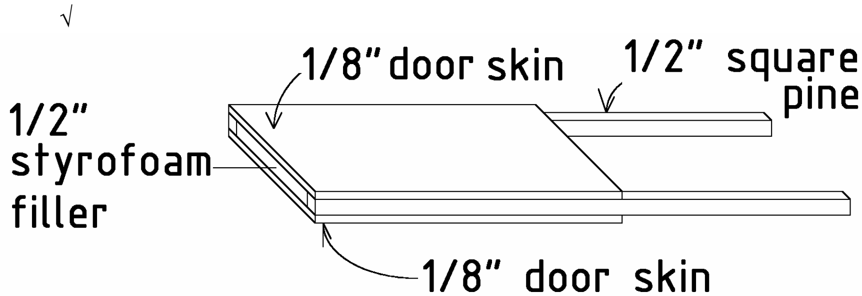
The TVNSP launch tower is six feet tall and made up of six, one-foot tall repeating units. Cross braces are glued diagonally between levels of the tower. Occasional sheets of 1/8” plywood door skin covers sides to strengthen the tower. The TVNSP launch tower is not as wide as an airframe, so the left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

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

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

Platforms

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



X-Ray View of Launch Tower Platform

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

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

- √ Cut eight pieces of pine trim to a length equal to the measured depth of the launch tower
- √ Temporarily clamp the platforms to the launch tower at the desired heights

  Note: You may have to trim the inside edges of the platform rail to get them to slide on and off the launch tower

  Note: Place an airframe on the platforms when doing this to ensure the spacing of the platforms is sufficient
- √ Use a carpenter's level to make sure the platforms are level
- √ Glue and clamp one piece of pine to the launch tower beneath each platform rail (remove the platforms before they have a chance to glue to the tower)

  Note: At this point you are attaching a two-piece railing to the tower for the platform rails to ride in
- √ After the glue dries, slide the platforms back onto the tower
- √ Glue and clamp a second piece of pine above each platform rail (again remove the platforms before they have a chance to glue to the launch tower)
- √ After the glue dries, test fit the platforms
- √ Add narrow pieces of plywood door skin above and below the tower rails to strengthen them
- √ Strengthen all weak joints in the tower
- √ Paint the tower

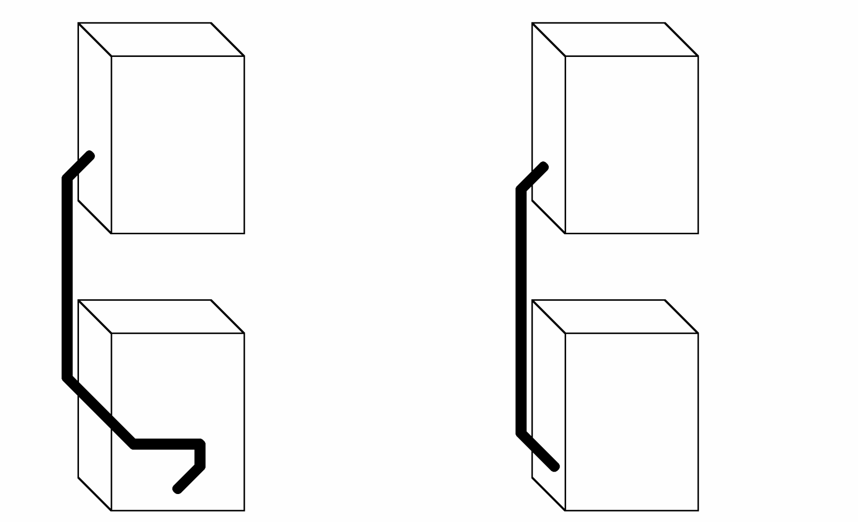
  Note: Radio towers have seven bands of color, with red as the top and bottom color and bands of white between

2.4.3. Using The Launch Tower

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

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

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



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

- Attach parachute to the top module

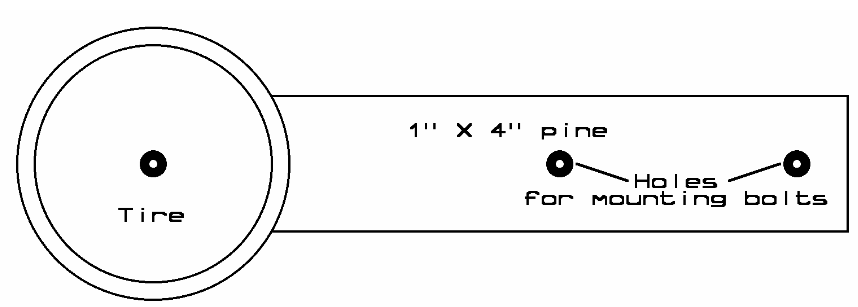
  Note: Have a second crewmember verify the split key rings are still properly attached to the Dacron loops of the abrasion jacket. Often, when someone is attaching a swivel to a split ring, they begin disconnecting the split ring from the Dacron loops of the abrasions jacket.

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

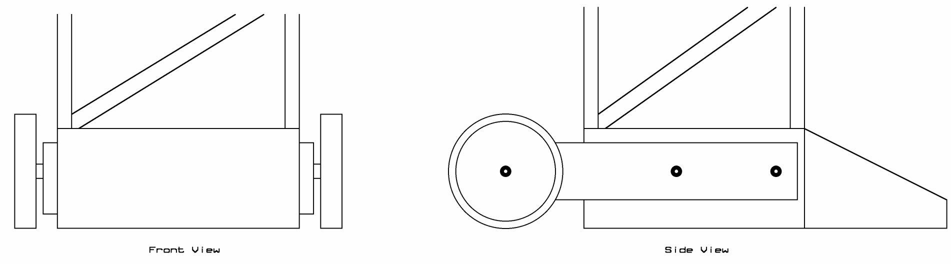
2.4.4. Possible Modification To Launch Tower

Tower Wheels

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

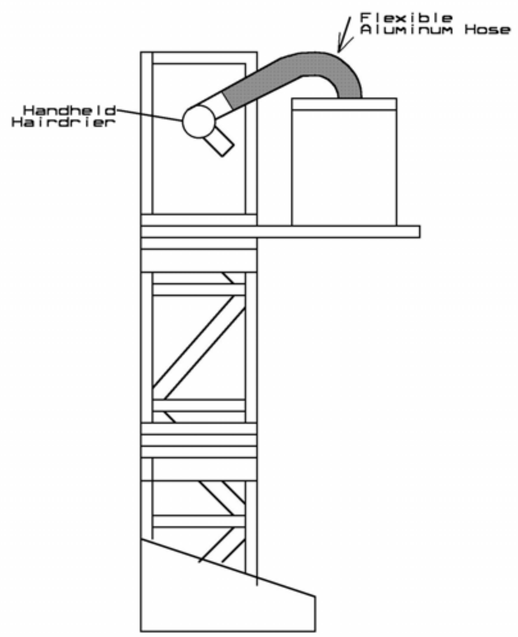


Wheel Diagram – *Make two. Use wing nuts on the wheels so they are easy to remove.*



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

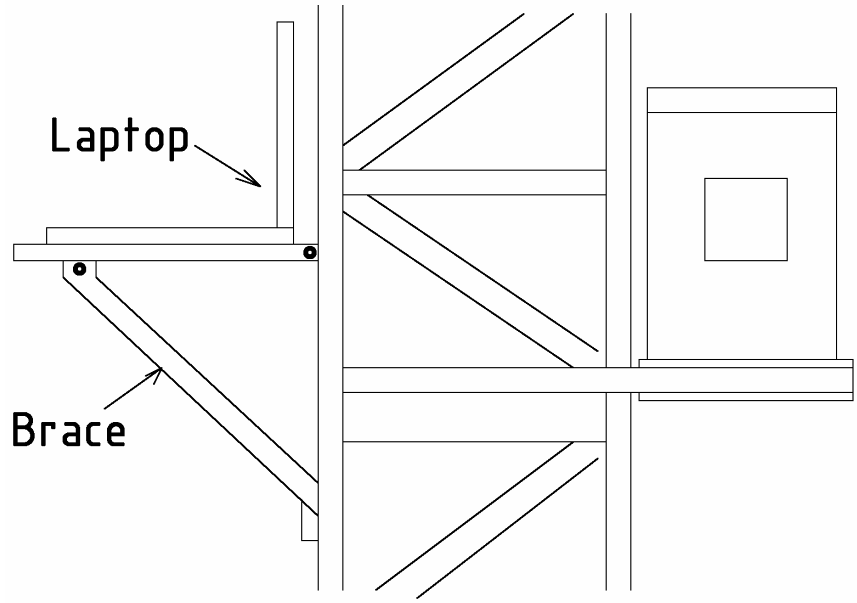
Module Heaters



Launch Tower Module Heater

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

Laptop Table On Tower



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

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

2.5. Warning Signs (optional)

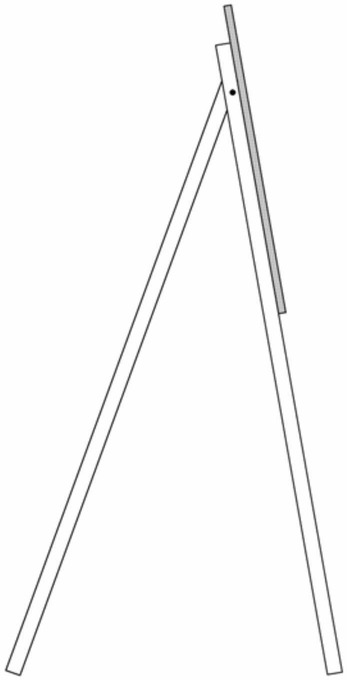
While filling the balloon, people may not be cognizant of the hazards they pose to the balloon. Placing warning signs near the balloon can help. The signs are designed to warn spectators and crews that the balloon envelope is fragile and that no sharp objects are allowed near it. Bursting a filled balloon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

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

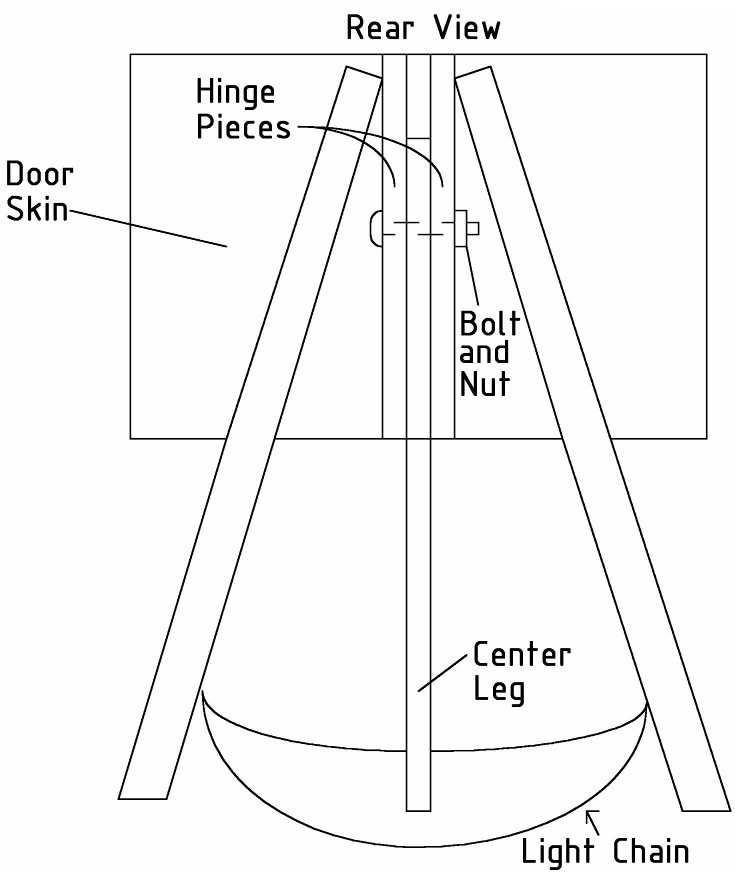
2.5.1. Materials

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

2.5.2. Procedure



Warning Easel – *Side View*



Warning Easel – *Rear View*

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

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

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

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

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

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

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

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

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

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

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

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

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

Determining Lapse Rates From Environmental Sounders

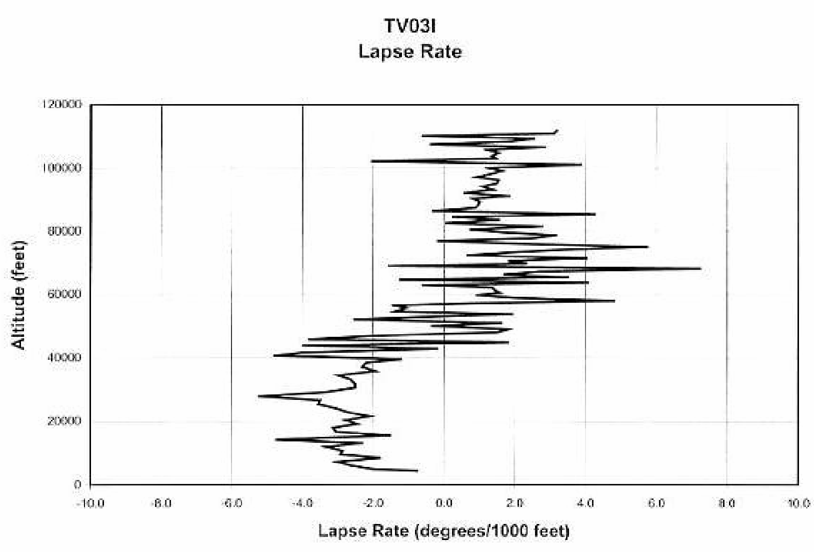
After processing air temperature and altitude data from a near space flight, create a new column for the lapse rate at each recorded altitude. Take the air temperature at a given altitude and subtract the air temperature in the previous record. Divide the change in air temperate by the change in altitude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

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

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

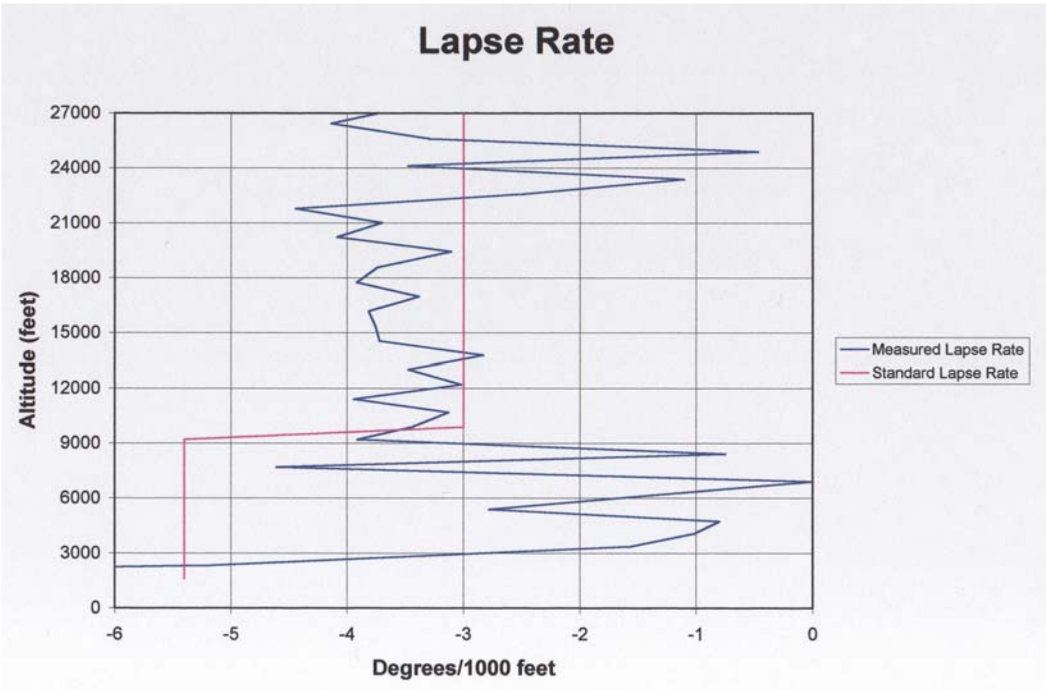
Note: Graphing the lapse rate in the troposphere is more important than in the stratosphere.

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



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

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



Lapse Rate Graph with Stability Line

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

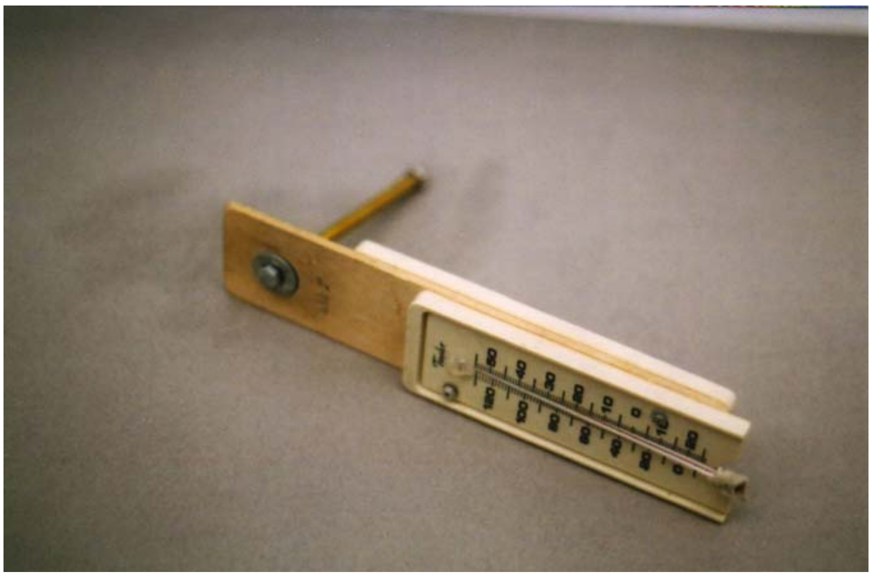
Making a Sling Psychrometer

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

Theory of Operation

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

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



Completed Sling Psychrometer

Materials

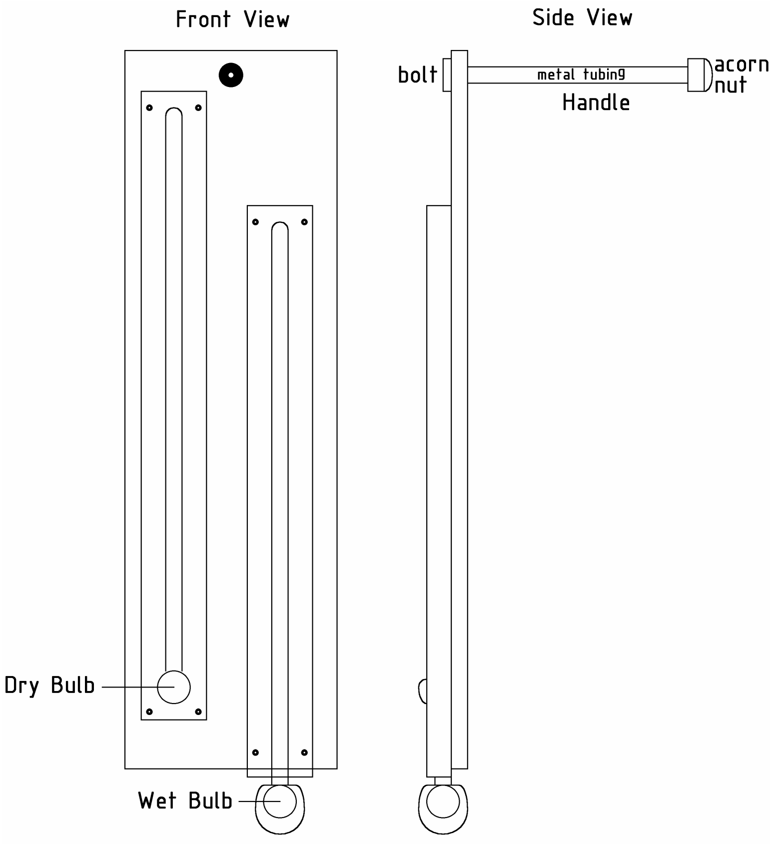
- Two small thermometers[E]

Or

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

Construction

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



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

Handle

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

Thermometers

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

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

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

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

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

Using The Psychrometer

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

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

Dew Point Table[G]

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

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

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

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

Near Space Humor - Near Space Comix #1

[A] One regulator is the Profill Balloon Regulator (Crammer Decker), model BR 3855 with gauge and hand tightener. If the regulator does not have a hand tightener, then also purchase a crescent or box wrench.
[B] As you no doubt recall from high school chemistry, the Ideal Gas Law is stated in the equation:

`PV=nRT`

Where:

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

[C] Water can remain a liquid below 0 degrees Celsius or above 100 degrees Celsius. But eventually the water does change phases, either with a little more time or with a further change in temperature. The purer the water, the longer it can remain a liquid.
[D] The name originates from psychro (cold), not psych (mind)
[E] These are available at school supply stores or science catalogs
[F] When purchasing thermometers, select two that read the same temperature
[G] Table from http://www.jsu.edu/depart/geography/mhill/phygeogone/unit2/dewtablf.html, Dr. M.H. Hill, Jacksonville State University

CHAPTER TEN

Launch Procedures

"It takes a stranger person to get up at five in the morning to go to Manhattan to chase a balloon across the state"
- Keith Dickinson (KC0USA)

Chapter Objectives

1.0 The Flight Readiness Review (FRR)

A discussion about readiness to fly a mission is called the Flight Readiness Review. The FRR is held a day or two before a launch (The TVNSP FRR includes a dinner get together of those involved with the mission) and can be broken into the following parts, a mission brief, final assembly, equipment preparation, and checklist completion. Feel free to adapt the FRR to your needs.

1.1. The Mission Brief

The goal of the mission brief is to familiarize the crew with what is to occur with the mission. Telling those assembled the goals of the mission, familiarizing them with the near spacecraft, and sharing the mission plan gives them the mission plan.

1.1.1. Mission Goals

Share the goals of the flight by explaining the experiments onboard the near spacecraft. Even if they are not involved with the construction of the capsules, or responsible for an experiment, it still gives everyone a greater chance to feel involved. It can be exciting for new participates to see the whole picture of a near space mission.

1.1.2. Near Spacecraft Familiarization

This is the time to formally introduce the near spacecraft. Let everyone know if there are any longer than usual projections on the modules, an umbilical to connect, special orientation of the modules, or other features they need to be aware of during the morning of launch.

1.1.3. Mission Plan

A mission plan should brief on at least these topics.

- Predicted Flight Path
- Launch Site And Time
- Planned Driving Course
- Communication Frequencies
- Recovery Procedures

Predicted Flight Path

Begin running predictions for the mission from several days to a week before the launch (predictions more than a week in advance are not very meaningful). Bring the latest winds aloft prediction to the FRR and run it through Balloon Track during the FRR. Be sure new crews see this process, as they may need to run the Balloon Track program, themselves someday. Pay attention to cases where the near spacecraft is predicted to descend over, or land in, undesirable locations. See Chapter Twelve, Section Three for information on making flight predictions. After making the prediction, copy the predicted flight path file to the PC's of crews wanting to see the predicted flight path (see Chapter 12, Section 3.2 for directions on making this file). One more function of flight prediction during the FRR is to determine the balloon's desired free lift or PPL based on the flight predictions (be sure to write down the final desired PPL).

Launch Site And Time

Depending on the predicted flight path, you may need to select a new launch site. Make sure everyone knows if there is a new launch site and that they have the directions to get there. TVNSP tends to have everyone met at an easy to find location and them caravan to the launch site. Before the FRR, check the time of sunrise for launch day. Arrange to meet at the launch site at the appropriate time (usually an hour before sunrise for most launches). Crews need to determine how long it will take them to get there.

Planned Driving Course

Once the launch location and recovery zone are identified, chase crews need to plan their driving course. Ideally chase crews take fast roads to get ahead of the balloon. With any luck, slow roads are never traveled, or if they are, only at the very end of the chase. Keep repeater coverage in mind when planning the driving course.

Communication Frequencies

Now that a driving course has been planned, determine chase frequencies. Use repeaters where possible. You'll be surprised at the people who listen in or even talk with the chase crews during a mission. Be sure there's no problem with the chase crew using a repeater before the mission (usually there isn't). Have chase crews program their HTs and mobile radios for any new repeaters. Also decide on a simplex frequency to use when out of repeater range and stick with it!

Recovery Procedures

Depending on the payload flown on the mission, the shut down procedures for the near spacecraft may change. The presence of a life science experiment on the manifest is an example where new shut down procedures may be required. Since it's not known who will arrive at the recovery site first, make sure everyone knows the updated shut down procedure. For most flights, chase crews are to leave the near spacecraft where it recovered, unless it is a danger or in danger. We like to give everyone a chance to see the near spacecraft where it recovers. See the recovered near spacecraft gives them more encouragement to participate in future missions. There's not a lot more discouraging than to drive three hours after a flight only to have everyone tell you to meet them at lunch because they have already removed the near spacecraft. Be sure to get an on-site photograph of the entire chase team with the recovered near spacecraft.

1.2. Final Assembly

Often there are module related tasks that cannot be completed until the night before launch. The following list is an example of the final tasks best completed at a FRR.

- Module Completion
- Final Weight
- Final Function Test
- Comm Check
- Initial Styro-Fill (if possible)

1.2.1. Module Completion

Most of the modules are completed and tested well before launch. However some items like Thermochrons and some cutdown devices should be programmed the night before launch, rather that several days in advance (once the expected time of launch has been determined). Loading life science experiments is another example of items that must wait until late in the launch cycle. As more people get involved with constructing the modules of a near spacecraft, the more often someone won't be able to have their piece of the flight ready early in the build cycle. Be sure to install any Remove Before Flight tags on items like cameras and beacons. The bright red tags help prevent near spacecraft from being launched with a silent audio locator beacon or a closed camera lens (KNSP and TVNSP has done both).

1.2.2. Final Weight

A final weighing of the capsules, with their batteries included, needs to be made and recorded (don't depend on memory). Now's the last time you will have to make changes to the launch manifest if one of the capsules turns out to be overweight (making a manifest change the morning of launch can be disastrous, so do it no later than the night before). Be sure things like mementos and QSL cards are onboard the modules before making the final weight. Along with recording the total weight of the modules, add the weight of the parachute, an FTU (if used), and any other recovery aids, like beacons. Finally add the desired PPL of the balloon and write the total where it won't be lost overnight. Balloon Dogs need this information the morning of the launch.

1.2.3. Final Function Test

Now that the capsule is in its final assembled state, it's a good idea to download a test program into the flight computer and exercise all capsule functions (I don't always do this, but should). Run the test program for everyone present to see, rather than running the test program the morning of launch when the Closeout Crew can do nothing about malfunctions. Having several people present to observe the test gives the mission that many more opportunities to identify problems before it's too late. Connect the link lines to the modules and check that the spacing between modules is not greater than the spacing permitted by the umbilical between the modules.

1.2.4. Comm Check

The Chase Vehicles planning to go on chase should be present at the FRR to run the Comm Check on the near spacecraft. During the Comm Check, chase crews verify that their trackers see the near spacecraft on APRS. Verification involves two things, first is that the location of the capsules is valid (the GPS has a proper lock) and second that Chase Vehicles can display good data from the capsules.

1.2.5. Initial Styro-Fill

Finally, if possible, begin filling the modules with Styrofoam peanuts. An airframe designed with a battery compartment often can have its lower compartment filled with Styrofoam peanuts at the FRR.

1.3. Equipment Preparation

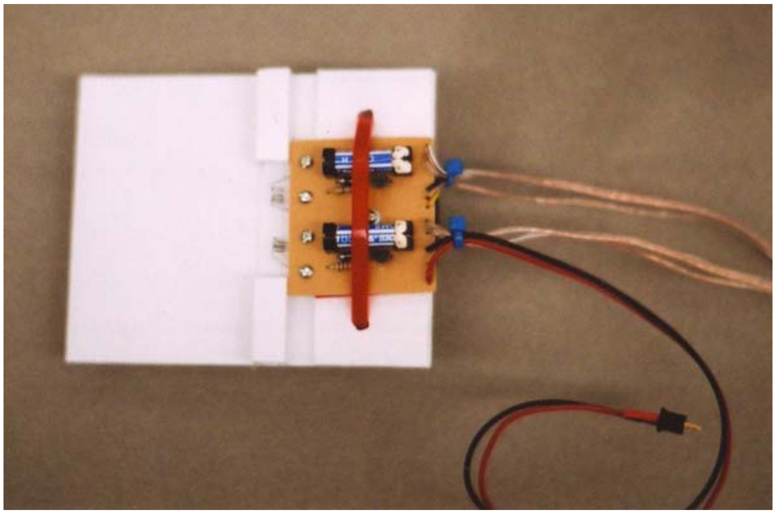
The FRR is the time to check over the launch equipment. For instance, make sure everything is packed and none of it is missing. Be sure someone has the balloon (or balloons) and someone is planning to haul the helium tanks (if they are not already at the site). Finally items like the parachute can be untangled and packed and any flight termination units (FTU) can be prepared.

Parachute

No matter how careful chase crews are with the parachute at the recovery site, the shroud lines will be tangled before the parachute makes it home. The parachute should be stored indoors with its shroud lines untangled. But it probably won't be, since there are a lot of things to do after the flight. Appoint two or three people to untangle the shroud lines during the FRR. Tie several twister seals on the shroud lines once they are untangled. Then carefully repack the parachute into its carrying case.

Flight Termination Unit

Cut a few feet of nylon load line and melt the ends of the cord to keep the ends from fraying. Pass one end of the cord through the swivel at the parachute apex. Double over that end of the cord and tie an overhand knot. Further secure the knot by applying a wrap of duct tape over the knot. Do not wrap the tape over the bearing in the swivel; only apply tape to the metal ring of the swivel, as the bearing must be free to spin. Check the shape and form of the nichrome coil in the FTU PCB. The coil should be a regular cylinder and large enough that it does not bind the nylon cord passing through it. Also check for continuity between the coil pads of the FTU PCB (this shows there is no electrical break in the nichrome coil). Thread the free end of the nylon cord through the nichrome loop. If it is less than 24 hours from launch, then set the termination time on the stopwatch. Double check that the set time takes into account AM and PM. Close up the FTU inside of its box and verify the nylon cord is free to move through the nichrome coil and box. Double over the free end of the nylon loop and tie an overhand knot in that end. Secure the knot with a second strip of duct tape.



Flight Termination Unit

1.4. Checklist Completion

Complete And Verify Checklist
Every mission needs a checklist. The checklist for the near spacecraft begins during the development of the modules for the mission. The final draft of the checklist usually isn't developed until the FRR. Review the entire draft of the checklist during the FRR. Consider even practicing the checklist on the assembled modules during the FRR so errors can be detected and corrected.

A good checklist includes flight configuration (where every experiment is mounted, both mechanically and electrically) and a step-by-step procedure of how to power the capsules and test them. A sample checklist is included in this section

1.4.1. Sample Checklist

John Stone (K7JPS) developed the following checklist for TVNSP Flight TV02F

Treasure Valley Near Space Program
Pre-Flight Checklist

Latitude
Longitude
Elevation
Dry Bulb
Wet Bulb
Launch Time

Record Launch Site conditions above

Relay Launch Site information to Mission Control when communications is available

Connect Link Lines between modules

Verify Dacron straps are securely inside the split rings

Connect Umbilical between modules
    Shutter release – green wire to green wire

Servo cable – black wire to black wire

Tape Umbilical connection

Connect and measure batteries in Module One
Main Power (four lithium "AA" batteries) - volts
TNC Power (alkaline nine-volt battery) - volts
Servo Power (four alkaline "AA" batteries) - volts
Radio Power (four lithium "AA" batteries) - volts
Audio Beacon Power (alkaline nine-volt battery) - volts

Connect and measure batteries in Module Two
Camera Power (lithium 2CR5 battery) - volts

Styro-Fill Module One

Secure Module One hatch

Check placement of temperature sensor cables in MLI experiment

Styro-Fill Module Two

Secure Module Two hatch

Open camera lens cover

Photographically document capsules (from two angles)

Complete Balloon Fill

Power up Module One
Main Power switch
TNC Power switch
Servo Power switch
Radio Power switch

Power up Module Two
Main Power switch

Verify valid APRS data from Module One

Verify valid APRS data from Module Two

Begin raising balloon

Open module straps on Launch Stand and remove modules

Power up Audio Beacon

Raise balloon until modules are suspended

Release first lanyard and pull free of stack

Release second lanyard

Record launch time above

Now inform everyone, through email and over amateur radio, about the results of the FRR. You should inform people of the following.

- The expected time and place of launch
- Directions for tracking the flight
- Note: This is usually over APRS or on http://maps.findu.com
- The repeaters and frequencies the chase team expects to use
- When and where the near spacecraft is predicted to recover

Now get some sleep, you have a busy day ahead, one filled with excitement and adventure.

2.0 The Near Spaceport

As it is with real estate, so it is with amateur near space exploration. The three most important aspects of an ideal near spaceport are location, location, and location (and in that order). A great near spaceport is a large building with tall doors, surrounded with a large field containing few trees or power lines, has low traffic and distant neighbors, and is a secure at night and early in the morning. Barring that, you'll find ways to make due with less like TVNSP.

2.1.1. Balloon Filling Building

If at all possible, fill the balloon indoor where breezes cannot buffet the balloon when it's near the ground. It's difficult enough to accurately determine a balloon's lift when the winds are knocking it around without having to worry about the balloon being blown into a sharp object. Launch crews can successfully fill balloons outdoors if it is necessary, but doing so adds additional risk. Besides, filling the balloon indoors usually means the temperatures are more comfortable. It's helpful if the selected building has power and lights so you can work safely around the balloon as you fill it at oh-dark thirty. As long as the balloon is filled with helium, you needn't worry about the building's electrical systems. However if you decide to fill the balloon with hydrogen (which I strongly discourage), then the building's electrical system must be sealed and explosion-proof. The building also has to be able to safely vent any escaped hydrogen (that means it must vent quickly).

Filling a balloon inside a building requires the building to have doors tall and wide enough to safely pass a filled balloon through out without rupturing the balloon envelope. Sometime when you meet me, ask about trying to get an inflated balloon through a door that was too small. Ideally the building needs at least ten-foot high doors with twelve-foot high doors being better. The doors can be narrower than they are tall like the balloon. Note that doors narrower than eight feet will not work. Ceilings inside the building need to be at least twelve feet high to safely fill the balloon since an eight-foot tall balloon will be filled with its nozzle a couple feet above the ground. The distance between the walls and the sides of the balloon must be several feet as crews have move around the balloon.

So what kinds of buildings make good balloon-filling buildings? Large industrial buildings or truck repair garages are good buildings. They tend to have large volumes, high ceilings, and large doors for moving equipment in and out. Buildings used to park buses or road-clearing equipment are other options.

An ideal building

2.1.2. Launch Field

Besides the size of the building and its doors, there are several concerns about the region surrounding the building. These concerns also apply when filling balloons out of doors. After the balloon is filled, it must be taken out of the building for launch. The further the balloon is carried away from the building, the greater the risk of damaging the balloon. To reduce the risk, the building needs to have enough open launch field surrounding it that the stack can be launched as soon as it's outside the building. The launch field must be clear of nearby obstacles like other buildings, trees, and fences. Be assured that if there's more wind at launch than planned, those winds will carry the stack into the nearest tree.

In addition to our desire to launch a near spacecraft without damaging it, the FAA requires the balloon to be launched in a way that doesn't create a hazard to uninvolved people and their property. So the launch field must be sufficiently large that the balloon will be high enough for the parachute to safely land the near spacecraft should the balloon burst over private property. Fortunately the balloon goes pretty much straight up after release and with very little horizontal drifting if launched in light winds. If the winds are not light, you shouldn't be launching a big balloon anyways. High surface winds burst balloons, rip balloons from stacks, or drag capsules into trees and fences. Select a launch field located away from major traffic. The sight of a large weather balloon being launched may distract drivers passing by.

2.1.3. Security

Finally there's the issue of security. If possible, bring the launch equipment and near spacecraft to the launch site the night before launch for final assembly, closeout and testing. There can be enough confusion the morning of launch without also having to closeout the capsules and test the avionics while filling the balloon and assembling the stack (although, many times this is the only option). The cost of launch equipment, the near spacecraft, and the tanks of helium require you to lock the building when crews leave for the night. If security is not available then transport the launch equipment and assembled near spacecraft modules the morning of launch. Be sure to transport the modules without breaking its booms and experiments.

3.0 Balloon Filling Procedures

It's finally the morning of your first launch. Last night's Flight Readiness Review (FRR) tested the avionics, selected the launch site, assigned tasks to launch crews, determined chase roads, and selected the launch time. Everyone has arrived at least an hour before launch to prep and launch the stack. Brought to the launch site is the following,

- The module(s) of the near spacecraft
- The balloon (and a backup)
- Film and batteries
- An assembled FTU (if used)
- The parachute (wrapped in its own bag)
- Bags or boxes of launch equipment
- Two or three tanks of helium
- Two or more chase vehicles with APRS

After looking everything over it's decided all is go for this mornings launch. So what's next?

This section applies to filling latex weather balloons and not polyethylene balloons. The procedure outlined here safely fills the balloon with helium.

3.1. The Latex Weather Balloon

Kaymont and Kaysam mail their latex weather balloon via UPS or Fed Ex packed inside of a cardboard box. There's minimal packing material around the balloon, so be careful when you open the box. It's difficult to rip the tape off the box, so when using a knife to open the box use a short bladed knife like an Exacto knife. Cut just the tape and do not stick the blade into the box, as you don't want to cut or nick the balloon trying to open the box. The balloon is stored inside a plastic bag that is tied shut with a rubber band. The balloon is vacuumed out before being rolled into a bundle and packaged. By removing the air from inside the balloon the balloon can be packed into a smaller volume. A balloon can be stored for over a year before being used. When storing the balloon long term, keep it in its box and out of the Sun. However it's best if you don't order the balloon until you need it. When exposed to air the latex of the balloon begins to age more rapidly. So do not open the bag until the morning of the launch. If it is later decided not to launch the balloon, roll the balloon up with gloved hands and put it back into the bag. You'll find the balloon is covered in a talcum powder. While filling the balloon the talcum powder remains on the balloon, but, if the helium is let out of the balloon, then a cloud of talcum will accompany the helium. So be careful not to inhale the helium venting from a balloon.

3.2. Ballooning Filling 101 For Balloon Dogs

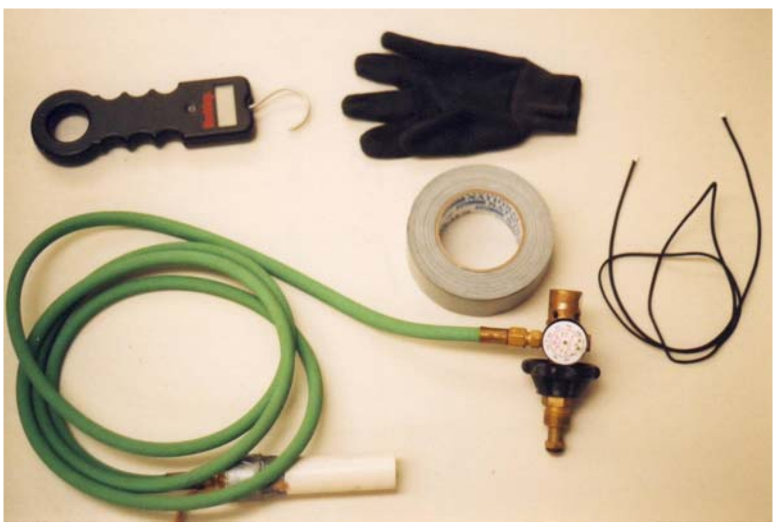
Read the procedure outlined in this section. Then practice the procedure before you launch your first balloon. However, feel free to modify these procedures if needed for your near space program. Whatever changes you decide to make, document and practice them before launching your first near spacecraft. TVNSP makes it a policy to review launch procedures every year at the beginning of the year's near space campaign.

Remember that a filled balloon will be worth over $100. So it pays to be a little paranoid around them. Bursting a balloon on the ground can end a near space mission real fast.

3.2.1. Laying Out The Equipment

√ Lay out the ground cloth (sewn bed sheets) and a tarp beneath the bed sheets if needed
√ Lay the helium tanks near one end of the bed sheet
√ Roll the tanks against each other with their valves on the same side
Note: Never leave the tanks attended standing up or with their caps removed
√ Lay out kneepads (if needed) near the tank valves
Note: Most balloon filling work takes place near the tank valves
√ Place warning signs near the bed sheets if you feel a need to use them
√ Place the balloon and equipment bags (boxes) near the tank valves
√ On the bed sheet, near the helium tank, leave the electronic scale and duct tape.
√ Keep all other work away from the balloon filling area
√ Have the Balloon Dogs put on soft cotton gloves and remove exposed jewelry and hats that may damage the balloon

Note: When working around the balloon, Balloon Dogs aren't aware of how close they are to the balloon until they bump their hats into the balloon. So have Balloon Dogs remove their hats if they have brims.
Note: Gloves protect the balloon from rough skin and prevent skin oil from getting on the balloon, which may weaken the skin of the balloon.



***Balloon Filling Equipment** – note the gloves*

3.2.2. The Balloon Filling Process

"L" size helium tanks typically have over 2000 PSI of gas at the start of filling which is enough helium for the balloon to lift over 12 pounds of payload. Watch the regulator's pressure gauge during the helium dump to get an idea of how much helium remains.

√ Unscrew the tank cap, exposing the tank's valve
√ Screw the regulator into the helium tank hand tight
√ Note: You'll probably have to change tanks during the filling, so keep the second tank next to the first
√ Cut about three feet of sisal cord (the Balloon Loop)
Note: Keep the scissors or knife used to cut the cord away from the balloon
√ Open the balloon bag and unroll the balloon

Note: Toss the trash into the empty box as you go along and keep the clutter to a minimum

√ Insert the PVC filler pipe into the balloon nozzle
√ Give the nozzle and pipe a wrap or two of duct tape to keep the balloon from sliding off the filler during the helium dump

Taped Nozzle

√ Note: The nozzle is the same material as the balloon skin, only thicker, so it's more durable than the balloon itself
√ Note: Double over the last one inch end of the tape to create a ½ inch tab for removing the tape after the balloon is filled (this really eases the job of tying off the balloon)
√ Verify the balloon is fully laid out, without twists or being doubled over
√ Open the tank part way, letting helium slowly fill the empty balloon
√ Note: The balloon jumps a bit at the start and makes some obscene sounding noises, don't let it startle you
√ Make sure the balloon is not knotted while it inflates
√ Once the balloon begins lifting itself off the ground, open the tank more fully, as you still have some 300 cubic feet of gas to dump
√ Note: It's easy to forget that the balloon is a large sphere when you're working around its base, so watch your head
√ Don't start measuring balloon lift right away as an entire tank is needed for twelve pounds of lift
√ Flip the electronic fish scale upside down and let it zero it self out
√ Note: Use the same scale to weigh the modules as to measure balloon lift
√ Hook the electronic fish scale to the filler's loop

Weighing Lift with Scale

The measurement from the scale bounces around a little bit, so use the middle value of measurements.

3.2.3. Switching Helium Tanks

If you empty a tank before getting enough helium (the most likely case) you'll need to switch tanks without losing the helium already in the balloon. It takes two Balloon Dogs to switch tanks.

- √ Shut off the helium tank
- √ Balloon Dog One grips the nozzle of the balloon and squeezes tightly

***Death Grip on Balloon Nozzle** – by Balloon Dog One. while Balloon Dog Two unscrews the regulator. Author, sans gloves, secures helium tank.*

- √ Balloon Dog Two unscrews the regulator from the tank
- √ Then remove the cap from the second tank
- √ Then screw the regulator into the second tank only hand-tight
- √ Balloon Dog One now release the balloon's nozzle
- √ Balloon Dog Two verifies the nozzle has been released before opening valve
- √ Note: Opening the second tank while the nozzle is still gripped will inflate the nozzle, possibly popping it off the filler
- √ Open up the second tank and continue filling the balloon
- √ Recap the first tank

3.2.4. Notes On Balloon Lift

The helium-filled weather balloon must lift itself, the capsule, and parachute. However, if you stop here, the near space stack is neutrally buoyant and will not rise off the ground. So extra helium must be dumped into the balloon before it is sealed. This lift generated by this extra helium is called the balloon's positive lift or free lift. KNSP filled its balloons with about one pound of positive lift (or one PPL). So KNSP balloons usually lifted one pound more than the total weight of the payload. TVNSP currently fills its balloon to at least two PPL. At 0.5 PPL the ascent rate is only about 300 feet per minute, which make s a very long flight. At one PPL the near space stack ascends at a rate of about 700 feet per minute. Ascent speeds of over 1000 feet per minute are possible with balloons filled to two to three PPL. The greater the PPL, the faster the ascent rate and the less distance the flight covers. A balloon is a high drag structure; therefore there is a limit to how fast it can ascend, which places limited on the usefulness of adding large amounts of PPL in increasing ascent rates.

A rapid ascent rate is most important when the jet stream is positioned overhead. The less time the balloon spends in a wind stream, the less distance it travels and the easier it is for chase crews to keep up with it (invariably, the jet stream never travels in the same direction as fast roads). Tuning the ascent rate with positive lift is important when the flight is predicted to recover in a less than favorable location. In those cases it may be necessary to extend or shorten a flight. One final consideration is the effect of PPL on the maximum altitude reached by a balloon. It should be apparent that if you fill a balloon with more helium (give it a greater PPL), the balloon's initial volume is greater. Expansion during ascent has less available volume to work with before the balloon bursts, reducing the balloon's maximum altitude. So we can conclude that a faster ascent rate also decreases the maximum altitude of the balloon. However, does the increased ascent rate strongly affect maximum altitude?

Let's say it takes 300 cubic feet of helium to make a near spacecraft neutrally buoyant. To give the balloon one PPL requires you add 14.25 cubic feet of helium. To give the balloon two PPL requires an additional 14.25 cubic feet of helium, or 28.5 cubic feet of helium over the neutrally buoyant condition. At one PPL, the stack ascends at about 700 feet per minute and at about 1200 feet per minute if given two PPL. So to give the balloon two PPL, which roughly doubles its ascent rate and halves its travel distance, requires an increase in initial volume of 4.75% over the one PPL balloon. Now the volume of the balloon must double for each additional 18,000 feet increase of altitude. So a 4.75% change in initial volume is not going to decrease the maximum altitude of a balloon significantly. Here's the take home message. Do not hesitate to add additional helium if you really need to bring the near spacecraft down sooner as you won't be changing the maximum altitude of the balloon significantly. In fact, latex balloons are not consistent from balloon to balloon. One time you may get a balloon with a slightly thinner spot that ruptures sooner and the next time you may be more uniform balloon that ruptures later. The variation from balloon to balloon has a larger effect on the balloon's burst altitude than the amount of helium you dump into the balloon to change the ascent rate by 500 feet per minute. However, the travel distance of a balloon is strongly influenced by the PPL of the balloon. A two PPL flight will travel only about half as far as a one PPL flight.

One additional complication occurs when filling the balloon outdoors. Even the slightest breeze throws off the scale measurements of balloon lift. To guard against an underfill in these conditions, TVNSP (which fills their balloons outdoors) shoots for four or five PPL when they fill balloons for their large missions.

For most flights, where the near spacecraft weight is near the maximum weight (twelve pounds), two PPL is fine (but there's nothing wrong with more PPL). However, if you have a very lightweight near spacecraft, say around three pounds, and a very large balloon then you should have more PPL. Very large balloons carrying very lightweight near spacecraft risk becoming neutrally buoyant. Even if you are using a flight termination device, I don't recommend risking a neutrally buoyant flight. So I recommend going with at least four or five PPL on a very light near spacecraft.

The following goes into calculating the amount of lift needed by the balloon.

- The total weight of each module making up the near spacecraft
- The weight of the parachute
- The weight of any FTU or other recovery system beacon
- The free lift or PPL of the balloon (at least two pounds)

The closeout crew determines the total weight of all modules in the near spacecraft at the FRR. The weight of the parachute was determined when it is first constructed and is documented on the shroud. Like the parachute, weights of FTUs or other recovery aid was determined when the unit is first constructed and is documented on the unit. The desired free lift of the balloon is determined during the flight prediction at the FRR (See Chapter Twelve for instructions about making flight predictions). The final desired lift of the balloon must be written down where the Balloon Dogs can see it.

Did you notice that we're not concerned with the weight of the balloon when calculating the desired lift of the balloon? When the Balloon Dogs measure the lift of the balloon, the helium inside the balloon tares the weight of the balloon.

Begin checking the balloon's lift more frequently when it's close to the desired lift. Make measurements with the helium flow shut off to let the scale-reading settle down. Along with measuring the balloon's lift, you're also weighing the weight of the filler nozzle and hose, so have as little hose as possible suspended beneath the balloon. When the balloon has the desired lift, prepare to tie it off. Note: If there's more helium than desired inside the balloon, don't attempt to bleed it out. It's less trouble to launch a balloon with extra helium than to try to get the amount of helium exactly right. Besides, the more you fiddle around with the balloon, the greater the risk of damaging it.

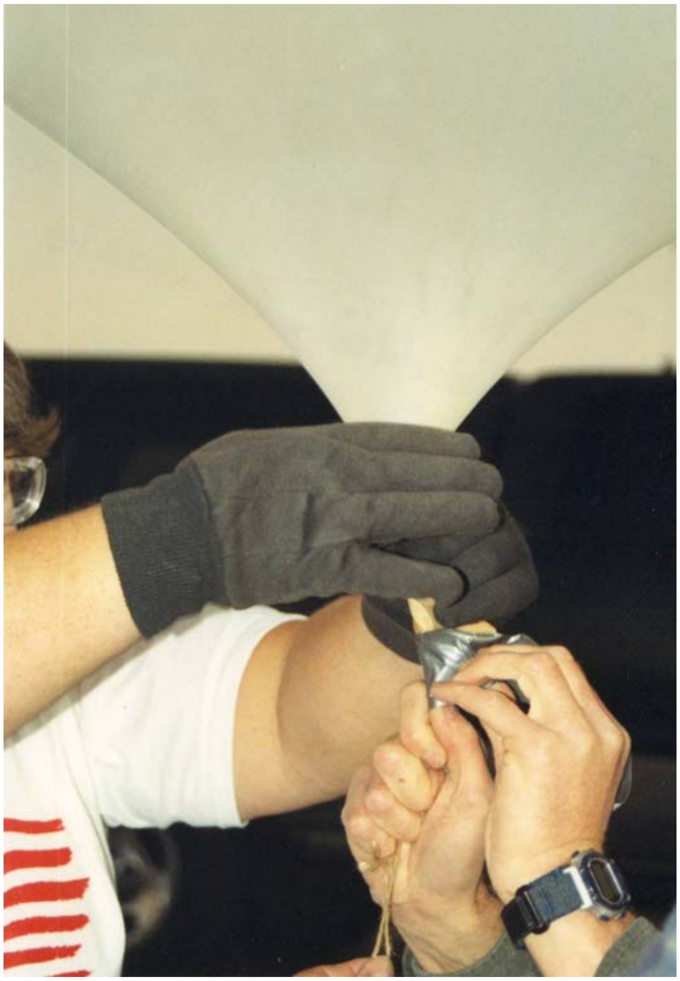
3.2.5. Balloon Tie-Off

Once the balloon is filled to the required lift, follow these procedures.

- √ Balloon Dog One firmly grasps the balloon nozzle (neck) above the filler pipe
- √ Note: Grab tight, you don't want helium escaping
- √ Balloon Dog Two carefully removes the duct tape sealing the balloon nozzle to the filler pipe
- √ Then slides the balloon filler out of the nozzle and get it out of the way
- √ Then twists the balloon nozzle below Balloon Dog One's grip

The NSTAR Alternative Method

- √ Balloon Dog One rotates the balloon above the nozzle with a gloved hand
- √ Balloon Dog Two carefully removes the duct tape sealing the balloon nozzle to the filler pipe
- √ Then slides the balloon filler out of the nozzle and get it out of the way

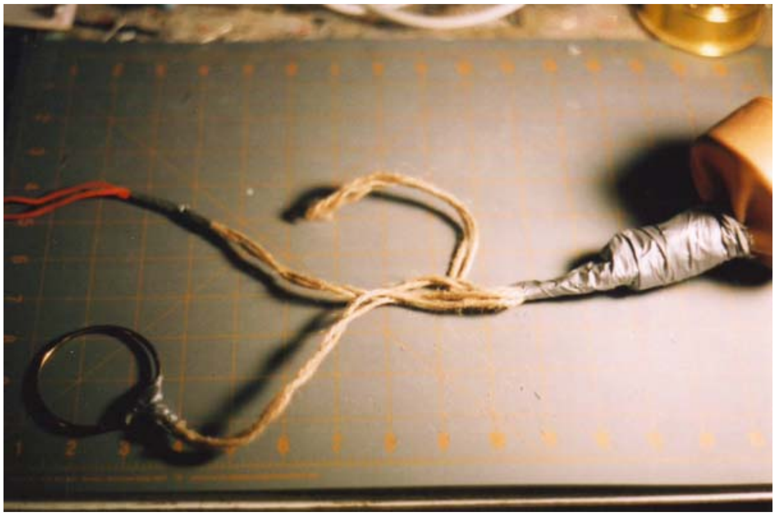


Balloon Tie-Off

- √ Double over the sisal cord and tie it around the twisted nozzle with an overhand knot
- √ Note: Leave a loop of cord hanging down from the knot to form the Balloon Loop
- √ Fold the twisted nozzle in half, trapping the loop's knot and free end of the cord inside
- √ Wrap the nozzle up in gray tape

Taped nozzle and loop

- √ Note: Seal the nozzle and knotted sisal completely; none of it should be exposed from beneath the tape
- √ Note: The loop end of the sisal is left sticking out of the bottom of the tape
- √ Note: Remember you only have a few PPL, so don't use one pound of duct tape to seal the nozzle and loop
- √ Cut another piece of sisal, three feet long (the lanyard loop)
- √ Fold it over and attach the lanyard ring with a Lark’s Head knot



Ring on Loop with Lark's Head Knot

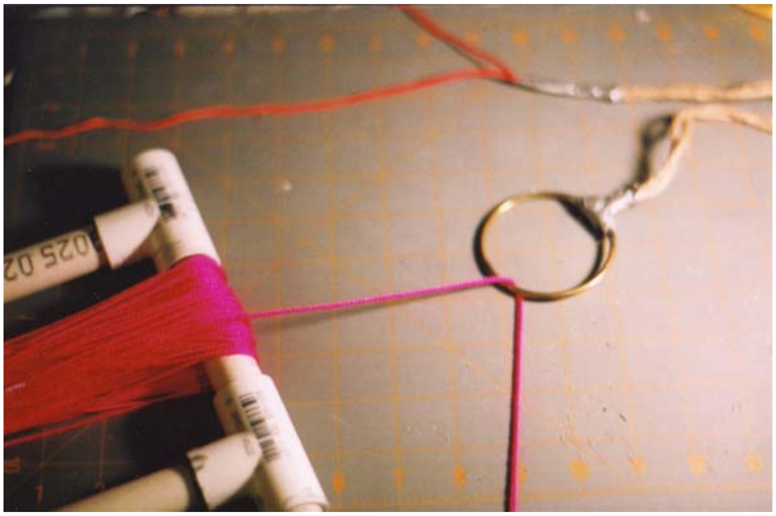
√ Rotate the joint in the Lanyard Ring so it is located under the Lark's Head knot
√ Apply a strip of duct tape around the Lark's Head knot and the joint in the ring

Note: The Lanyard Ring is made heavy wire bent into a ring and the ends butted together. The joint may or may not be welded together. This leaves a rough spot to snag the lanyards. To protect the lanyards, the joint is rotated beneath the knot and wrapped in a little duct tape. The Lanyards are not to pass over the joint or the tape.

√ Tie the lanyard loop to the balloon loop, leaving the lanyard loop hanging about one foot below the bottom of the balloon loop

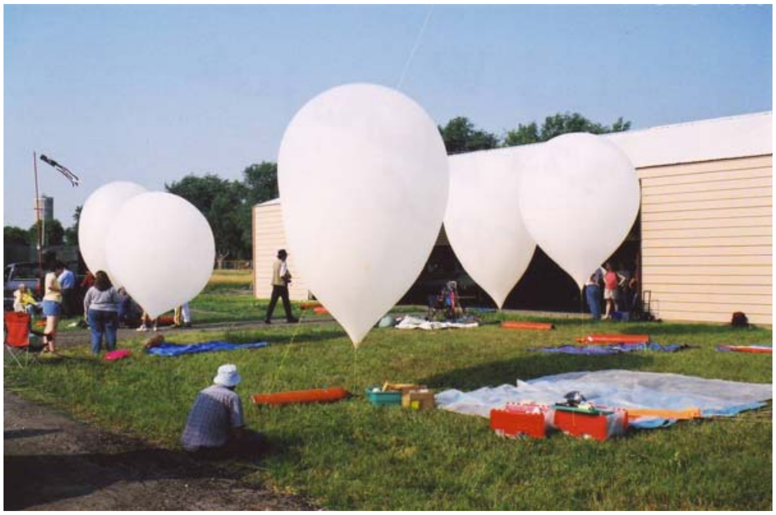
Tied Lanyard Loop

√ Wrap a layer of duct tape around the knot of the lanyard loop (wrap every knot in tape)
√ Tie the load line from the parachute to the Balloon Loop
√ Note: The Load Line is tied next to the Lanyard Loop with a small gap between them.
√ Unwind a few feet of cord from the lanyard winders
√ Pass the lanyards through same side of lanyard ring as explained in Chapter Nine, Section 2.3.4.



Lanyards passing through lanyard ring

√ Assign three individuals to handle the lanyards
√ Keep the lanyards close to the balloon and keep them from unwinding
√ Slip the loop of cord over the end of a helium tank valve and let the 150-pound helium tank hold down the balloon as Balloon Dog One probably has a fatigued arm by now
√ Take a few moments and admire your work as you're half way to launch



Admiring the work

4.0 Near Spacecraft Closeout

Typical activities for the Closeout Crews are as follows

- Set up the Launch Stand
- Strap Modules To Launch Stand
- Connect Flight Batteries
- Assemble Boom Extensions And Antennas
- Connect Link Lines And Umbilical Between Modules
- Power Up Near Spacecraft
- Verify Valid GPS Fix
- Measure And Document Battery Voltages
- Complete Final Styro-Fill

If the morning's mission is just to launch an APRS tracker, then the Closeout Crews have a simpler list of activities to complete. Avoid at all costs, last minute changes to the near spacecraft unless the near spacecraft has failed due some broken item.

Set Up Launch Stand

The Launch Stand is very useful, not absolutely essential. If your team uses one, then have the Close Out crew set it up first. Make sure it's reasonably level then place a sand bag or bag of traction sand at the base to stabilize it.

Strap Modules To Launch Stand

Place each module on its tower platform and confirm the modules are aligned with each other properly. Usually this means the umbilical face of each module is aligned with each other. Now strap the modules to the tower. Don't be in such a hurry to skip this step. Closeout Crews move constantly around the Launch Stand and near spacecraft modules and may bump into them. Strapping the modules to the tower helps prevents an accidental knock-over from ending launch preparations.

Connect Flight Batteries

Flight batteries must be stored in a warm location over night. Cold-soaking batteries over night leaves them below their capacity at the time of launch. Don't give the cold of near space a head start on weakening the batteries. Store the warm boxes for each battery in a warm location also.

Assemble Boom Extensions And Antennas

Mount long boom extensions and antennas after the modules are strapped to the Launch Stand. Depending on the distribution of weight, modules may be unstable with their booms, so make sure the modules are strapped in the Launch Stand. Antennas and long booms can snap a passerby. This may be a justification for purchasing blinking LED beacons. Leave them attached to any possible arm catcher until just before lanyard release.

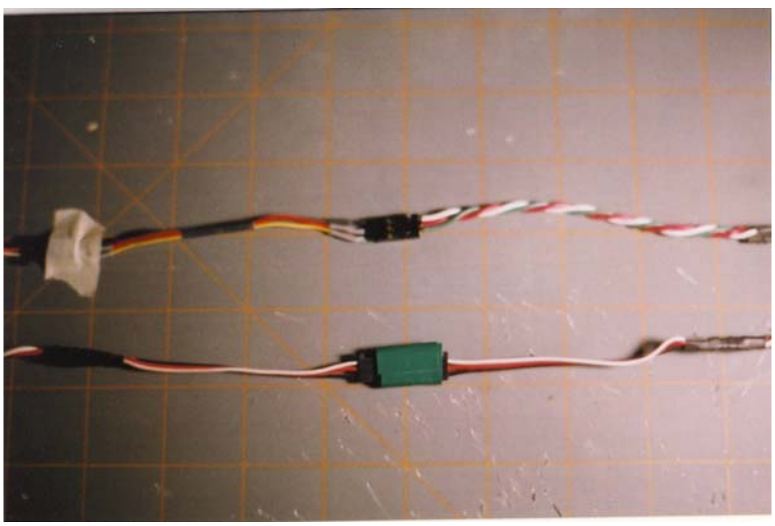
Connect Link Lines And Umbilical Between Modules

Select four identical length link lines for each pair of modules in the near spacecraft and connect corners of two neighboring modules. Verify that the split rings on the corners of the modules are still fully on the Dacron loops of the abrasion jackets. It's very easy when connecting link lines to begin rotating the split ring out of the Dacron loops (a slipped ring). Have a second person go back and verify all the link line connections are good.

Ring Securely Attached

A Slipped Ring

Connect the umbilical between modules if there is one for the mission. Watch the polarity of the connections closely. Sending servo power to an experiment may leave a trail of smoke emanating from the near spacecraft after launch. After making the umbilical connections, cut or rip a one inch long by ¼" wide strip of duct tape and wrap it around the plastic housings of the connected umbilical. The tape prevents the weight of the umbilical from pulling itself a part, especially during descent.



Umbilical - *Untaped example at top, properly taped umbilical on bottom*

Power Up The Near Spacecraft

Flip power switches on the near spacecraft and verify the near spacecraft starts up properly. If a PC or laptop is available at the launch site, the Closeout Crew can download and run a program to test the operation of the near spacecraft. The test program is one last opportunity to verify all connections are made correctly. If you decide to run a test program as part of Closeout, then be sure to reload the mission flight code. Launching a near spacecraft with a test program may look neat, but its murder on getting experiments completed. Double check the program slot the program is being downloaded into (if applicable). Do not shut off power to the near spacecraft until recovery. Write flight code that takes into consideration that the near spacecraft may sit on the ground a while before it is launched.

Verify Valid GPS Fix
If Closeout takes place inside a building, then it will most likely be necessary to carry the Launch Stand outside to perform the GPS verification. More than one person needs to be involved with moving the tower. Check at one of the chase vehicles that the position of the near spacecraft is displayed properly. It may take a couple of minutes for the GPS to determine its correct location, so be patient. Chase vehicles should begin logging data at this point. If there is no valid fix being displayed, check that the HT power is on, that the HT is transmitting, and that the GPS receiver is properly connected.

Measure And Document Battery Voltages
Measure the voltage of each battery only after they have been used for a few minutes (if possible) because a measurement under load is a more accurate reflection of battery condition. Record the battery voltages. After recovery the recorded voltages are used to “scale” the flight data battery voltage readings.

Complete Final Styro-Fill
Completely fill the modules with Styrofoam peanuts after testing and once it’s known the modules won’t need to be opened until after recovery. Use only clean Styrofoam peanuts to fill the battery compartment of each module (and avionics compartment if it isn’t already filled). Using a frame to hold the mesh laundry bag of peanuts open makes the Styro-Fill easier. Clean peanuts from a previous flight can be reused. Avoid using peanuts that got dirty falling by on the ground. Also avoid using biodegradable Styrofoam peanuts. These wheat starch-based peanuts dissolve in water. With them, you could find your airframes filled with a gooey mess.

Filling module with packing peanuts – *Note the peanut bag*

If power is available on-site, you may want to consider warming the module interiors with a handheld hair drier. Warming the modules is important (but not critical if using lithium cells) when the modules must be left outside in the cold air. KNSP’s only attempt to warm a module before launch caused no harm to the airframe of avionics. More tests are needed to determine the effectiveness of pre-warming modules before launch. If you decide to experiment with warming module interiors, then use a low setting to avoid melting the Styrofoam peanuts and airframe or softening the hot glue adhesive.

5.0 Assembling The Near Space Stack

Take a step back and admire the filled balloon and assembled modules. Soon they will be united into a near spacecraft and make a flight to 90,000 feet. Pinch yourself, this is not a dream, it's for real. You really are going to send all this work and effort into near space where it will experience an environment unlike anything you've ever seen before. At this point things begin moving pretty fast.

Starting with the modules on the Launch Stand, the stack is assembled as follows. Feel free to change the order.

- The Parachute and FTU
- The Load Line
- Balloon Carryout
- Verify Telemetry

5.1.1. The Parachute and FTU

It is not necessary to use an FTU on each mission. If the mission does not use the FTU, skip those steps.

- √ Remove the parachute and FTU from its transportation container
- √ Open the FTU and set the timer if it has not been done yet
- √ Verify the timer is set correctly in regards to AM/PM
- √ Install the FTU battery and close the FTU
- √ Remove the twister seals on the shroud lines
- √ Connect the parachute shroud lines to the parachute ring, matching shroud line number with the ring's split ring number
- √ Verify the shroud lines are not twisted

- √ Note: If the shroud lines are twisted, disconnect only one split ring at a time and reconnect the ring before disconnecting the second ring.

- √ Link the parachute ring to the top module.

Chute linked to module

5.1.2. The Load Line

- √ Cut 30 feet of load line from nylon cord
- √ Note: There's no need to melt the ends of the nylon cord, as the taped knots prevent the cord from unraveling for the three-hour flight.
- √ Tie one end of the load line to the balloon loop
- √ Note: Tying knots weaken the cords the knots are tied in. To keep the knot from loosening and to keep the load line strong, apply a wrap of duct tape over the knot and where the load line and balloon loop meet.
- √ Tie the other end of the load line to either the free loop of the FTU (if used) or the swivel bearing of the parachute
- √ Apply another strip of tape to the knot to keep if from unraveling or weakening
- √ Note: Do not wrap the tape over the bearing in the swivel; only apply tape to the metal ring of the swivel, as the bearing must be free to spin.

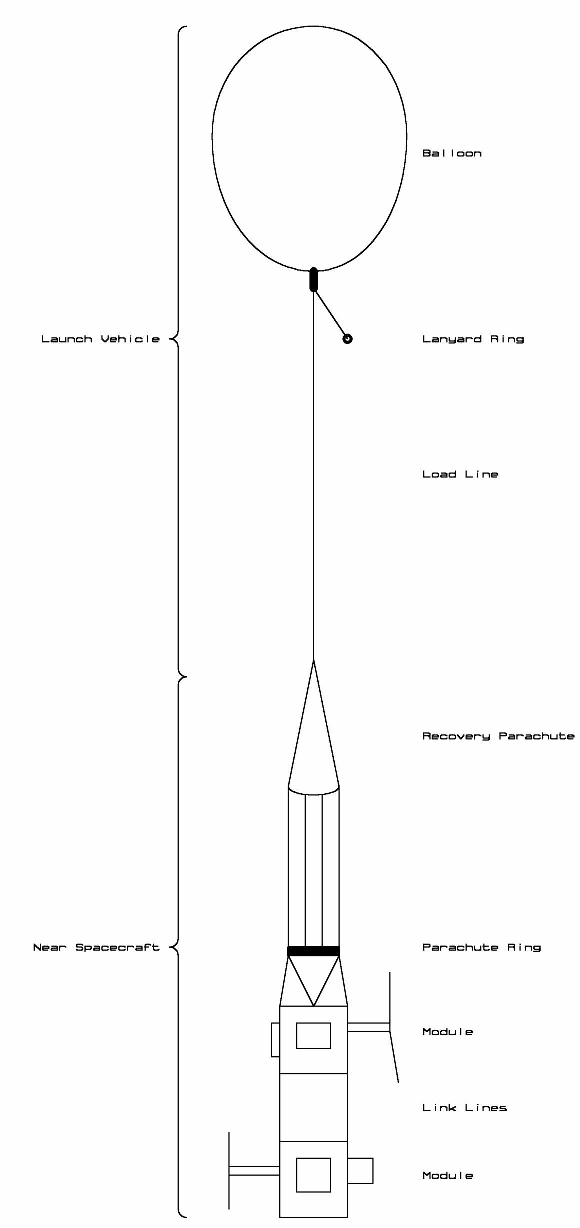


Diagram of Stack

5.1.3. Balloon Carryout

It’s time to carry the stack outside of the filling building if one was used. The Balloon Carrier, who is wearing cotton gloves, carries the balloon by grasping the balloon’s well-taped nozzle. Launch crews must watch clearances around the building doors; this includes the sides and top. Carrying the balloon outside the door may require the Balloon Carrier to crouch over or even crawl out of the door. Make the process as comfortable for the Balloon Carrier as possible so the balloon can be carried out slowly. Watch that the Balloon Carrier does not head butt the balloon. It doesn’t take much of a bump to punch a hole in the balloon. Let the Balloon Carrier know he or she is clear of the building, as they'll probably be hunched over at this point and would appreciate a chance to stand up straight. The Closeout Crew carries the Launch Stand or modules away from the building as the balloon is carried out. Remember there is only thirty feet of load line and parachute between the balloon and modules, so watch the distance between the balloon and Launch Stand. To prevent the load line from being stepped on or tripped over, one or more of the Launch Crew must carry the load line. The parachute requires another person to carry it. Keep the parade tight; you don't want anyone tugging on the load line, balloon, parachute, or modules. Also keep the parade moving slowly. Once outside and away from the building, keep the balloon a short distance away from the Launch Stand and its modules with their antennas.

5.1.4. Verify Telemetry

Check chase vehicles again for telemetry from the near spacecraft. Again verify that a log is being recorded. If the launch site is within repeater range, make an announcement that the launch is about to occur.

The entire stack is completely assembled now. The near spacecraft modules are either on a table, Launch Stand or in the hands of Launch Crew (one module per crewmember). If there's more than one module in the near spacecraft, then the modules are connected with link lines and each split ring is fully looped inside a Dacron loop (no slipped rings). The umbilical connection (if there is one) is covered with a strip of tape. The parachute and ring are attached to the top module and all split rings are fully looped inside their Dacron loops or cords. If an FTU is used, it is secured to the parachute apex with its timer set and battery power applied. Tied and taped to the parachute apex or FTU is thirty feet of load line. Tied at the other end of the load line is the balloon loop, which is securely taped to the balloon nozzle. On the balloon loop is also a two-foot loop of cord with the lanyard ring. Step back a moment and take a breather.

6.0 Raising And Launching The Stack

Several release methods are discussed in this section. Feel free to modify any one of the methods to your needs. Note that everyone involved must wear gloves for protection from string burns.

6.1. Current TVNSP Release Method

Someone must be in charge of the raising. This Launch Director keeps an eye on the balloon's position and directs the position of the crews and the balloon.

- √ Have the lanyard operators tighten up their lanyards before proceeding with raising the stack
- √ Note: They must be holding the balloon down before the balloon carrier can release the balloon or else the balloon snaps up when released. In other words, before release, the balloon carrier is in full control of the balloon. The lanyard operators must be in full control before the balloon carrier transfers control to them by releasing the balloon nozzle.
- √ Position the lanyard operators in 120 degrees arcs relative to the balloon, which is located at their center

Balloon on lanyards – *With rocket looming in background*

- √ The Balloon Carrier can now carefully release the balloon.
- √ The lanyard operators move around as necessary to keep the balloon rising near the Launch Stand
- √ Note: Watch that the raising is not faster than the crews can react and that there is always some slack in the load line
- √ Once the balloon is well above the ground, move it closer to directly above the Launch Stand
- √ The Parachute Handler carefully releases the parachute once the balloon is high enough to begin lifting it
- √ Call a hold and stop the lanyard operators while the Closeout Crew removes the modules from the Launch Stand
- √ Start the audio locator beacon and any other items with Remove Before Flight tags
- √ Before resuming the balloon raising, check that the parachute shroud lines are not wrapped around an antenna or other projection from the top module
- √ Continue raising the balloon until there is no slack between the parachute and the top Module
- √ The first module handler can gently let go of the top module
- √ Note: At this point the bottom module handler continues supporting the bottom module. This person is not be lifting up on the module as much as just keeping it from swinging around.

- √ Lanyard operators continue raising the balloon until the balloon is supporting the bottom module
- √ Before releasing the bottom module, make sure no antenna, line, or experiment is twisted on the link lines
- √ At this point the last handler should be able to release the last module without it wildly swinging around
- √ Continue raising the balloon to give the lower module greater clearance above the ground, but not so high that a launch crew can't grab the bottom module if a problem should occur

Because of lanyard twisting experienced recently by TVNSP, the following release procedure is recommended by the author. TVNSP has been more successful using twisted nylon line than using woven Dacron kite line for their lanyards. Be sure you do not twist the lanyards as you wind them on their kite winders.

- √ All three lanyard operators must have a cutter ready to cut the lanyard if they hang up during release
- √ Identify the first lanyard operator and his or her lanyard
- √ A launch crew grabs the lower module
- √ The lanyard releaser releases the first lanyard from the PVC pipe
- √ Note: The lanyard can be either let to slip off the pipe or cut
- √ The first lanyard operator carefully pulls the lanyard through the lanyard ring
- √ Note: Look for signs of the load line twisting and wrapping the lanyard
- √ When the first lanyard is free of the lanyard ring, the lanyard operator quickly pulls the lanyard away from the stack and calls "clear the lanyard"
- √ Note: If the lanyard does not clear, see if it can be carefully pulled out. If not, then cut the lanyard as high as possible.
- √ Verify the last lanyard operator is ready for lanyard release
- √ Release the last lanyard and carefully pull it free of the lanyard ring
- √ Note: Call "clear the lanyard" once the lanyard is free of the lanyard ring
- √ Note: If the lanyard hangs, call "cutting lanyard" and cut the lanyard at the winder. When the lanyard is cut, then call "lanyard free"
- √ Once the lanyard is free release the bottom module
- √ Record the time of launch for mission elapse time (MET)

Now you can hop into your chase vehicle and pretend you're a part of the movie Twister (although we know that balloon chasing has more adventure and realism).

6.1.1. Notes On Lanyard Release

The lanyard release is the weakest link in launching near spacecraft. Many of the TVNSP launches released lanyards with no one at the bottom module. When the lanyards were released (either singly or at the same time), the near spacecraft rose without catching on the lanyards. But until the problem with lanyard twisting is resolved, the author recommends the lanyards be released individually with a launch crew present at the bottom module. Oh, and you may want that person to wear a hard hat in case the modules pull lose from the load line or an experiment is prematurely released.

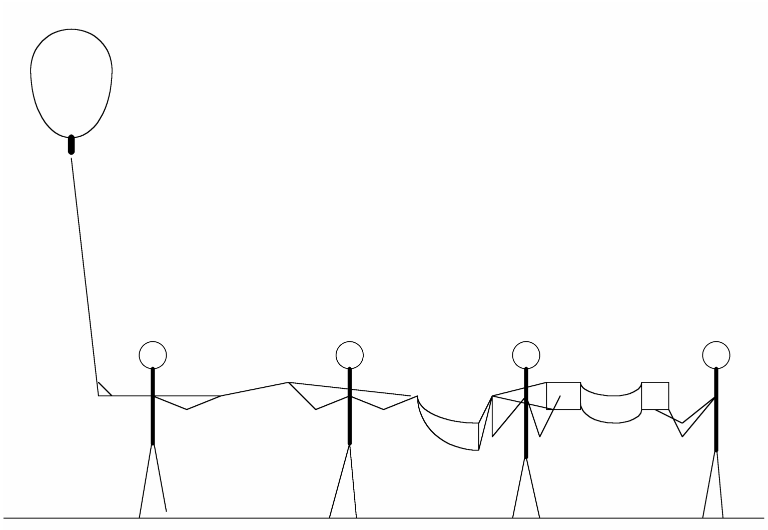
6.2. KNSP Release Methods

KNSP used a combination of two methods for launching near spacecraft. For the first three years balloons were as outlined in Subsection 6.2.1. For its last year, KNSP used the method outlined in subsection 6.2.2. Both methods worked, but the first method is more difficult for the load line handlers. This method should be reserved for launching lightweight near spacecraft using small balloons with small amounts of lift. As an example, a tracker inside a lunch bag and carried by a 300-gram balloon works well with this method.

6.2.1. KNSP's First Release Method

Look at the cover of amateur radio magazine, QST, for the moth of January 1999. On the cover you will see the KNSP launch crew preparing to release a near spacecraft. Note that everyone was wearing gloves (hint hint).

- √ Tie the stack together as normal, but do not attach a lanyard ring to the balloon
- √ Appoint two load line handlers
- √ Spread the launch crew out, each holding a piece of the near space stack
- √ Note: The modules are not on a Launch Stand, each module is held by a launch crew
- √ Spread out the entire stack with the balloon downwind
- √ Begin raising the balloon by grabbing the load line instead of the balloon nozzle
- √ Two load line handlers work the way down the load line by about one foot at a time
- √ Each time the load line is grabbed one foot closer to the parachute, the balloon rises one foot higher
- √ Launch crews fall out of the stack when they reach the load line handlers
- √ Note: Restraining the balloon by just the thin load line is difficult work if the balloon has significant lift, but much easier once the parachute is reached
- √ Continue raising the stack until the load line handlers are at the parachute shroud lines
- √ Load line handlers carefully let tension build on shroud lines as they let the parachute up
- √ Ensure the last module handler is ready to be the only one in control of the stack
- √ Carefully release the parachute
- √ Note: The last module handler on feels the balloon lifting with its free lift or PPL
- √ Release the module



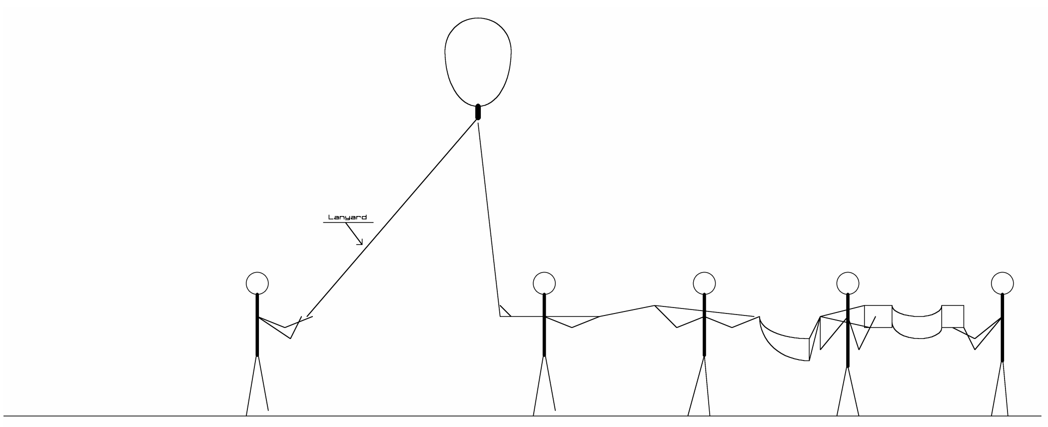
KNSP First Release Method

If there is any wind, the last handler must walk or run downwind with the module before releasing it. While running with the wind, let the module lift from your hands. When you do not run with the wind when releasing the last module, the stack swings like a pendulum below the balloon. This leads to all sorts of havoc should the module swing into the ground before gaining enough altitude to clear the ground or other obstacles.

6.2.2. KNSP's Second Release Method

After experiencing difficulty launching in winds, Dan Miller (KE4SLC) recommended the following release method, which I believe, has been used with SSOK in Salina, Kansas. Remember, everyone must wear gloves.

- √ Tie the stack together as normal, but do not tie a lanyard ring to the balloon
- √ Instead, tie one or two additional cords of additional load line (lanyards) to the nozzle of the balloon
- √ Note: The additional lines were left wrapped on their cardboard cores.
- √ Raise the balloon as outlined in Section 6.1, except no there are no winders attached, the lanyards and the load line is used as the load line is the previous method
- √ Cut the lanyards to length before releasing the near spacecraft
- √ Note: Lanyard handlers still keep hold of the lanyards
- √ Release the near spacecraft by simultaneously releasing the load line and lanyards
- √ Note: The lanyards hang down to the to the modules during the flight, but since there is no weight on their ends, they tend to swing out and away from the parachute, rather than wrapping around it.



KNSP Second Release Method

The first flight this method was used on, successfully launched the near spacecraft in higher winds that KNSP was accustomed to, however, one of the lanyards remained in front of the slow scan camera for most of the flight!

6.3. <u>Other Release Methods</u>

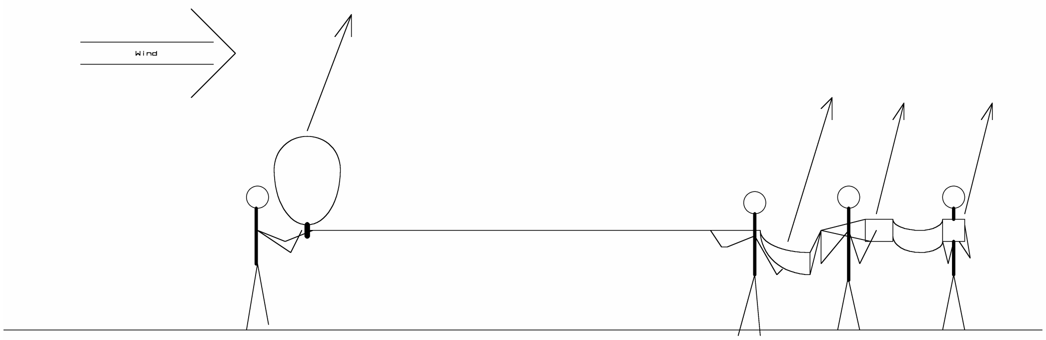
The remaining release methods have been brought to the author's attention by the near space programs, EOSS and HABET.

6.3.1. EOSS Release Method

Sometimes referred to as a Hail Mary launch. Need I mention it again, but everyone wears gloves.

- √ Appoint a launch manager
- √ Tie the stack together as normal, but do not attach a lanyard ring to the balloon
- √ Spread the launch crew and stack out, each crewmember holding a piece of the stack
- √ Note: The modules are not on a Launch Stand, each module is held by a member of the launch crew
- √ Spread out the entire stack with the balloon upwind
- √ Everyone but the balloon handler holds their part of the stack out away from their body

- √ Note: Do not grab hold of your piece of the stack, just support from falling
- √ At the launch manager's signal, the balloon handler releases the balloon
- √ The balloon rises and drifts downwind, picking up all the pieces of the stack

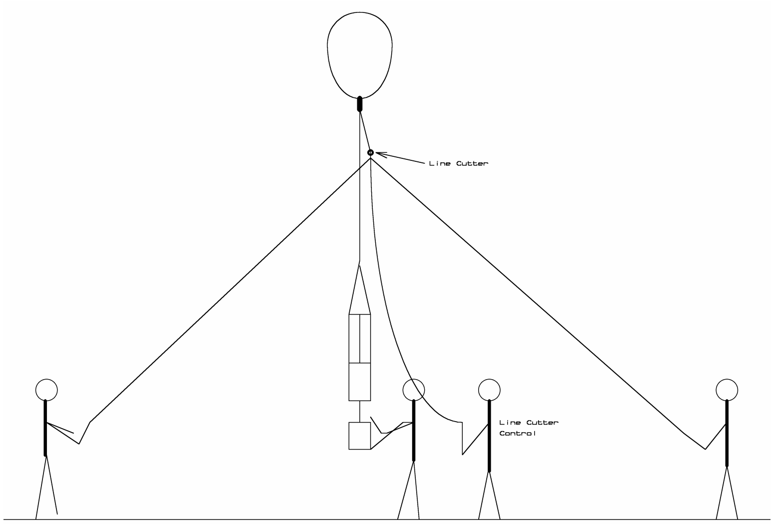


Hail Mary Launch (EOSS) *Arrow shows wind direction*

TVNSP has used this method to launch in high surface winds. The stack was released in the wind shadow of a building.

6.3.2. HABET Release Method

This is probably a better way to release the lanyards but requires extra equipment. In 2000, the author was privileged to meet with the HABET crew, thanks to the efforts of Ralph Wallio. At the time, HABET used an FTU device to sever the lanyards restraining the balloon. As the author recalls, the lanyards passed through a plastic tube. The lanyards were tied to the load line near the balloon nozzle or where tied to the nozzle. Cut on the side of the plastic tube was a slot large enough for the FTU. The FTU's nichrome coil stuck into the tube where the lanyards could pass through it. After the balloon was raised and ready for launch, a current was sent through the nichrome coil, melting the lanyards. The plastic tube with the FTU fell away from the load line.



HABET Release Method

7.0 What To Expect

Here's what to expect for a flight and some advice.

7.1.1. What To Expect

You won't sleep well the night before a launch. When you wake up, you'll begin your day running on adrenaline. You'll have a fear that it will be windy this morning. You'll also have an unnatural fear that you've forgotten something critical. After a few launches, you'll get a custom to it.

It takes about one hour to fill a balloon and close out the near spacecraft modules. Plan to be at the launch site at least an hour before launch, which means for an early morning launch (when winds are usually at their lowest) the launch crew needs to arrive to the launch site in the dark. A typical ascent rate is 700 to 1200 feet per minute, with an average around 1000 feet per minute. Typically the ascent rate is a little faster for the first 20,000 or so feet, and then it levels off to a constant ascent rate for the rest of the flight. There appears to be no slowing down in ascent rate before the balloon bursts. If at possible, get ahead of the balloon and find a place to stop before the balloon bursts. Chase Crews can see the balloon in flight and detect the balloon's burst with the unaided eye. It absolutely amazes people to see a 25-foot diameter balloon at an altitude of 100,000 feet. Use APRS to determine the bearing and elevation to the near spacecraft. The elevation of the balloon is close to the inverse tangent of the balloon's altitude divided by its range (the reason is this approximate is that it takes take into account the Earth's curvature). Here's a quick table for estimating the balloon's elevation. The first column is the ratio of altitude to range and is rounded to one decimal place. The elevation is given in degrees.

Altitude	Range Elevation
0.3	15
0.6	30
1.0	45
1.7	60
3.7	75

With your arm extended, the distance between your upright thumb and bottom of your hand is about 15 degrees.

The balloon is visible as a star in the sky. With binoculars, some people can detect the parachute. Place the balloon next to a light pole or similar object to help other people locate it. By watching the balloon in reference to a fixed object, you will detect the balloon's drifting. Expect the ascent to require between 1.5 to 2 hours.

At the time of burst, the balloon "star" fades out over about one second. Initially at balloon burst, the near spacecraft descends very rapidly. Anywhere from just the balloon's nozzle to most of the balloon remains on the load line (the rest drifts down on its own and much slower than the near spacecraft). Depending on burst altitude, the initial descent speed can be in excess of 100 mph or 8000 feet per minute. During descent, the near spacecraft experiences lots of shaking and bouncing. This is why it is important to pack the interiors of the modules in Styrofoam peanuts or find some other way tie the avionics and cables down. Don't let the high descent rate worry you, as the near spacecraft gets closer to the ground, the descent speed slows down to safe levels. The burst balloon hanging off 30 feet of load line tips the parachute several tens of degrees, causing a lot of swinging and spinning of the near spacecraft (another reason to pack the interior with peanuts). If an FTU is active on the mission, the descent becomes much more gentle after balloon is cut away. Plan on having one hour before landing once the balloon bursts. Estimate a rough predicted landing site by extending the distance from launch to burst by 50% while maintaining the same heading as from launch to burst. If the ascent followed a curvy path, so will the descent. Don't let changes in the descent course fool you into thinking the predicted recovery zone is going to be different. Expect the descent course to be a mirror image of the ascent course, but only to cover half the distance. The parachute (if it is brightly colored) can be seen more than 5000 feet above the ground. Stop the chase vehicle if you wish to look for it, but remember, stopping lets the descending capsule get ahead (parachutes are under no obligation to stop for you). It gets more dangerous if you are very close to the landing near spacecraft because you want to see it before touchdown. Be cautious at this point and keep your eyes on the road. If the near spacecraft recovers in a tree, chances are it will be suspended by the parachute on an outside branch. Exercise caution when recovering the near spacecraft caught in a tree. If Recovery Crews are not close enough to see the parachute land, APRS may not get them right to the recovery site. Depending on the terrain and your distance, telemetry may be lost several hundred or even more than one thousand feet above the ground. Go to the last known site and begin traveling downwind. As Recovery Crews get close, telemetry from the near spacecraft will be received. The audio beacon described in this book can be heard 100 feet away, so carry one on each mission to help locate the recovered near spacecraft.

Also be sure to get permission before walking into private property to recover your property. KNSP and TVNSP have never had trouble with landowners. Indeed, almost all of them have been interested in what we have done. KNSP and TVNSP have sent landowners either pictures or a bumper sticker that went up in the near spacecraft.

7.1.2. Some Advice

Teach all launch procedures to your launch crews. Consider teaching launch procedures to your local astronomy or radio club as you may interest them in participating. Have launch crews practice filling and launching the balloon annually, before beginning the year’s new near space campaign. Test the APRS setup of chase crews before their first launch. Take a module of the near spacecraft out for a drive and verify new chase crews are able to track and find the module. Don’t attempt to hide from chase crews, as the near spacecraft doesn’t try to hide either (all good near spacecraft want to be found). After building new avionics, run them for at least four hours on the ground for sending it up on a mission. Document everything! When possible, launch close to sunrise before the winds have a chance to pick up. Expect the first launch to take more than one hour. If financially possible, have an extra balloon and helium at the launch site. Be gentle with the balloon, but not paranoid. The balloon is surprisingly durable when first filled, except around sharp objects. Remember, the balloon is going to expand several times in diameter before it bursts; so dull or blunt objects are less likely to burst the balloon. Keep first flight simple, perhaps even a low altitude flight (low for amateur near space is 50,000 feet). Clearly explain to everyone interested where the balloon is predicted to travel to and recover. Plan a driving route before the launch. Usually you will be able to follow the routine until near the recovery zone. Coordinate chase frequencies before launch day. Be sure chase crews know the frequencies and have programmed them into their HTs. Most of us do not know how to program new frequencies into our HTs without the directions that came with the radio.

Good To Know - The Lifting Ability Of Gases

I wrote an article for QST on high altitude ballooning back in early 1999. In the article I discussed the lift of balloons based on their volume of gas. I made an error in my calculations and didn't explain the material in as much depth as I would have liked. So here’s an attempt to expand the content of my QST article. I hope you enjoy the physics and chemistry content as much as I did.

The near spacecraft reaches near space because its expendable booster, the balloon, has buoyancy. Buoyancy occurs when an object's volume displaces more weight than the weight of the object. As an example, if a balloon displaces a volume of air that has a weight of 12 pounds, but the balloon and its gas has a weight of only three pounds, then the balloon has buoyancy of nine pounds and it floats.

In this example the balloon can lift a payload with up to nine pounds of weight. At nine pounds of weight the balloon becomes neutrally buoyant and will no longer rise.

The way to determine the weight of a volume of air is to multiply the volume by its density. To determine the density, we'll make use of some material you learned in college chemistry. The mass (which will be treated as a weight, although strictly it is not a weight) of a chemical compound or element is given by its atomic mass. We can convert atomic masses into grams by taking advantage of the law that a physicist by the name of Avagrado discovered. Since compounds and elements consist of atoms or combinations of atoms, the weight of a mole of a compound or element in grams is equal to its atomic mass. This occurs because every atom of the same element has the same mass and the atoms in each molecule of a gas are identical. So the mole becomes just a conversion factor, like converting pounds to kilograms. Since we're working with gasses, we take advantage of their equal volumes at the same temperature and pressure. We'll use standard temperature and pressure (STP), which is 0 degrees Celsius at one standard atmosphere (760 mm Hg).

One mole of a gas at STP has a volume of 22.414 liters. One mole of the gas has a weight in grams equal to its atomic mass. The density of this gas (and in fact, of anything) is equal to the weight of the body divided by its volume. If the density of a gas is less than the density of air, then that gas is buoyant and will float, or rise. Our atmosphere consists of 79% nitrogen (with a molecular mass of 28.013 grams), 21% oxygen (with a molecular mass of 31.999 grams), and 1% argon (with an atomic mass of 39.948). Remember that oxygen and nitrogen are diatomic molecules, so the atomic mass of these molecules is twice the atomic mass of the individual atom. Averaged together and we get an average mass for a mole of atmosphere of 29.249 grams. Divide by the volume of a mole of gas at STP and we get a density of 1.305 grams/liter (g/l)

Compare this density with the density of hydrogen, helium, ammonia, and nitrogen. The atomic or molecular masses of these gasses are 2.016 grams, 4.003 grams, 17.030 grams, and 28.013 grams, respectively. Their densities come out to 0.090, 0.179, 0.760, and 1.250 g/l respectively. Notice that all of them have a density less than air, and so all will float in the air. Their effectiveness at lifting payloads into near space depends on how much lower their density is compared to the air. To determine this, let's convert the lift of each of these gases in pounds/cubic foot (I'm avoiding metric because of my American audience). We'll do this by subtracting the density of each gas from the atmosphere and converting grams per liter to pounds per cubic foot. The conversions are 28.32 liters per cubic foot and 453.6 grams per pound. A mole of gas occupies 0.79 cubic feet of volume. So one cubic foot of each of these gasses lifts the following weight when compared to air.

Gas	Lift (pounds/ft3)
H_2	0.070
He	0.070
NH3	0.034
N_2	0.003

Because of rounding errors, helium appears to lift as much as hydrogen. Hydrogen only lifts 8% more than helium (1.215 g/l vs. 1.126 g/l).

Let's create a situation where a balloon/payload combination will reach 100,000 feet when hydrogen is used as the lifting gas. Then how high will these other gasses get the payload before bursting?

Gas	Maximum Altitude
H_2	100,000
He	98,000

NH3	78,000
N_2	About 0 feet

So we can see that using hydrogen in place of helium in the balloon will get the near spacecraft about 2% higher, although the effect is more pronounced with heavier stacks and smaller balloons that reach lower altitudes. Ammonia does reasonably well, in fact I hear that there are hot air balloonist who fly on ammonia. Nitrogen provides such little lift that it achieves unacceptable altitudes (it may be unable to even lift the weight of the balloon).

Now let's compare the cost of hydrogen to helium, and calculate an altitude per dollar. Back in Kansas I purchased a tank of helium for $60. The tank held 245 cubic feet, so it had a cost of $0.24/cubic foot. Hydrogen was available at $30 per tank and each tank held 300 cubic feet. So hydrogen cost $0.10/cubic feet. Taking into account that helium lifts less payload weight per cubic foot (about 8%), I get the following values for cost per foot altitude, normalized to hydrogen.

Gas	Cost/altitude
Hydrogen	1
Helium	2.5

By this table, it's apparent that hydrogen is your best value for the dollar, if your only concern is for getting the highest altitude for the dollar. Let's take a look though at the chemical properties of these two gasses.

Helium is a nonflammable, inert gas. This means helium is incapable of chemically combining with other elements. It will neither chemically absorb nor give off energy when it mixes with other gasses in the atmosphere. Helium is a simple asphyxiant that displaces oxygen in the air. However, it does have the benefit of giving you advanced warning by causing you to talk like Donald Duck. So if your Balloon Dogs begin speaking funny, it's a warning to get them out to fresh air. Hydrogen is also a simple asphyxiant, but it gives even less warning that you're not getting enough oxygen. In low concentrations of helium or hydrogen, individuals may develop headaches, dizziness, and deeper breathing.

Of course we know the other hazard of hydrogen, it chemically combines with oxidizers like oxygen (as do a lot of elements). The chemical combination is very energetic. Fortunately though, it burns up, rather than spreads around like liquid fuels. On the other hand though, hydrogen burns with a clear flame and produces very little radiant heat. If hydrogen is slowly escaping and burning, you probably won't notice until you walk into the flame. The greater risk from hydrogen is from it escaping from a burst balloon and rapidly mixing with the air. The balloons you receive from Kaymont and Kaysam are vacuumed out prior to shipping, so there's no oxygen to mix with the hydrogen in a balloon. A spark then can cause an explosion that will literally bring the house down. So as long as the hydrogen stays inside the balloon, there's no risk. Possible sources of spark include lights and electrostatic discharge. A source of electrostatic discharge comes from the filling process itself. As hydrogen gas flows rapidly through a plastic and ungrounded filler, it generates a large static potential that can discharge when a balloon bursts. The Hindenburg Disaster is a terrible example of the dangers of hydrogen.

My take on the matter is that the risk of an explosion is too great to use hydrogen. I've seen balloons burst and leak indoors, when you would have thought it wouldn't happen. If you feel the need to use hydrogen, here are a few safeguards to use. But please do not think this list is complete, because it's not. However I think it will convince you that hydrogen is not worth the trouble of using. First, fill the balloon outdoors, or inside a building without a roof or a very leaky roof. Second, use a grounded filler. Use a hydrogen hose and connect it to metal filler. Ground the hose and filler to an earth-ground. Third, allow no smoking or flames around the balloon while filling. If filling indoors, all electrical equipment, including lights need to be explosion-proof or non-sparking. Do not shut off the lights, or turn them on, when a balloon has burst. Making or breaking an electrical contact inside the switch creates a spark. Fourth, be familiar with the electrical properties of the near spacecraft. Are their switches to turn on before launch? If so, save it for after the near spacecraft is outdoors. Finally, Balloon Dogs should be well protected. Wearing eye and ear protection is a must. In fact wearing a motorcycle helmet would probably be a good idea. Consider the clothing balloon dogs are wearing also. Are they wearing a nylon jacket? Nylon creates static and will melt and cling when it burns. Look into borrowing flame resistant clothing when filling a balloon.

Large quantities of natural gas are transported across the United States everyday. We have tankfuls of the stuff in many homes and still we seldom experience a disaster with it. We should have the same level of safety with hydrogen, but since you're handling it on the amateur level, expect more trouble.

Whether its helium or hydrogen, there are safety concerns when transporting gas cylinders. When transporting compressed gas, avoid carrying the tanks inside closed cars. Ruptured tanks cause explosions in a closed container, like a car. Its best to move cylinders in the back of an opened truck. In all cases, immobilize the tanks during transport. You don't want tanks falling over and rolling around. I can tell you the clank of colliding tanks is very disconcerting. Pack material like a blanket between the two tanks to keep them from rolling into each other. Take the tanks straight to the launch site by a safe route. Don't risk an accident or involving innocent travelers.

Near Space Humor - Humorous Events Of Near Space Programs

Bill Brown
WB8ELK Field Day Balloon 1992 Hancock, NH

I decided to do something entertaining for Field Day. I designed a simplex repeater with a converted Fischer Price kid’s talking toy and an ICOM 2-AT. It worked great, 8 seconds record and 8 seconds playback. I flew it during high noon of Field Day and listened as some folks nearly 400 miles away managed to contact me through the balloon repeater. I believe hams from 8 states were able to talk through it.

Since everyone was at Field Day, I couldn’t convince anyone to come help me launch the balloon or chase it. So I filled the balloon and launched it all by myself in my backyard. Also, none of the foxhunt crew was available either, but I managed to get some of the Field Day sites to give me some final beam headings just as the payload landed near Manchester, NH. One of the fellows who had been at the Nashua Field Day site was on his way home and managed to hear the balloon briefly as he zipped along on the highway. He contacted me late in the evening and told me about it. I fixed up my makeshift DF gear and headed out to the area he told me about. Sure enough I could hear a very very weak signal for about 100 feet along the highway. It was very very strange, only that one spot had a signal. I drove all around the region and only could hear it there. So I started to walk down a gravel path in the now near pitch dark. I didn’t have my flashlight with me at that point. Suddenly the signal got a lot stronger and I started to walk faster toward the signal. Then I stopped as I was about to put my foot down since it seemed a bit strange. In the very dim twilight, my next footstep seemed to be very very dark gravel. I carefully lowered my foot and it just kept going down and down. I backed up a bit and went back to my car for my flashlight. After retracing my steps I was startled to see that my last footstep was on the very edge of an 80-foot deep gravel quarry!!!!

I found my way down a path to the bottom of the quarry and walked directly to the payload. It was lying in the gravel and sand at the very bottom of the quarry!!! No wonder I had a hard time hearing the signal from the road.

EOSS (From Mike Manes, W5VSI)
Our candidate is the transcript Tom Shillings testimonial at Cec Girz's retirement party in September (2002). Tom is a member of the GAINS team at NOAA that Cec managed until her retirement. We saw a video of it at one of the EOSS meetings, and it had us rolling in the aisles! Here's a snippet off my error-prone head.

Tom is rushing to finish dinner with his wife so he can make the EOSS meeting that night:

Tom S: "I've got a meeting I've got to get to at 7 tonight."

Tom's Wife: "Oh really? Who with?"

Tom S: "The Edge of Space people."

Tom's Wife: "Oh…..some space people, huh? Where's the meeting?"

Tom S: "Fort Logan."

Tom's Wife: "Fort Logan….isn't that the state mental hospital?"

Tom S: "Yeah. They have a room there."

KNSP
From the author's recollection.

This would be KNSP's third flight (Flight 97B). Being so early in the history of KNSP, there was still lots of interest in chasing the balloon. So over eight chase vehicles were assembled for the mission. The mission carried a backup locator beacon that ultimately created this story. The beacon was a two-meter milliwatt beacon based on a clock crystal. It weighed around ½ pound and was tied to the load line. After weighing the capsules and parachute, the balloon was filled for one PPL. After checking everything out, the balloon was taken outside the Johnson Near Space Center and launched. It was immediately obvious that there wasn't enough lift in the balloon from it's very anemic ascent rate (about 300 feet per minute). In fact it looked like the balloon was traveling horizontally about 100 feet above the ground (I imagined it would be bouncing off the ground the entire mission). It did eventually gain enough altitude to make a safe, but very long flight. It traveled north from Manhattan, Kansas for five hours before landing. Recovery was in a cornfield near Lincoln, Nebraska. The Chase Crew was able to keep up with the stack for the entire flight, so when it landed, we were only minutes away.

A farmer and his wife spotted the descent into their cornfield while they were finishing their lunch. Since there was a sky diving class nearby, the farmer thought it might be a student in trouble. The farmer boards his ATV and drives out to render assistance. As he gets closer (the near spacecraft was ½ mile from their home), he sees that this is definitely not a skydiver. It was a six-sided object with antennas and making a beeping noise. At that point, if I were the farmer, I would have high-tailed it out of there. Instead, he retrieves it, loads it on his ATV and drives back home with it. Remember that I said we were minutes away from the near spacecraft as it landed? Well, by the time the farmer got back home, there were eight out of state cars parked in his driveway waiting for him. I can't imagine what he must have been thinking at that point. All ended well, though. The family was pleased to get the attention and we gave them an autographed bumper sticker that had ridden in the near spacecraft to an altitude of 79,000 feet.

NSTAR

Don Pfister reminded me of this one over the weekend while we were at the St Joe Hamfest.

I went to one of the Near Space Balloon Group's launches near Gardner, Kansas one weekend. I believe this one was in early spring of 1999, but can't remember for sure. Bill (N3KKM) and Don (KA0JLF) each had a payload flying. The surface winds were a little breezy, about 10-15 mph from the north. We were launching from a large parking lot near some softball fields.

The fill was fairly normal, and Don and Bill measured the lift as well as they could given how much the balloon was bouncing around in the breeze. They got the balloon tied off, all the payloads attached, powered up, and tested, and finally we were ready for launch. The balloon was released and the other handlers lofted their payloads into the air.

The balloon rose normally for a few seconds, and then began to come back down. It was immediately apparent we didn't put enough helium in the balloon to get everything airborne. Downwind of the parking lot was an unfenced and plowed cornfield, so we weren't too concerned with obstacles. By the time the balloon had reached the edge of the parking lot, the lower payload had struck the ground. We started walking over to the payloads to catch them.

Now that the lower payload was resting comfortably on the ground, the balloon had more free lift. Up it went again, jerking the bottom payload off the ground and drifting downwind again. Of course, once the lower payload was off the ground the whole train was again too heavy to fly, so it came back down, but another 30 yards away.

After seeing this happen, we realized it was a little more serious. This up-and-down cycling would continue indefinitely, and the whole works was moving south with the breeze at about 15 mph. The nearest obstacle downwind was close to a mile away - a fence and a set of power lines. Our only choice was to run after the payload and get it under control before it got to that fence and power lines. What began as a walk turned into a full sprint, with several of us hauling butt across this plowed cornfield chasing a balloon the hard way.

I think we were about 200 yards into the cornfield before we caught the balloon. We brought it back to the launch area (where many of the rest were still having a good laugh at the sight of us sprinting after the balloon) and talked about what to do next. Since it would be difficult to untape the balloon neck and get it back on the filler, it was decided to cut loose the bottom payload (the top one had the GPS tracker in it). There was enough lift to get this payload airborne and so we let it go solo.

Somewhere I think there's a videotape of all this.

CHAPTER ELEVEN

Chase And Recovery

"Do you chase UFO's?"
"No, I know what I chase."
- Conversation with a stranger at a gas station in Kansas

Chapter Objectives

1.0 The Chase

Chasing balloons makes my Saturday a fantastic day. Being on a mission that most people will never experience. Using high tech equipment that really catches the eye. Feeling like I'm on a mission like the actors in the movie, Twister. It all adds up to a great day.

High tech equipment -
Really catches the eye

1.1. The Chase Or Tracking Vehicle

Two names are commonly heard for the cars that chase after the balloon, Chase vehicles and Tracking Vehicles. I suppose if the car carries an APRS tracker, then it is more properly called a Tracking Vehicle and if the car only carries communications equipment and depends on a Tracking Vehicle it is more properly called a Chase Vehicle. Take your pick or make up a new name. Most automobiles work well for near space chase. Any car capable of carrying an APRS tracker and/or communication equipment is suitable for a Near Space Tracking And Recovery vehicle. You'd be amazed at the 1984 Ford Escort the author took on many balloon chases. It's amazing that gutless wonder didn't have a heart attack. There are times when a car designed for off-road driving is better. A Jeep of other SUV (or should that be UAV for, Urban Assault Vehicle?) is a good match at the end of the chase where the roads may become non-existent. In the author's experience, the Midwest has descent roads very close to the recovery site, but in mountainous states like Idaho it's a bit more problematical. There aren't many paved roads on the tops of 12,000-foot mountains.

Chase Vehicle Interior

1.1.1. Mobile APRS Setup

The next four subsections will help you set up a mobile Automatic Packet Reporting System (APRS) tracker for your near space tracking and recovery vehicle. Your local APRS community is usually happy to help also. Before launching and chasing a balloon, there must be at least one Tracking Vehicle. For added insurance, at least two cars should be tracking. Multiple trackers prevent one tracking failure from stranding the Chase Team and losing the near spacecraft. Of course it even better if every car carries an APRS tracker, but this isn't realistic. There are enough versions of APRS that any laptop can be used as a tracker. The quality of the maps depends on the capabilities of the laptop. There's even a version of APRS for Palm Pilots. APRS functions by parsing text data received through the laptop's comm port (at 1200 baud, N81) and displaying it on moving maps. Not only does APRS display graphical data, it can also send and receive text messages sent over packet radio. It is truly an amazing program.

Along with the laptop, a terminal node controller (TNC) is required for APRS. The TNC connected to a laptop running APRS completes the following steps.

- Accepts text data from a PC or laptop
- Breaks the text string into shorter packets (if the text is larger than one packet)
- Adds the appropriate address headers to the packet
- Creates a cyclical redundancy code (CRC) for each packet for error correction purposes
- Keys the radio connected to the TNC
- Converts the text packets into audio tones for transmission over the radio
- Unkeys the radio

Packets received over the radio go through the same process, but in reverse order and without having to key and unkey the radio.

A PC (usually a laptop) with a TNC and radio are required to operate APRS. However a GPS receiver connected to the laptop makes APRS an even more powerful tool for the Chase Team by displaying their position along with the near spacecraft's position on a moving map. Any standard GPS receiver is suitable for APRS (the author would hesitate using an older model GPS receiver until after it is determined that the GPS receiver follows the NMEA 0183 standard.

Don't let a balloon chase be a tracker's first exposure to using APRS. Give a new tracker a chance to practice using APRS by letting them track a functioning near spacecraft carried around in a car or truck. At a minimum a tracker should know APRS well enough to do the following tasks.

- Start and stop logging TNC data
- Determine the near spacecraft's position in relationship to the landmarks
- Zoom the display in and out
- Estimate distances on the display

1.1.2. Setting Up A Mobile APRS Tracker

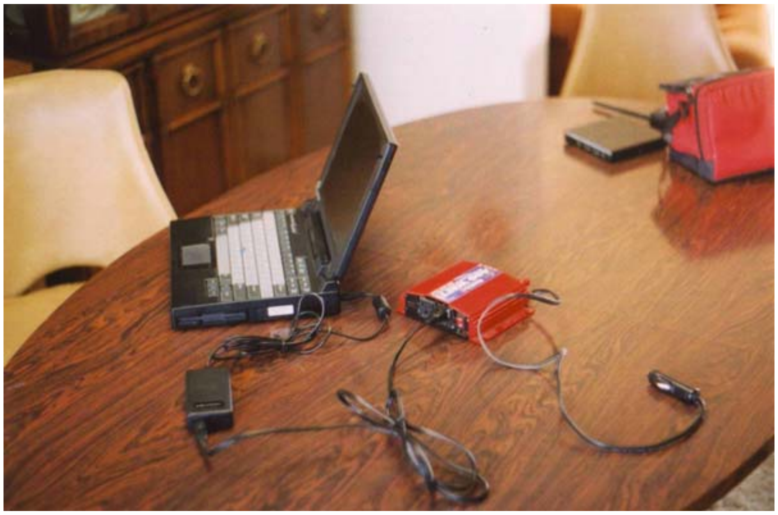
The next eight items are suggested for your APRS Tracker. For additional help, contact your local APRS community, they will be happy to show you the ropes and help you set up a tracker. This section assumes the tracking and recovery vehicle carries a laptop to run APRS. There are other ways to run APRS that uses a Palm Pilot or Kenwood Data Radio. These last methods are not as useful as a laptop because of their limited mapping capability, but they do complement a laptop APRS tracker.

Laptop

The newer the model laptop used, the more powerful the tracking program that can be loaded on it. If your TNC does not include a second comm. port, the PC should have one (possibly through a PC card). With the bouncing around inside a chase vehicle on a mission, it is very difficult (read, almost impossible) for the Navigator to use the built-in mouse cursor on the laptop. So instead of relying on the installed mouse, use a larger external mouse and give the Navigator a mouse pad and solid base.

Power

A good quality inverter connected to the cigarette lighter (the only good use of a cigarette lighter in my not so humble opinion) should be the primary power source for the laptop. The laptop's batteries should be used to provide power when the car is shut off. Use an inverter because most laptops cannot be connected directly into an automobile's 12-volt system. Even if the laptop uses a 12-volt wall transformer, the voltage spikes present in the electrical system plays havoc with the laptop and sooner or later will damage the laptop. Wal-Mart carries a line of inexpensive 12-volt inverters. Check the power requirements of the laptop's wall transformer before purchasing a 12-volt inverter. All inverters list the amount of current they can supply, so make sure this number is greater than the laptop's requirement. Another option for external power is to carry a separate 12-volt battery for the laptop. In this case, use a deep cycle battery, like a marine battery. The deep cycle battery design allows them to be deeply discharged before being recharged. Deep discharging a standard automobile battery reduces the battery's lifetime. Mount the separate battery inside a marine battery case and place it on the car floor where it cannot tip over. In addition, consider adding a voltmeter and ammeter to the battery to monitor its voltage and discharge rate during the chase



Power Setup – *Laptop and cord, inverter, and cigarette lighter jack*

TNC

The newest TNC model is not required for the APRS tracker, which saves money. There are several TNCs are available. The list below is not a complete list of available TNCs.

Model	Manufacturer	URL
KPC2	Kantronics	http://www.kantronics.com
KPC3+	Kantronics	
MJF-1270C	MJF	http://www.mjfenterprises.com
HandiPacket	Paccomm	http://www.paccomm.com
PicoPacket	Paccomm	
TINY-2 MK-II	Paccomm	
PK-96	Timewave	http://www.timewave.com
PK-12	AEA	

After email consultations with five individuals active in the near space community, the following observations and recommends were made

Several TNCs have reliability issues. They lose settings in memory when their power fluctuates or is shut off. Some Paccomm and AEA TNCs have been observed with this problem. Some TNCs, like the PK-12, limit control over TNC functions. Kantronics seems to be the company that is most responsive to the amateur radio community. Amateurs comment positively on the KPC3's high reliability and durability. The KPC3+ with version 8.3 and later EEPROM provides a second comm port, allowing a GPS receiver and laptop to be connected to it (as opposed to the laptop having a second comm. port). Finally, it only requires nine-volts, as opposed to 12-volts for other TNCs. The instructions below are written for the KPC3+ ver 8.3 EEPROM. Modify these directions if using a different TNC.

The following steps are required to adapt the KPC3+ ver. 8.3 to near space chase and recovery. The hardware changes involve soldering a battery snap to the KPC3's printed circuit board and making the HT/GPS cable. The software changes involve programming the KPC3 for the second port. Older versions of the KPC3 and all the KPC2s do not have a second comm port. If you decide to use the KPC2, or older KPC3, then skip the directions for wiring the second comm port for the GPS receiver and only wire it for the HT.

Hardware Changes
Battery Snap
The KPC 3+ does not have a factory installed battery snap. You must add one.

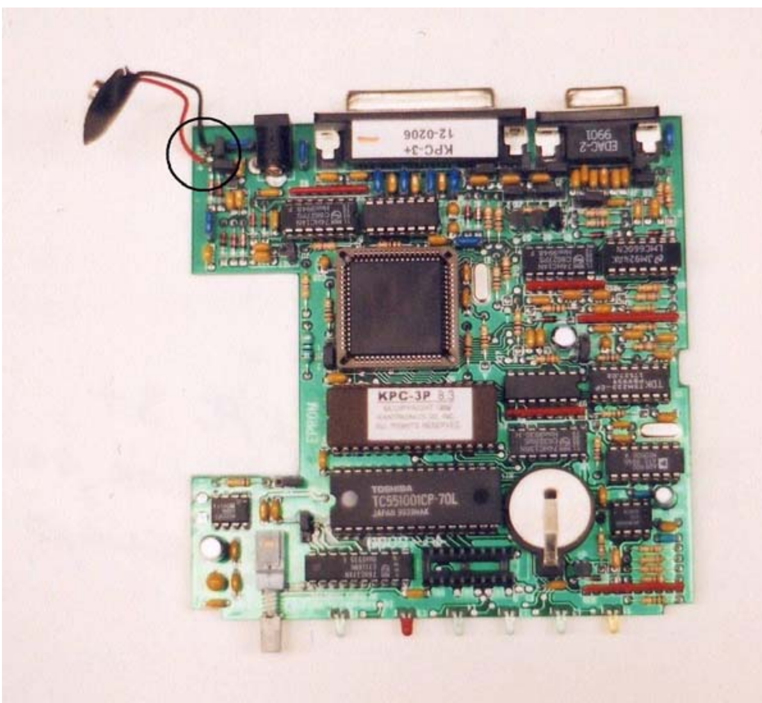
List of Materials
9-volt battery snap (use the heavy-duty battery snap from Radio Shack, 270-324)

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

Look in the KPC3+ Manual for directions. Instructions are located under the section, Installing Your KPC3+ in subsection, Internal Power, from a Battery. Currently the nine-volt battery snap is soldered to pads located in the back left of the TNC's PCB.

- √ Solder the red 9V battery snap lead to the + pad and the black lead to the - pad
- √ Glue a sheet of foam rubber onto the inside of the lid, over the battery

This places pressure on the battery once you bolt the lid back onto the TNC. The pressure keeps the battery from bouncing around inside the case, possibly causing mischief.

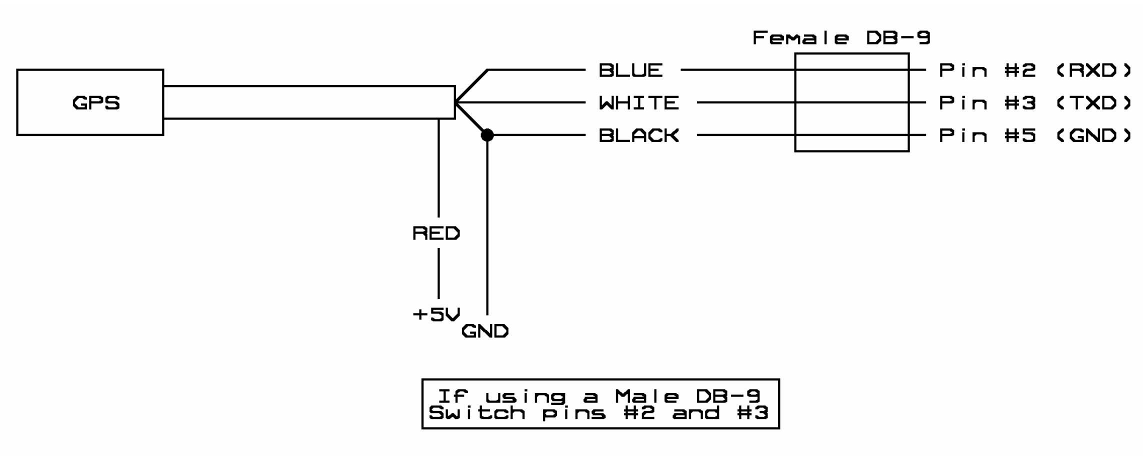


Inside of KPC 3+ - *Note the solder pads for the battery snap, circled at upper left.*

HT and GPS Cable
The Radio Port will be wired for the HT and GPS Receiver.
List of Components
- Six lengths of #22 or #24 gauge stranded wire (about 12" long)
    - Use three different colors of wires, with two black wires for the ground connections
- Capacitor (see KPC3 directions for proper capacitor value for your HT)
- Resistor (see KPC3 directions for proper resistor value for your HT)
- 1/8" male phono jack

- 3/16” male phono jack
- Two male D-subminiature connectors (DB-9)
- Female D-subminiature connectors (DB-9)
- Three ½” lengths of ¼” diameter heat shrink
- Two ¾” lengths of ¼” diameter heat shrink
- Two DB-9 plastic housing kits

Procedure To Make The HT Cable



Connection Diagram for HT Cable

√ Strip back ¼” of insulation from one end of each wire
√ Solder the wires to the solder cups of one of the male DB-9 connectors as listed below

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

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

- √ Use hot glue to cover the solder cups of the DB-9 connector

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

- √ Place the bolts into the DB-9 housing
- √ Pour some hot glue into the bottom half of the DB-9 housing
- √ Place the DB-9 connector and it's wires into the housing
- √ Pour some hot glue into the top half of the DB-9 housing
- √ Close and bolt the housing halves together
- √ Back fill the housing with hot glue
- √ Label the housing as Radio Port

The GPS Cable
(Skip to Close DB-9 Housing step if not using a version 8.3 or later EEPROM)

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

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

Close The DB-9 Housing

- √ Place the bolts into the DB-9 housing
- √ Pour some hot glue into the bottom half of the DB-9 housing
- √ Place the DB-9 connector and it's wires into the housing
- √ Pour some hot glue into the top half of the DB-9 housing
- √ Close and bolt the housing halves together
- √ Back fill the housing with hot glue
- √ Label the housing as GPS

Completed GPS cable

Laptop Comm Port
Use a standard DB-25 to DB-9 serial cable to connect the TNC to the laptop.

Software Changes
The following commands instruct the KPC 3+ ver 8.3 TNC to operate as an APRS tracker.

```
INT                 TERMINAL
GPSPORT             4800 NORMAL CHECKSUM
BT                  "Your message about the chase, or being a part of it"
                    Note: Precede text with a right caret (>)
BLT 1               00:05:00
GPSHEAD 1           $GPRMC
HEADERLINE  OFF
CD                  SOFTWARE
LTP 1               GPSLV VIA RELAY,WIDE2-2
```

LTP1 notes

GPSLV under the LTP1 setting indicates the icon to display under APRS for your chase vehicle. A few of the options are as follows

```
GPSLV      Van Symbol
GPSMV      Car Symbol
GPSLK      Truck Symbol
```

Check with your local APRS community about the RELAY and WIDE setting. Not every location accepts the same settings.

GPS Receiver
A GPS receiver is not strictly needed, but it is so useful that there's no reason not to carry one during chase. Any GPS receiver outputting NMEA 0183 standard signals (this should be all commercially available current GPS receivers) works with APRS. There are two popular locations for the GPS receiver, on the dash and on the roof of the car. There are benefits for using each type of GPS receiver. The roof mounted GPS receiver has more consistent satellite reception and is normally desired over a dash-mounted position where satellite reception depends on which way the car is pointed. The roof-mounted GPS receiver costs more than the basic Garmin Etrex (a handheld GPS

receiver without a magnetic face). A roof-mounted GPS receiver needs a connection to the car's cigarette lighter for power whereas the handheld Etrex uses internal batteries (two AA cells). With two fresh alkaline cells, the Etrex operates for 22 continuous hours, almost enough time for a year's worth of chases. Also, with internal batteries, the clutter of wires inside the chase vehicle is reduced. It's left as an exercise for the reader to determine how useful it is to have fewer cables snaking their way around the dash. A roof-mounted GPS receiver comes with a serial and power cable already attached to it. However, hand-held models require the purchase of a serial cable. Use the Pfranc serial cables for the handheld models to save money over the manufacturer's serial cables. The serial cable for the roof-mounted GPS receiver is another cable snaking its way around the car. The Etrex is positioned near the laptop where its serial cable is out of the way. A good place to order some GPS receivers is TAPR, which helps to support amateur radio. Outside of TAPR, 4X4 sells affordable Etrex GPS receivers. There is a hybrid option, using a dash mounted GPS receiver with an external antenna. GPS receivers like the Garmin GPS 48 allows for an external antenna, but the Garmin Etrex does not.

The GPS is connected to a second comm port, either on the TNC or the laptop. There are no modifications to make to the GPS in software. Hardware changes only have to be made to roof-mounted GPS receivers with serial cables that do not terminate in DB-9 connectors.

Terminating the Garmin GPS35

These directions are for Garmin GPS35 receivers that do not terminate in a DB-9 connector (the end of the cable is bare). The directions are modifications to the directions in Chapter Four, Section One.

Materials

- Female DB-9 connector kit with solder cups
- DB-9 plastic housing kit
- Short length of #22 AWG wire
- A three or four foot length of two-conductor stranded cable for GPS power
- Note: The final length depends on the placement of the laptop relative to the cigarette lighter
- One cigarette lighter power connector
- Sort lengths of heat shrink tubing with large enough diameter to cover the solder cups of the DB-9
- Hot glue

Procedure

Strip back two inches of the outer jacket of the GPS35 cable. You'll see about ten wires inside the cable. The wires needed are the following,

Wire Color	Signal
Blue	RXD1
White	TXD1
Black	GND
Red	Vin

√ Strip ½" of insulation from one end of the wires in the power cable
√ Strip back ¼" of insulation from the Blue, White, Black, and Red wires of the GPS35 cable
√ Slide a short length of heat shrink on the Blue and White wires
√ Solder the White wire to pin #3 solder cup of the DB-9 connector
√ Solder the Blue wire to pin #2 solder cup of the DB-9 connector
√ Slide a short length of heat shrink over the end of the ground wire of the power cable

- √ Strip ¼” of insulation from the end of the short length of wire (ground extension)
- √ Twist the power wire to the Black GPS35 wire and the short length of wire
- √ Measure the length of the ground extension wire needed to reach pin #5 of the DB-9 connector
- √ Cut the ground extension to length and strip ¼” of insulation from the end
- √ Solder the ground extension wire to pin #5 solder cup of the DB-9 connector
- √ Slide a short length of heat shrink over the end of the positive wire of the power cable
- √ Solder the 22 AWG wire to the Red GPS35 wire
- √ Slide the heat shrink over all soldered connections and shrink them
- √ Fold back the power cable so it will exit the DB-9 hood through the back end, where the data cable enters
- √ Note: You may have to enlarge the hole slightly to get both the data and power cable through the same hole
- √ Squirt some hot glue over the solder cups of the DB-9
- √ Put a layer of hot glue in the bottom half of the DB-9 hood
- √ Place the DB-9 into the bottom half of the DB-9 hood, being careful not to ooze hot glue all over the place
- √ Squirt some more hot glue over the top of the wires in the hood to fill in gaps
- √ Put a layer of hot glue in the top half of the DB-9 hood
- √ Close the top over the bottom half, being careful to wipe up any excess hot glue
- √ Bolt the halves together

- √ Strip one inch of insulation from the exposed ends of the power cable
- √ Insert the free ends into the cigarette light power plug
- √ Note: Depending on the design of the power plug, this may require the wires to bolted or crimped to metal contacts

GPS Signal Strength

Harry Muller (KC5TRB) of ORB in Oklahoma tested the quality of GPS signal with a Tripmate GPS receiver in several locations in his van. Condensed down, the test shows the following results[A].

Location	Number of Satellites	Average Signal to Noise Ratio (SNR)
In The Open	10	36.3/99
Underneath A Fiberglass Roof	10	39.5/99
Six Inches Beneath Carpet, Wood, And Fiberglass Roof	10	38.0/99

From these results it can be seen the placing a GPS receiver beneath the fiberglass ceiling of a van does not attenuate signals enough to drop the number of Navstar satellites detected by the GPS receiver. Oddly enough, it seems to help. The increased SNR may be more affected by the reduction of outside interference rather than the attenuation of GPS signals.

Radios (usually an HT)

Almost any HT will work as part of an APRS Tracker as long as it supports an external antenna (this removes the Alinco DJ-S11 from consideration unless it is modified for external antenna). Most HTs have greater transmitter power when connected to the 12-volt battery of the chase vehicle than when it runs off its own internal battery. Rather than make a power cable, use the 12-volt cigarette lighter jack supplied with the HT (this assumes the HT is designed for 12-volt use and comes with a cigarette lighter adapter).

Magmount Antenna

An external magmount antenna for the HT is the only suitable antenna, as an internal antenna is blocked from most APRS transmissions. Where the antenna coax enters the car, a pass through is needed or else the wind whistles inside the car from the partially opened window.

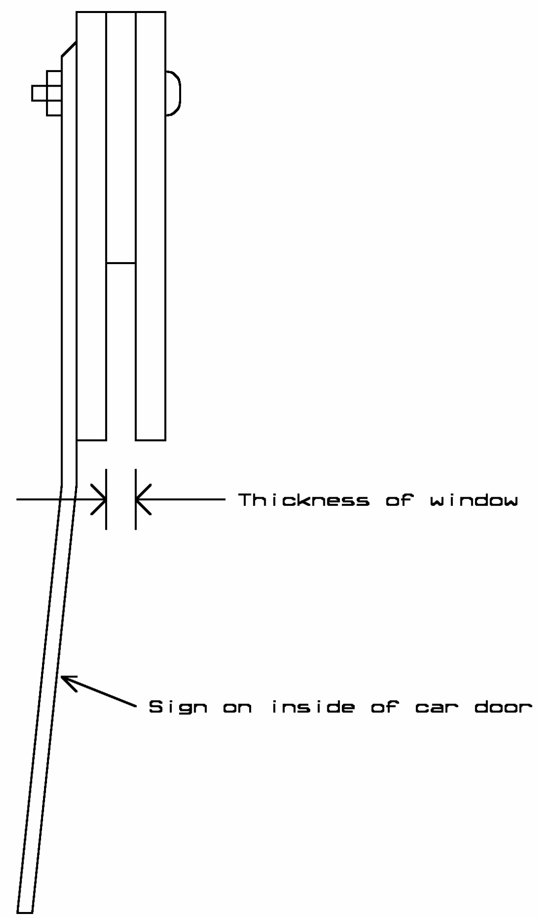
Window Pass-Through

Example of Window Pass-Through on Vehicle – *Sign reads "STOP Emergency Exit Only"*

Materials

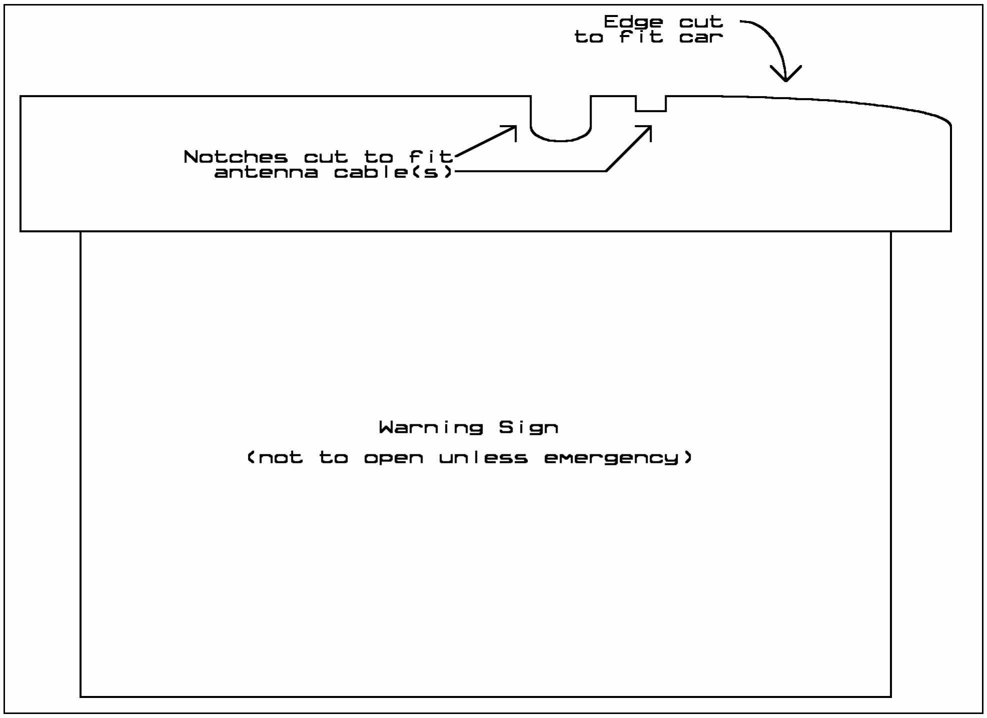
- 3/8" thick plywood[B]
- #6-32 hardware
- Wood construction glue
- Spray paint
- Laminated sign[C] (if desired)
-

Procedure



Window Pass-Through Diagram

- √ Measure the width of a car window the antenna cables are to pass through
- √ Cut two strips of plywood to measure the width of the window and three inches deep
- √ Cut a third strip of plywood to measure one inch deep and the length of the window
- √ Glue and clamp the wood together, sandwiching the narrow strip inside the two wider strips and all pieces flush at the top
- √ Measure the diameter of the coax cables that must pass through the window
- √ At the top of the pass-through, cut and smooth notches in the wood for the coax cables
- √ Paint the pass-through
- √ Drill two holes in the pass-through for the bolts
- √ Note: Center the holes in the narrow inner piece of plywood and two inches from the sides (I don't trust the glue to hold-up, so I also add bolts)
- √ Bolt the glued plywood pieces together with the sign
- √ Note: The sign must be bolted to the inside face of the pass-through or else winds generated while driving will eventually rip it off



APRS +SA
The letters in APRS + SA stands for Automatic Packet Reporting system, plus Street Atlas. There are many versions of APRS, including some that do not require Street Atlas. Other mapping programs can be used, including maps that you generate yourself. This book focuses on using APRS +SA because it has become something of a standard and because of its usefulness.

All versions of APRS can be found at the Tucson Amateur Packet Radio (TAPR) website at http://www.tapr.org. Download and install the Shareware version on a PC or laptop.

Street Atlas
There are many versions of Street Atlas. Versions beginning with version four (and possibly earlier versions) are capable with APRS +SA. The newer versions have more complete road information. However, an older version still may be actuate enough for chase, which may save you money.

Using A Monitor
If laptop visibility is an issue (for example, when glare makes the laptop's LCD screen unreadable), consider connecting a monitor to the laptop's video port. Vans, with lots of space between the driver and passenger, are examples of cars where monitors can be used.

1.1.3. TVNSP Suggested APRS Setting

These are the APRS setting most frequently used by the TVNSP Chase Team. Note that APRS is an evolving program. Settings and the names of the settings change from time to time, but this guide will get you through most of the hurdles.

SETUP Menu
Main Dropdown Menu
Callsign: Enter your callsign
Lat: Enter your latitude in decimal degrees

Long: Enter your longitude in decimal degrees
Registration: Enter your APRS registration number

Note: If west of the Prime Meriden (like the US), the precede the longitude with a **negative sign**

Optional, if not programmed in the TNC
Symbol Button: Select symbol from the Primary Symbol Table

Via: RELAY,WIDE3-3

TNC Configuration
Select your TNC's initialization settings
Note: INITKAM works for KPC2
INITKPC works for KPC3
INITVHF for other TNCs

Port 1 TNC
Baud: Enter your TNC baud rate (normally 4800)
Port: 1 Com1
Note: This is assuming your TNC is connected to COM Port 1.
Mode: Pico

Note: Ignore **PORT 2 GPS** if using the KPC3+ GPS Port
Port 2 GPS
Baud: 4800
Port: 2 Com2: (or 1 Com1: if using a HSP)
Mode: NMEA
Click the **Smart** button

Click **Enable Transmit TNC/TCPIP** option
Note: At least one chase vehicle should enable this feature, it lets Mission Control locate the position of the Chase Team

Click **Smart** button
Note: Accept the defaults to begin with

Close **Main** Window

SETUP Menu
Lists Dropdown Menu
Click the **Only Track This List** option

Close **Lists** Window

SETUP Menu
Program Dropdown Menu
Click **SA4** (or your version of Street Atlas) option
Click **Turn Scrolling On After Menu Action On Position Page** option

Note: The above option is called **Turn Pause Off After Menu Action On Position Page** in older versions of APRS.

Click the **Position Page Update On New Positions Only** option

Fill information in **Agent Character** window to use a text-to-speech add-on like Peedy

Close **Setup** Window

COMMANDS Menu
Map Dropdown Menu
APRS Tab
Click **Include Track Lines** option
Click **Bring SA To The Front On New Map** option
Click **Include Callsigns** option
Click "**Locate" Functions ignore Fixed Center** option

Click the **OK** button

COMMANDS
Clear
Click **Remove Lat/Long = 0 90 180** option

COMMANDS
Click **Start Street Atlas** option

If using a Tripmate GPS receiver, then complete the following step
COMMANDS
TNC Commands
Tripmate
Select either
ASTRAL To TNC Port
Or
ASTRAL To GPS Port

Note: The Tripmate does not come with a power switch. If the Tripmate is connected to the KPC3+ GPS Port, then select ASTRAL To TNC Port. If the Tripmate is connected to the laptop, then select ASTRAL To GPS Port. Sending the text ASTRAL to the Tripmate over its comm port starts it.

1.1.4. Notes On TVNSP Suggested APRS Settings

SETUP/Main
FCC regulations require all amateur radio transmissions to identify themselves with a callsign at regular intervals. Every APRS packet that is transmitted with the callsign prefixed. The latitude and longitude is the initial location of the APRS station and is the position reported if the GPS is left off when APRS is started. A negative longitude is the standard for a west longitude as a positive longitude is the standard for east longitude. Many APRS stations in the US are displayed in the Asia because longitudes are not preceded with a negative symbol.

SETUP/Main/Port 1 TNC and Port 2 GPS
The most effective APRS stations appear to use two separate comm ports for the GPS and TNC as opposed to a hardware serial port (HSP). The HSP electronically switches one comm port between

two serial devices. Note, the serial port for the GPS can be located on the KPC3+ TNC (version 8.3 EEPROM), rather than on the laptop. Currently, most packet traffic occurs at 1200 baud (although the technology for 9600 packet does exist[D]) and NMEA compliant GPS receivers operate at 4800 baud. Setting the TNC mode to Pico, the GPS to NMEA and clicking the smart button activates smart beaconing. In smart beaconing, positions from the GPS are sent less frequently as long as there is no change in the speed and direction of the chase vehicle. When the speed or direction does change, an immediate position report is transmitted notifying Mission Control the Chase Team has changed directions. Smart beaconing reduces the amount of packet data required to specify the position of the Chase Team. When using Smart Beaconing, program the TNC to CLEAR the LT Buffers after each packet to avoid sending old position reports.

SETUP/Main/TNC Configuration

TNC configuration files are text files containing TNC commands for each particular TNC. When started, a PC running APRS puts the TNC into the proper setting by sending the commands in the TNC's initialization file to the TNC.

SETUP/Main/Via

Note: Consult with your local APRS community. Some locations do not support RELAYing. A WIDE3-3 setting lets packets from the near spacecraft be relayed three times through digi-peaters.

SETUP/Program

Click the Turn Pause Off After Menu Action On Position Page (in older versions of APRS) or Turn Scrolling On After Menu Action On Position Page (in newer versions of APRS) prevents the position reports from scrolling down automatically as packet reports come in. Selecting to Position Page Update On New Positions Only prevents APRS from updating the map with every position report it receives (this includes position reports from stations other than the near spacecraft). If the map is updated every time someone reports a position, you'll lose track of the near spacecraft.

Several text to speech programs are available for APRS. Peedy is one popular one. Peedy is a parrot program that moves its beak when speaking the text it is receiving. Peedy also moves his head around between text packets. Text-to-speech agents are popular with the civvies that have never watched the tracking of a near spacecraft.

Other Microsoft Agents include, Genie, Merlin, and Robie. They can be found at http://www.microscoft.com/msagent/

COMMANDS/Map/APRS Tab

Track lines show the past location of the near spacecraft. Without track lines only the current location is seen, and without the context of a history (previous flight path). Bringing SA to the front keeps the Street Atlas map in the front window. If the map is not brought to then front, then the Chase Team must click to bring the map to where you can see it. Displaying the callsigns of tracked objects is optional, but useful when trying to identify chase vehicles.

COMMANDS/Clear

Removing Latitudes and Longitudes containing 0, 90, and 180 degrees prevents a bad GPS coordinate from sending the map to a location off the west coast of Africa. Bad coordinates can occur when a GPS loses its lock or when an APRS' GPS has not been started. In which case, a latitude and longitude of zero degrees is sent.

COMMANDS
By selecting to start Street Atlas, APRS opens Street Atlas when you start APRS. There is no need to start both programs.

1.1.5. Chasing With APRS +SA

Now that APRS +SA and Street Atlas are installed and configured, here are the directions for starting APRS for the near space chase.

Start APRS, which also starts Street Atlas
Click **SETUP**
Click **Lists**
Enter callsigns to be tracked in the **Keep All Tracking Data** column

Click **Maps** Tab
Click **Select Maps** button
Click **Maps** in dropdown menu
Click **Map3: Map3**

Click **Maps** Tab
Click **Select Maps** button
Click **Maps** in dropdown menu
Click **Map4: Map4**

Click **Track** tab
Click **ENABLE TRACKING** option
Click **Auto Map Update** option

Enter callsigns to track in the **<Callsign** window
Or
Double click callsigns to track in either the **Stationary** or **Moving** columns

Now the stations selected are displayed on the SA map

Click **Position2** tab
Right click on callsign of near spacecraft
Click **Turn ON Range/Bearing Update** option
Click **My Location** option

Click **File**
Click **Start Logging TNC Data**
Enter name for log file in the window and click the **Open** button

After recovery of the near spacecraft, stop logging TNC data
Click **File**
Click **Stop Logging TNC Data**

1.1.6. Chasing With Balloon Track

Rick von Glahn (N0KKZ) of EOSS has done it again. His latest update to Balloon Track for Windows not only predicts the flight of a near spacecraft from winds aloft data, but also displays a wealth of information during the mission. Rick has written a manual for Balloon Track. The manual along with the program is available at the EOSS website, http://www.eoss.org. Select the Downloads option. Here are just three of many reasons to track near spacecraft with Balloon Track for Windows.

Dash Board

Balloon Track has a Dash Board window displaying such information as, altitude, course and speed of the near spacecraft, and bearing, range, and distance of the near spacecraft from the tracking vehicle. The questions asked most frequently after, "Where is the balloon?" are, "How high is the balloon?", "Where is the balloon heading?", and "How fast is the balloon moving?". All this information is quickly accessible from Dash Board and not APRS, which is a more generic packet radio program and not fine tuned to the needs of amateur near space exploration like Balloon Track.

To get to the Dash Board, do the following

- √ Start Balloon Track for Windows
- √ Click on the **Packet Data** menu
- √ Select P**acket Terminal** from the drop down menu
- √ Click the **Dash Board** button

Flight Analysis

Another useful window is the Flight Analysis window. Flight analysis much of the same data as found in the Dash Board, but also includes selectable graphs of flight characteristics over time like, Attitude, Ascent Rate, Speed, Range, Track, and Course. In addition, trends in vertical speed, horizontal speed, and course are also displayed.

To get to the Flight Analysis, do the following

- √ Start Balloon Track for Windows
- √ Click on **Packet Data** menu
- √ Select **Packet Terminal** from the drop down menu
- √ Click on the **Flight Analysis** button
- √ Click **YES** to Clear Data File

Updated Predictions

No flight is launched without first making a prediction of its flight and recovery zone (unless it is a disposable flight). Once launched, the near spacecraft is traveling winds that are different than those used to predict its recovery zone. Wouldn't it be great if new predictions could be made from the winds experienced by the near spacecraft as it travels through them? Rick has added just this feature to Balloon Track.

To activate this feature, do the following

- √ Start Balloon Track
- √ Click on **Packet Data** menu
- √ Select **Packet Terminal** from the drop down menu
- √ Enter the callsign of the near spacecraft in the **Target Callsign** field
- √ Click the **Target Capture** button

After the balloon bursts, click on the **Extract Data** button

1.1.7. Communications

The most popular band to chase with is two-meters, since almost every ham radio operator owns one and two-meter repeaters are plentiful. Most hams only have a handheld to take on chase, rather than a portable, so they require a magmount antenna on their car. Coordinate which frequency (or frequencies) to use several days before launch. If you'll be passing close to a repeater, use that frequency to increase the participation in the chase. Even those staying at home will be listening in on the excitement of the chase. Of course you'll need permission to use the repeater if it doesn't belong to your club and you’ll need to use the repeater for a while (I have yet to see or hear permission to use a repeater denied).

Chasing the near spacecraft may lead the Chase Team away from the coverage of a repeater, so have a simplex frequency picked out for the chase. One member of the Chase Team should be responsible to determining when to change frequencies. There's nothing worse that having multiple people trying to decide when to change frequencies. This Frequency Coordinator needs to be familiar with repeater coverage and frequencies, as you may pass through several repeaters during a flight.

After selecting the chase frequency, make sure all radios have the chase frequency programmed into it. Most hams forget how to program their radios and seldom carry the radio’s directions around. It would be a good idea to have a programming party for members of the Chase Team many days in advance of the launch. Decide on a simplex frequency and a set of repeaters to use and program them into all the radios. If possible, program chase frequencies into the same memory locations to simplify changing chase frequencies.

Other Forms Of Communication

Citizen Band (CB) And Family Radio Service (FRS)

Give some consideration to carrying a CB or FRS radio. Why? Not everyone interested in near space is a licensed ham. Of course amateur near space is a good reason to get a radio license, and you should mention this. But not everyone is going to earn his or her ticket. For those in the process of studying for his or her license, CB or FRS is the only reasonable way to chase a balloon. To increase support for your program, have someone carry a CB or FRS radio. Besides, FRS radios are getting very inexpensive and very popular.

Cell Phones

There are two audiences for cell phone use on a near space chase. First is those requesting official communications during the launch, chase, and recovery. For example, your FAA contact may ask for updates on the launch or flight. The cell phone is the best way for the Chase Team to contact them. The other audience is members of the Chase Team without any radio in their car and possibly the local media that may be interested in a status update during a chase (this happened once with KNSP). Keep in mind that more people own a cell phone than amateur, CB, or FRS radios.

Keep Everyone Informed

Speaking of communications, the Chase Team needs to use them. There’s almost nothing worse for the first time chaser than to drive after the other chase vehicles with no idea what is going on or why decisions where made. Remember that not all members of the Chase Team have an APRS tracker available. Most people really are interested in knowing the status of the balloon and chase. Update members of the Chase Team to status items like, the near spacecraft’s altitude, speed, and heading. The near spacecraft’s range and bearing from the Chase Team or whether or not the Chase Team is ahead of the balloon is also something people like to hear. When the balloon enters the jet stream is another interesting tidbit to know. Informing the rest of the Chase Team of the predicted time to burst or landing or the updated predicted recovery zone is some more useful information.

It’s not just status information that is important, but also the reasoning behind a decision is also important. Missions don't go as predicted, there's always some kind of change. For example, sometimes the predicted recovery zone changes and there is a corresponding change in the driving directions. Think of chase as on-the-job training. Explaining the reasoning behind a change in plans teaches future chase team leaders how to lead the chase. Not only that, but an important factor for a decision may have been left out. Someone listening in may catch it and prevent a wasted side trip. Keep the Chase Team informed if you want them all back to chase another day.

Using Multiple Bands
If a vehicle carries mobile APRS with it’s own radio and a multi-watt mobile two-meter radio for communications, there is a good chance communications from the two-meter mobile rig will desense the APRS radio. For these situations, select an alternate 440 frequency for the Chase Team to use.

1.1.8. Safety

The standard safely rules apply when chasing near spacecraft; everyone wears their seat belts and the driver must keep a safe distance behind the car ahead (at least two seconds is recommended).

Laptops In Accidents
The position of the laptop running APRS is an important safety issue. The airbags in a car isn’t concerned with the location of a laptop. If an accident should occur, the deployment of the airbag can hurl the laptop with great force. Place laptops where the Navigator can see them but not where an air bag will turn the laptop into a two-pound projectile.

A Safe Laptop

Just A Driver Won’t Do
You can tell when the driver is looking at the laptop by how the car drifts out of the lane. Look at how cell phones are becoming a factor in auto accidents. The person who is driving the automobile (the pilot) is doing too many things to be talking to the rest of the Chase Team and watching an APRS display.

Don't Track and Drive!

The pilot really needs someone else (the navigator) to perform navigation and communication functions. Don't add to the statistics by trying to run both communication and navigation while you drive the car. Try to have at least two people per vehicle if there's a laptop or cell phone onboard.

Pilot and Navigator

Spare Tire And Tools

Every vehicle needs to carry simple repair tools. The extra oil, radiator fluid, or a spare tire and jack may be just the thing to keep a chase from going sour. Just ask TVNSP Chase Team what it's like to have a flat tire during chase (at midnight no less!).

The Flat Tire

1.2. The Organized Chase

1.2.1. The Chase Leader

Someone really needs to coordinate radio frequencies to use and when to change to them, and another person should coordinate the roads to take during the chase. By laying out these functions, someone is responsible for monitoring two important aspects of the chase. A clearly appointed person will reduce the uncertainty of where to turn or what frequency to use during a chase. Note, I'm defining two functions for the Chase Team, but they don't need to be tasked to two separate people. One team member can fulfill both roles.

1.2.2. Bring Something To Eat And Drink

Members of the Launch and Chase Team have been up for a couple of hours by the time the chase begins. Their energy levels may be sagging a little bit by now (but you may not notice it because they tend to run on adrenaline during a mission. Bringing a snack and drink for the chase can help keep those energy levels high.

1.2.3. Document On Windshield

Who can you afford a HUD (heads up display) in their car? The author finds it incredibly useful to bring a dry erase marker on trips, including chase (it’s funny how such a simple idea surprises people). Document information like frequencies or driving plans on the windshield where they can be found without having to dig around a pile of paper notes. Even if the information is sitting on the passenger seat, taking your eyes off the road to look at them increases the risk of driving. Of course you defeat the usefulness if the windshield is cluttered with factoids. Just write brief statements. After chase, wipe the windshield down with a Kleenex.

1.2.4. The Night Before Launch And Chase

Stopping right after launch to call the AAA or to correct a flashing oil light has a way of slowing down a chase. Do the following before a launch

√ Check the car’s fluids

- √ Check tire pressure
- √ Fill the gas tank

1.3. Mission Control

There should be a controller just for the flight on the amateur radio repeater. This creates a mission control position allowing those who don't chase to be very involved with the flight. The person selected as Mission Control should be familiar with the flight procedures and balloon prediction. A flight may be launched before the next winds aloft report is available, but may recover after its available. Mission Control should know how to run the prediction software (Balloon Track for Windows) and update the recovery prediction during the flight.

1.3.1. Function Of Mission Control

While not strictly necessary, a good Mission Control is invaluable. A Mission Control performs the following three actions in support of the Chase Team.

1. Ascent Functions
    - Give updated status reports on the near spacecraft
    - Monitors repeater traffic on the near spacecraft repeater

2. Guide Functions
    - Communicate with other individuals who know the area the Chase Team is traveling through
    - Consults maps of the recovery zone
    - Forwards information to the Chase Team

3. Recovery Functions
    - Makes new recovery zone predictions from current winds as they become available
    - Posts updated predicted recovery zones

Ascent Functions of Mission Control

Depending on how busy the Chase Team is, Mission Control may be in a better position to keep everyone informed on the near spacecraft's status. Mission Control is the ideal source for those listening to the chase and recovery on the repeater, but who are not otherwise involved with the mission. One of the best ways to get more people involved is to explain to them what is happening during the mission. That burden is not really appropriate for the Chase Team. If a radio repeater is part of the manifest on a near spacecraft, then someone at Mission Control needs to be tasked with controlling communications over the repeater. Occasionally they need to explain to listeners where the repeater is located and how to use it. In addition, Mission Control should monitor callsigns using the repeater to issue QSL cards after the flight. By the way, the QSL cards should be carried inside the near spacecraft.

Guidance Functions Of Mission Control

Mission Control is in a location that has large tables and no motion. So it is easier for Mission Control to consult maps that it is for the Chase Team. There are times when people listening to the chase on the repeater will be more familiar with the recovery zone or how to get there than anyone in Mission Control or the Chase Team. Mission Control needs to responsible for collecting this information and making it available to the Chase Team. This means Mission Control also needs to control who is speaking to the Chase Team. It is very confusing for the Chase Team that to get multiple and contradicting instructions over the radio.

Recovery Function Of Mission Control

Often new winds aloft reports are available after the launch of the mission. Mission Control is in the ideal location to run the new winds aloft reports through Balloon Track and report the new predicted recovery zone. The Balloon Track program should run another set of predictions should be run after the balloon bursts with the Extract feature of Balloon Track. APRS allows positions to be posted. Mission Control should post the updated recovery zone after the balloon bursts. Chase Teams will see this posted location, making it easier to drive there (as opposed to being told where to drive).

How To Post A Position In APRS

To post an icon at the predicted recovery site of a near spacecraft, Mission Control must send a position report in APRS. These directions explain how to post a location.

In APRS, click the Message Screen
Enter the location packet in the message window in the following format

!3602.654N/11149.559W-Recovery Location

Where:
The position report begins with an exclamation point (!)
No Space
Latitude is given in the format of degrees, minutes, decimal point, fractional minutes,N
A slash and no Space
Longitude is given in the format of degrees, minutes, decimal point, and fractional minutes,W
A Dash (-)
A Text message, not to exceed 43 characters

If the above position report is sent, a message stating Recovery Location would show up at the Grand Canyon.

1.3.2. Good Locations For Mission Control

Depending on the ultimate function of Mission Control, it can be located either at someone's ham shack (usually includes a well equipped APRS station) or in a more public location. When located at home, it's easier for that person who lives there, especially if the launch is very early. When located at a more public location, it's easier to get civvies involved with the program. Good public locations are at malls, schools, museums (like aerospace museums), or parks. Get permission top set up Mission Control in a public location, as there's nothing more embarrassing for a near space program than to have someone ask you to leave. In a public setting, make sure power is available. Determine if the program will have to bring its own tables and chairs. Locating Mission Control in a more public location requires the launch to occur later in the day, unless Mission Control has a captive audience likes scouts or students getting extra credit for attending that early in the morning. When located in a public space, give visitors a chance to talk to the Chase Team. It may be necessary to assign someone to take the role of Public Affairs. Display materials showing the kind of environment conditions the near spacecraft is experiencing. Photographs and video are great to have on hand.

Test a private Mission Control before a launch. Test it by monitoring APRS traffic for a couple of hours. Even have someone drive around with the near spacecraft. Set up a public Mission Control the night before launch. Then give it test by monitoring APRS traffic for a while.

1.3.3. Equipment Needed For Mission Control

The following items are needed for a Mission Control (read, an APRS station). If Mission Control is going to be portable, then keep the equipment in plastic tubs (when possible) along with a laminated list of equipment to verify nothing was left behind.

- PCs or laptops
- TNC with spare batteries or a wall-wart
- Radio with extra battery of wall-wart
- Extension cord
- Power strip
- APRS on PC
- Maps
- Documentation from the FRR

2.0 The Recovery

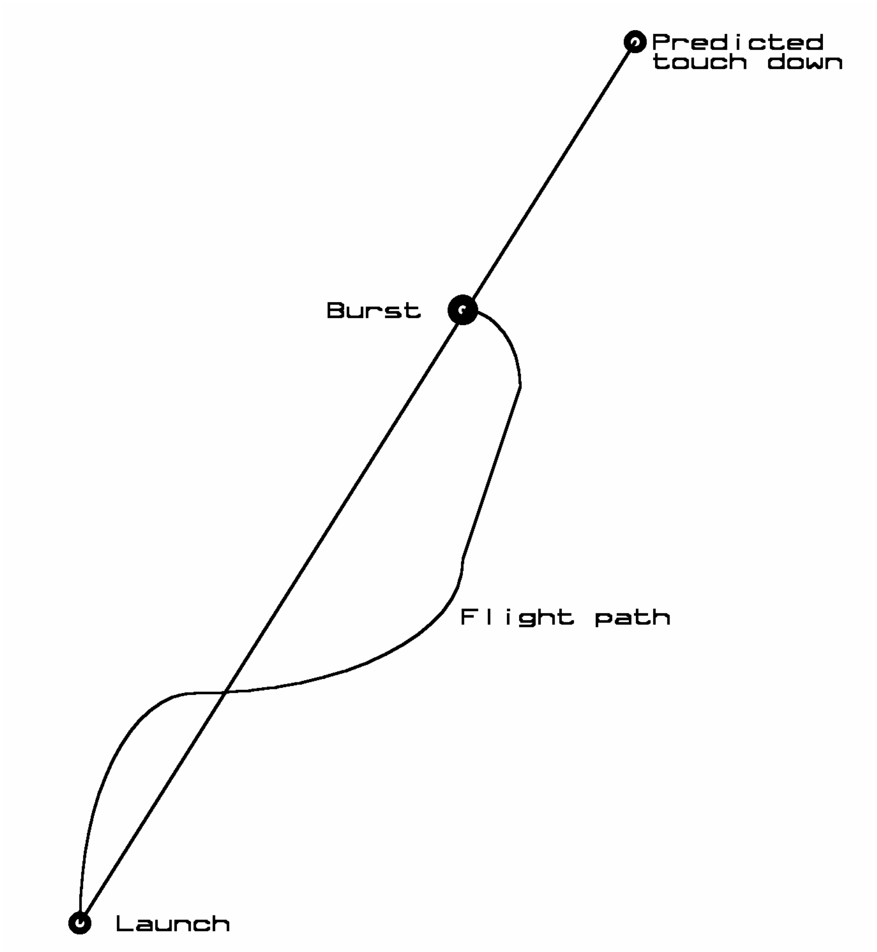
The balloon has now burst, and is on its way down. Initially the near spacecraft descends at speeds in excess of 100 mph, even though the parachute is fully opened! Now the Chase Team becomes the Recovery Team and has about an hour before the near spacecraft touches down.

2.1. Making The Final Prediction

The true winds aloft are never as they are predicted. On Street Atlas you will notice the near spacecraft deviating from the predicted flight path. This is to be expected, so don't worry when you see it. However it does mean that your driving plans will have to change to an extent.

2.1.1. Making The Final Prediction For Chase

Either let Balloon Track make a prediction based on the balloon's ascent or make a prediction manually. Click the Extract Data button of Balloon Track to make a prediction based on the wind profile determined by the balloon's performance. For a manual prediction, take a line from launch site to burst point, and extend it out 50% farther. This method makes the assumptions that the average descent rate is twice as great as the average ascent rate and that the wind profile doesn't change significantly over the flight. These two assumptions are quite reasonable and helped KNSP make updated predictions for the Recovery Team. The ascent and descent profiles for the near spacecraft are more accurately determined after the first flight.



The 50% Method

2.1.2. Making The Final Prediction For Hiking

If the Recovery Team is lucky, they will have GPS data from the near spacecraft as it lands. However, if there's any hills or mountains in the recovery zone, the Recovery Team will get a last GPS report from the near spacecraft when it is still some distance above the ground. Instead of hiking to the last know position, take into account what the surface winds will do the descending near spacecraft. Ask yourself, “What did the near spacecraft do on the way up?” For instance, did it change its direction of travel at a particular altitude? What ever it did on the way up it will do on the way down. You may have a last report of the near spacecraft traveling north at 5,000 feet, but if the traveled west for the first 4,000 feet, then expect to travel west from the last known position. As you get closer to the near spacecraft, look into the current surface winds. A valley can force a change in wind directions that wasn’t seen at launch.

2.1.3. Last Word On Updated Predictions

Now is probably the most dangerous time of the chase. Everyone will want to rush to the landing site. This is one justification for being close to the recovery zone before stopping to wait for balloon burst. By being close to the recovery zone, the final chase is more leisurely. So avoid stopping early during the chase and don’t be upset if the near spacecraft lands before the Recovery Team gets there. That said, the KNSP Recovery Team has often been less than a mile of the landing near spacecraft. This is close enough to visually observe the landing. In one particular instance in October 1998, the KNSP Recovery Team observed the near spacecraft under its parachute at an altitude of 2,000 feet

AGL and drifting along a county road. The team continued down the road for less than a mile where Dan Miller (KE4SLC) was able to jump out of his car and catch the balloon as it landed. I do not believe this has happened for any other near space flight. It was quite amazing to see.

Now that you have finally caught up with the near spacecraft again, it's time to take a hike and get your equipment back. Suggested here is a list of equipment to bring and how to make the final recovery.

2.2. What To Take On Recovery

They can tell you're a nerd from a mile away when you chase near spacecraft properly. Here are some suggestions on what to take when you chase. Some of them are very important, so please do not skip this section.

2.2.1. Recovery Chic

You won't believe the places a near spacecraft will recover. Ticks, thorns, and poison ivy are just a few of the wildlife waiting for you at recovery. The clothing you wear can make the difference between having an adventure or having a miserable time.

Suggested Wear
A good pair of boots makes the hike to recovery safer for your feet and ankles. A pair of hiking boots with ankle support helps out when crossing rough or steep terrain. Remember, the near spacecraft is under no obligation to recover on paved roads or sidewalks. Always wear long sleeve pants on chase, even if it's a hot summer day. Make sure the pants are durable enough they won't rip a part when you walk through a thorny patch. Not only do long pants keep your legs from being ripped up, they also give protection from Lyme disease and Poison Ivy. If you get either of these problems, the recovery will be very memorable. Even with long pants, do a tick check after recovering the near spacecraft. Hats. If you're hiking any distance on a sunny day you'll need the sun protection. Getting heat stroke is another way to create a memorable recovery experience. If I sound a little paranoid, I am being a little paranoid (only a little though). Having suffered through poison ivy and Lyme disease, I can tell you how perfectly miserable they can be. There's no need for either of them to be the results of a balloon chase. The suggested clothing items aren't very expensive, and in fact you probably already have them. So wear them on chase.

Nice To Have
Here are two other items found to be useful during chase. First is a pair of rain or mud boots. Several KNSP missions recovered in muddy farm fields. On one mission, members of the Recovery Team spend over ten minutes cleaning the mud from shoes before they could get back into their cars (that means we were ten minutes late for lunch). From that point on, several of us carried an inexpensive pair of rain boots in the trunks of our cars. The rain boots are tall (calf high) and cost $10 at a farm supply store. Another nice item to have is a vest with pockets. Most members of the Recovery Team are carrying an HT and GPS with them. Pants aren't very comfortable when their pockets are filled with bulky items like these. Something like a fisherman, hunter or photographer's vest is ideal.

2.2.2. The Recovery Bag

It's easier to return the near spacecraft to the chase vehicle if you can stuff the parachute and balloon into a backpack or knapsack. By why limit this recovery bag to just hauling parts of the near spacecraft back after it's found? A backpack filled with recovery gear should be put into one chase vehicle. The recovery bag is also a great place to store your snacks and drinks. I recommend the following equipment be packed into the recovery bag.

- Tree spikes
- Limb Saw
- Nylon cord
- Fish Weights
- Pocketknife or scissors
- Film Changing Bag
- Nylon Mesh Laundry Bag
- Compass
- Binoculars

Tree spikes, a limb saw, nylon cord, and fish weights are tools for recovering a near spacecraft caught in a tree. Be aware that in National and State Forests, you probably won't be allowed to cut limbs from a tree. In that case you will rely on climbing the tree or using a fish weight on the end of a cord to pull the near spacecraft lose. Bring a pocketknife or scissors to cut load lines. In the field it is easier to cut the lines than to try and untie them. Save untying knots for home, after you've recovered the near spacecraft and had lunch. Never open cameras in the daylight to retrieve their film. The cold of near space may have jammed the film rewind function of the camera. Use the film-changing bag when removing the film from a camera in the field. While a roll of film isn't expensive, the cost or replacing the image on the film may be impossible. The film-changing bag is your insurance. At times, it is desirable to remove some items from inside the near spacecraft at the time of recovery, in the field. Please don't be a litterbug. Upon opening a near spacecraft in the field, Styrofoam peanuts will blow all over the place. You should reuse the clean Styrofoam peanuts and try to keep the mess down. Use a nylon mesh bag to collect the Styrofoam peanuts inside the modules of the near spacecraft. A GPS receiver indicates heading only when it is moving. A compass indicates headings independent of whether it is moving. So toss an inexpensive compass into the recovery bag. Binoculars let Recovery Teams cover an area faster than they can on foot. They also eliminate false sightings without spending the time to investigate them on foot. When possible, get up to a high spot and you can scout around with the binoculars.

Nice To Have
The following items would be nice to carry into the field.

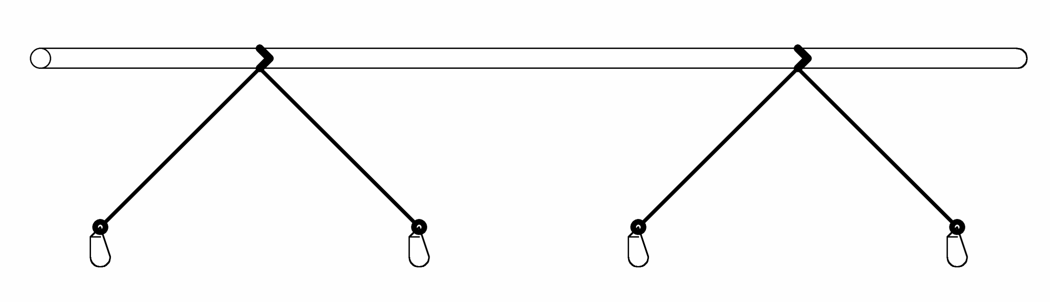
- Walking stick
- First aid kit
- Camera
- Foxhunter Antenna For a HT
- Amplifying Microphone (Big Ear)
- Module Carrier (to be built)

As any hiker can tell you, a walking stick is useful for rugged terrain. That extra foot on the ground helps prevent you from tripping up. Pick up a basic first aid kit from an outdoor supply store. Each recovery is unique and there should be a record the condition of the recovered near spacecraft and it's terrain. If a camera is tossed inside the recovery bag, be sure the camera lens is covered. If not, then the lens can be scratched during the hike to the near spacecraft. Alternatively, the camera can be carried on a camera strap. However, if you have ever had the opportunity to carry a swinging camera with you on a hike, you'll realize how unpleasant that can be as the heavy metal camera slams into your chest with each footstep. Fortunately a restraining belt is available at photography and outdoors stores. The nylon belt is adjusted to size and wraps around your chest. A neoprene disk in the belt traps the camera between your chest and the neoprene pad, preventing the camera from swing around. Best of all, the neoprene pad lets you pull the camera free, where it is instantly available to take photographs. There's no need to open the recovery bag just to pull the camera out.

If APRS onboard the near spacecraft has failed but the near spacecraft is still transmitting, then radio direction finding (RDF), or foxhunting is the only reasonable method to find the near spacecraft. Foxhunting antennas for HTs are available. At least one should be carried on each mission as it is better to have carried one and not needed it that is to leave one at home when your needed it. There's no need to carry RDF equipment in the recovery bag. Just store the RDF equipment in the car until it is needed. It's beyond the scope of this book to teach you to foxhunt. There are books that go into detail that you should reference. Basically foxhunting involves finding several azimuths to the transmitter from several locations. The intersection of these azimuths indicates the location of the hidden transmitter. EOSS has found they get a lot more support in recovering the near spacecraft if they let foxhunters look for the near spacecraft first. There's no reason foxhunters can't be involved with a chase and recovery when APRS is working. Letting them practice on a perfectly good near spacecraft trains them for those times when the near spacecraft may not be perfectly good. A near spacecraft on the ground may hide itself with bushes, tall grasses, or trees. Even when you are only 100 feet (which is a typical precision of a GPS receiver) away from such a hidden near spacecraft, you will have difficulty in locating it. The audio beacon shines when foliage hides the near spacecraft. Just listen for the 90 dB beep! You may want to add an amplifying microphone (Big Ear) to your recovery pack, in case you are still too far away from the near spacecraft to hear it. Besides, using a Big Ear is a really cool thing to do!

The Module Carrier

After the near spacecraft is recovered, it needs to be carried back to the chase vehicles. It takes two hands to safely carry each module back. This means each person with a module has no free hands during the hike back. Depending on the terrain, this can be a dangerous situation that leads to injuries and damaged modules when someone slips or falls. I myself have slipped while carrying modules, once on a mountain trail and another time while walking on level ground. I've come up with this idea (but have not yet tested it) and believe it will help prevent accidents, which may damage a module. The idea is to mount the modules to a stick that can be carried over one shoulder or between two people.



The Module Carrier

Materials

- ¾" or 1" diameter wooden dowel (broom handle)
- 200# test Dacron line
- Four snap swivel bearings
- Thin heat shrink tubing, large enough to cover a knot in the Dacron line
- Four wide rubber bands

Procedure

√ Cut the dowel to a length between four and six feet

- √ Set two modules next to each other, with about a one foot gap between them
- √ Mark on the dowel the location where the module's spilt rings touch the dowel
- √ Drill four small holes through the dowel for the Dacron line to pass through
- √ Cut four pieces of Dacron line to a length of three feet each
- √ Melt the cut ends to keep them from unraveling
- √ Find and mark the center of the lines
- √ Pass each line through one hole in the dowel and center the lines
- √ Tie two knots in each line trapping the lines in the dowel
- √ Cut eight pieces of heat shrink tubing, one inch long
- √ Slide a length of heat shrink tubing on to each end of the Dacron line
- √ Tie snap swivels at the end of each Dacron line
- √ Slide the heat shrink over each knot and shrink

Using The Module Carrier

- √ Wrap the Dacron lines around the dowel before taking the carrier out
- √ Use the rubber bands to keep the lines from unwinding
- √ Removed the modules from the parachute and balloon
- √ Note: The parachute and balloon should be carried in the recovery bag
- √ Latch the snap swivels to split rings of each module

2.2.3. HT and GPS

Anytime recovery crews divide up and are out of sight, they must carry an HT. Never let anyone separate from the group without having some way to keep in contact. Not only will radios help locate a lost or injured team member; they also get the entire Recovery Crew to the near spacecraft quickly once it is found. Think how frustrated you'd be if the near spacecraft was found and brought back to the car before you had a chance to see it or if you had to wait for someone to come back from the bush after the near spacecraft had been recovered an hour ago.

Bring a GPS receiver if the near spacecraft has recovered in an area like a forest without hiking trails. You'll be surprised how fast you can get turned around walking among trees with no external source of direction. Before leaving the cars and starting the hike to the near spacecraft, program two positions into the receiver. The first is of the chase vehicles. This is especially necessary if the hike is going to be long and it might be difficult to find the cars again. Error on the side of caution and mark the location of the car if there's the slightest chance of possibly getting lost. The second location is the last known location of the near spacecraft into the GPS. Depending on the last recorded position of the near spacecraft, the GPS can then lead an on-foot Chase Team to the near spacecraft's location. Otherwise it gives them a starting position to begin the search for the near spacecraft.

Programming Positions Into A Garmin Handheld GPS Receiver

The Garmin series of handhelds are probably the most popular GPS receiver. Here's how I add a new location to my Garmin GPS48, which should be similar to other Garmin GPS receivers

- √ Press the MARK button a second time to record your current position
- √ Press the Up Arrow button to the name field
- √ Press the ENTER button to edit the name field
- √ Use the Right Arrow button to select the next character field
- √ Use the Up or Down Arrow button to change each character
- √ Note: Use a meaningful name, as you'll have to select this location form the GPS receiver's waypoint list
- √ Press the ENTER button to exit the name field

- √ Press the Down Arrow button to select the save option
- √ Press the ENTER button to save location
- √ Press the PAGE button until the GPS is on the Main Page (MAIN MENU)
- √ Press the Down Arrow button to high the NEAREST WPTS option (nearest waypoints)
- √ Use the Down Arrow button to highlight the saved location
- √ Press the ENTER button to select the waypoint
- √ Press the Down Arrow button to enter the latitude position field
- √ Press the ENTER button
- √ Press the Right Arrow button to move the cursor to the latitude numeric value that needs to be changed
- √ Press the Up or Down Arrow button to change the numeric value
- √ Continue pressing the Right Arrow button to enter the longitude position field
- √ Press the Right Arrow button to move the cursor to the longitude numeric value that needs to be changed
- √ Press the Up or Down Arrow button to change the numeric value
- √ Press the ENTER button
- √ Press the GOTO button
- √ Use the Down Arrow button to highlight the saved location
- √ Press the ENTER button to select the waypoint
- √ Start walking and follow the compass rose to the last known location of the near spacecraft

2.2.4. Get Permission Before Going Into The Field

Chances are the near spacecraft has recovered on private property. If at all possible, contact the landowner before recovering the near spacecraft. However, there may be times when it lands in private property miles away from the owner or the landowner cannot be found. If a landowner cannot be found, then contact a neighbor and explain what you want to do. In some cases the neighbor can locate the landowner when you can't. When a landowner or neighbor cannot be located, KNSP has recovered the near spacecraft quickly. Do not leave the burst balloon or any other debris behind. Do not damage private property while recovering the near spacecraft. Close all gates that you opened. Treat private property like you'd want someone to treat yours.

2.2.5. Carry Snacks, Drinks, And A Hat

If the hike to the near spacecraft is any significant distance or the terrain is difficult, each Recovery Crew needs to carry something to eat and drink. Going on a hike is not the time to diet.

Recovery Crews need to keep their bodies functioning properly. Energy and hydration levels can drop fast when hiking. To keep the pace of the hike brisk and the recovery short, eat and drink during the hike to the near spacecraft. This is less of an issue for KNSP in Kansas, but a significant concern for TVNSP in Idaho with Idaho's rugged terrain. Most near space missions take place in summer months. Hiking significant distances in the sun without a hat is asking for trouble. Everyone on foot needs to bring a hat with a brim for protection from the sun.

2.3. Powering Down, Documentation, And Lunch

You've finally reached the recovered near spacecraft. Now what?

2.3.1. Site Documentation

The following applies if there is no immediate danger to Recovery Crews of the near spacecraft. Avoiding hazards takes precedence over site documentation. Before handling or moving the recovered near spacecraft, document the recovery. Most and perhaps all near space Recovery Crews record the recovery site. Its location is recorded in a GPS receiver and the location photographed. Record the condition of the near spacecraft photographically. Identify and damage experienced by the near spacecraft during the flight and landing (most damage is incurred during landing). This way any damaged incurred during the trip home can be separated from mission damage.

The way the near spacecraft is laid out can indicate its direction of movement. Seldom will the near spacecraft be positioned in a single heap of Styrofoam and fabric. More typical, the near spacecraft is laid out in a line, with the modules at one end and the parachute and balloon at the other end. Here are a couple more things to document.

- Is the balloon free of the parachute?
- Is there a debris field, was the near spacecraft dragged by the parachute after landing?
- Is there unusual damage, for instance, did the near spacecraft recover on a rock or fence?

- Are experiments in the positions expected, for instance, are droppers retracted and samplers closed?
- How many photographs does the camera claimed to have taken?
- Has the camera rewound the film?

Recovered Near Spacecraft

2.3.2. Power Down And Disassembly

You may want to generate a Power Down and Disassembly checklist for the near space missions. Here's a suggested checklist, similar to what KNSP and TVNSP has used.

√ Shut off audio locator beacon (While helpful in locating the near spacecraft, these beacons are a major pain to work close to)
√ Shut off power to modules (Main, Servo, TNC, and HT)
√ Disconnect link lines between modules
√ Disconnect the umbilical
√ Shut down the camera
√ Rewind the camera's film
√ Open camera and remove film in a changing bag
√ Collect experiments that need to be removed from the near spacecraft (Like biological samples)
√ Pack removed experiments into their storage and transport container (KNSP transported Petri dishes in an ice chest)
√ Cut the balloon loose from the parachute
√ Disconnect the parachute shroud lines from the top module
√ Roll up the parachute
√ Pack the parachute and balloon into the recovery bag
√ Scout the recovery area for loose materials (Pick after yourself)
√ Say thank you to the landowner and get their address (Send them photographs taken by the near spacecraft)

Once back to the cars, let anyone who couldn't go on the hike see the modules. I know I keep stressing this, make sure everyone who is present see the recovered modules. On my first chase I arrived a little late and didn't get a chance to go recover the capsule and not much of a chance to see the recovered capsule. Let everyone see the equipment and answer questions about how it works and how it was recovered. You never know when a new chase crew will become one of your greatest crewmembers or begin designing their own modules to launch.

Outstanding in their field – *Loading the modules*

Afterward, load up the modules and other recovery equipment. If you recovered in a muddy field, doff your mud boots and put on your clean shoes. Determine where the Recovery Crew wants to eat lunch and how to get there. Make sure everyone present knows how to get back to the main road. Be sure to ask who wants photographs.

2.3.3. Lunch

Ideally, lunch is at a restaurant located near a one-hour photo processor. Drop off any film at the processors and request enough copies for everyone. Inform the photo lab technician that these are photographs taken at high altitude where the skies will turn black. Some machines in photo labs attempt to balance out the colors on photographs. In that case, images with lots of contrast can end up being printed gray. Most of the Chase Team will probably want a copy of the pictures, so get a count and have enough copies made. After one near space mission, KNSP blitzed the Lawrence, Kansas Wal-Mart photo lab with copy requests. After dropping off our photographs, the lab was no longer one-hour. The photo lab was telling customers to expect their photographs in an hour and a half.

Lunch

Next, head on over to the restaurant. In some cases, KNSP and TVNSP crews have split up, with one group reserving room at the restaurant while a second group dropped off the film. There may be a bunch of you, be sure the restaurant can handle all of you. Ask for a location where tables can be pushed together and that is near an outlet, as you'll need power for the laptops.

Bring the following items to lunch (depending on what experiments were flown)

- Laptop
- Digital camera cable
- Thermochron reader
- Extra diskettes and labels
- Near spacecraft with Flight Data Recorder

I toss my digital camera downloading cable and Thermochron Reader into my laptop bag, so I can't forget them. The extra diskettes are for Recovery Crews who want their own copy of the data from the mission.

During lunch, KNSP and TVNSP crews do the following

√ Download digital photographs
√ Download Thermochron data
√ Download flight data
√ Copy APRS logs
√ Make diskette copies for everyone who wants one
√ Eat lunch!

I find these lunches to be one of the best aspects of the chase. It's a good meal with good company that has similar interests and now a shared experience. After lunch, if you borrowed a launch site, head back and finish cleaning up the site. Don't lose a good launch site by leaving equipment lying around all day.

Good To Know - An Introduction To Packet And APRS

There are several digital communication modes in use today. From the old Radio Teletype (RTTY) which sent simple text data at 60 words per minute with no error correction, to PACTOR used on HF radios, to packet radio. Before 1980, packet radio did not exist. In March of that year, the FCC granted amateur radio operators permission to transmit ASCII data over radio. Canadians were granted permission to transmit ASCII data over radio earlier and at the time of the FCC decision, were designing a protocol for what would become packet radio. Along with the protocol, A Canadian by the name of Doug Lockhart (VE7APU) was developing a device for transmitting and receiving packet radio. The device converted the binary ASCII text into a series of tones in a process referred to as modulating. The device keyed its radio and transmitted the tones. At the receiving end, a separate device received the tones and demodulated then, that is converted the tones back into binary-based ASCII. The process of modulating and demodulating signals is used to name the device, the modem (MODulate-DEModulate). The Canadians further when on to give this radio modem a new name, the terminal node controller (TNC).

By the end of 1980, Hank Magnuski (KA6M) of the California Bay Area developed his own TNC and began digipeating on two meters. Local amateur radio operators joined with Hank, forming the Pacific Packet Radio Society. Later other groups formed, including AMRAD and TAPR (more about TAPR, later). A popular networking protocol at the time, called X.25, was adapted to packet radio use. The modified protocol was renamed to amateur X.25, or AX.25

TAPR (Tucson Amateur Packet Radio) formed in 1981 to experiment with packet. Two members of TAPR developed their first successful prototype TNC on 26 June 1982. By 1983 they were selling a TNC of their own design, the TNC-1. TAPR went on to develop standard designs for TNCs in the TNC-1 and TNC-2. The TNC-1 that forms the basis for the majority of the TNCs we use today and the TNC-2 that was the first commercially available TNC kit available to the public. Today there are many TNCs on the market. The three TNCs mentioned in this book are the Kantronics KPC 3+, the Byonics Tiny Trak II and Tiny Trak III, and Dr. Clement's (now Spacecraft Kits) MIM.

Today you'll find packet on VHF and UHF radios communicating at 1200 baud. Compare this to the much older RTTY, which transmits data at only 45 baud. Packet can send the entire ASCII character set and binary files. RTTY is limited to the numbers, letters, and some control characters. The only digital communication mode older than RTTY is CW (Morse code).

APRS, the Automatic Position Reporting System, made modern amateur near space exploration possible. Early amateur near space flights relied on radio direction finding to recover capsules after they landed. Flight data collected during the mission was encoded on a radio carrier that had to be interpreted during or after the flight. The amount of data that could be collected was limited as was the flexibility in designing experiments for near space. Without APRS we wouldn't have as much detailed data about the flight as we can now have. Currently the National Weather Service relies on this old method of collecting and transmitting weather conditions from radiosondes to the ground.

Packet radio originally started out as a DOS program that displayed text data on a PC monitor. With the advent of APRS, this data is now displayed graphically. The difference between packet radio and

APRS is the same difference as between MS-DOS and Windows. They both work with the same data, but APRS displays the data in a graphical format that is more intuitive. The term APRS is only half descriptive. Not only is position data from a GPS receiver displayed graphically, but so are sensor data and messages. How the data is displayed on the monitor depends on how the data is formatted within the packet. Because data follows a defined format, each PC running APRS can quickly parse and display the data. This makes APRS a real-time method for displaying information. The series of rules used to format pieces of data according to their nature is referred to as a protocol. If you want to send APRS data in a way that it is presented correctly, then the data must be formatted according to the protocol for that data.

Bob Bruninga (WB4APR) initially developed the APRS protocol and a program for displaying data written in his protocol on PCs running MS-DOS in 1992. The Sproul brothers, Keith (WU2Z) and Mark (KB2ICI) developed the Macintosh (1994) and Windows versions (1996) of APRS. APRS centers around a map displayed on the monitor of a PC or LCD screen of a laptop. Most packets transmitted for APRS are displayed some place on that map.

Data sent over packet radio doesn't get transmitted just as you enter it on the PC. Depending on the length of the message or data being sent, it may be broken into shorter length blocks of data, or packets. Each packet is transmitted with information used to verify the content of the packet was decoded properly at the receiving PC. In some cases, corrupted packets can be corrected by this verification information. Each packet is preceded with the callsign and SSID of the station transmitting it. You should be familiar with callsigns, but what about SSIDs? The SSID is the Secondary Station Identifier of a packet station. It shows up as a modification to a callsign that allows multiple devices to use the same callsign. In my chase vehicle my callsign and SSID would be KD4STH-9 and my near spacecraft's callsign and SSID is KD4STH-11. With the SSID, one can operate several packet stations and know which station is being referenced. Also, the SSID graphically explains how APRS is to display the icon for that that station. So the –9 SSID is displayed as a car icon while the –11 SSID is displayed as a hot air balloon icon (okay, so a hot air balloon is not quite right for a near spacecraft, but it's close enough). Think of the confusion that would result if no one understood if the packet they just received was from your chase vehicle (SSID-9) or your near spacecraft (SSID-11).

In the olden days, most packet data was sent to a specific callsign and SSID. In this case, the intended recipient of the message was also added to the packet. However, packets formatted for APRS are preceded with a UI, or unnumbered information frame. These packets are not meant for a specific individual, but instead are meant for anyone listening. These packets typically contain the location of the transmitting station (usually from a GPS receiver at the station) and a message in the proper format. The message is then displayed according to the APRS protocol at the location specified in the packet. Everyone running an APRS terminal sees the data displayed the same way and in the same location on the map. APRS makes a very fast way to send information to everyone.

Every APRS station must include a TNC and radio. A GPS receiver and PC is optional. Fixed locations don't require a GPS receiver, as they never move. However, the position of the station must be known before going on air. The coordinates are coded into the station and transmitted with each packet. APRS stations that just transmit status information do not require a PC running APRS to display incoming data. A typical station without a GPS receiver and PC is a weather station. Examples of status data transmitted by an APRS station include weather conditions, speed and heading, current status, and announcements and bulletins. The APRS protocol is very flexible and capable of displaying a wide variety of information.[E]

Near Space Humor - Top Six Chase Songs

1. The Battle of New Orleans
2. On The Road Again
   Willy Nelson
3. William Tell Overture
   Rossini
4. Ride of the Valkryies
   Richard Wagner
5. When Johnny Comes Marching Home
   (This reminds me of the bomber scenes in the movie, Dr. Strangelove)
6. Carefree Highway
   Gordon Lightfoot

My Modification To "On The Road Again"
(With apologies to Willie Nelson)

On the road again,
Just can't wait to get on the road again,
My life's love is balloon chasing with my friends,
And I can't wait to get on the road again

On the road again,
Traveling bad roads I've never been,
Searching for capsules I'll never find again,
I can't wait to get on the road again.

On the road again,
Looking like the X-Files, we drive down the highway,
We're the best of friends,
Hoping the balloon's drifting our way,
And our way….

Is on the road again.
Just can't wait to get on the road again,
My life's love is balloon chasing with my friends,

And I can't get on the road again,
And I can't get on the road again.

[A] The values are the average of the first six satellite vehicles for three consecutive records taken over a period of a few minutes before the movement of satellites could influence the results.
[B] This should be just greater than the thickness of window glass in the car.
[C] For example, a sign warning people not to open the door (to prevent pulling on the antenna cables)
[D] Most amateur radios do not pass a 9600 baud signal. To use 9600 baud packet requires radios with direct connections to the transmitter modulator varactor and discriminator, which is not available on most amateur radios (notes from Mike Manes, EOSS).
[E] Information for this précis was found at the following sources. Consult them for more in depth information.

APRS Protocol Reference, The APRS Working Group, http://www.tapr.org

Getting On Track With APRS, Stan Horzepa (WA1LOU)

Introduction To Packet Radio, Larry Kenney (WB9LOZ), http://www.choisser.com/packet/part01.html
http://home.teleport.com/~nb6z/frame.htm

CHAPTER TWELVE

Weather and Flight Predictions

"It's easier in Kansas than Idaho"
-Conversation with a stranger
in a mall parking lot about chasing
near space flights

Chapter Objectives

1.0 An Introduction To Weather

Whether you launch or not, and where the Recovery Crew recovers the near spacecraft, are both influenced by the weather. So let's spend some time discussing weather. Two times a day the National Weather Service radiosondes measure four characteristics of the atmosphere, pressure, temperature, humidity, and winds.

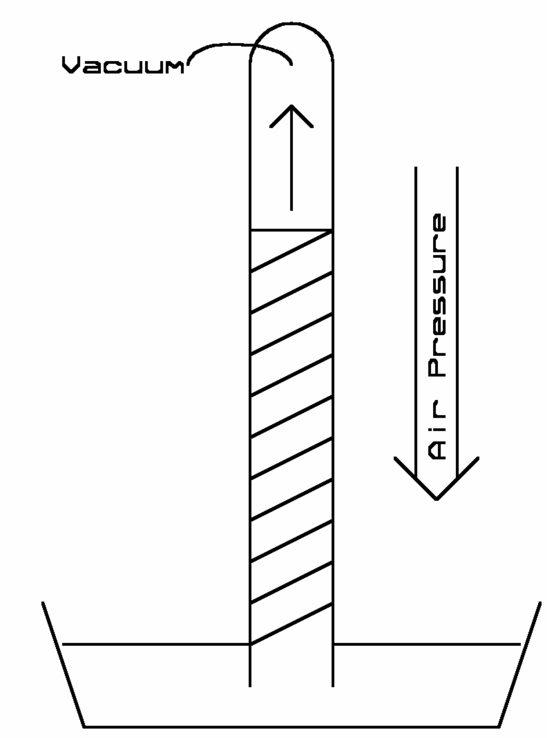
1.1. Pressure

1.1.1. What Is Pressure?

Since air is made of molecules, air has mass. Gravity is a force that acts on all mass. So gravity causes the air above the Earth to exert a force (weight) on the Earth. Air is also a fluid medium. As a fluid, it flows around objects. Therefore the force exerted by the atmosphere does not just push down, it also pushes in all directions. The force exerted by the weight of the air (in all directions) is called pressure.

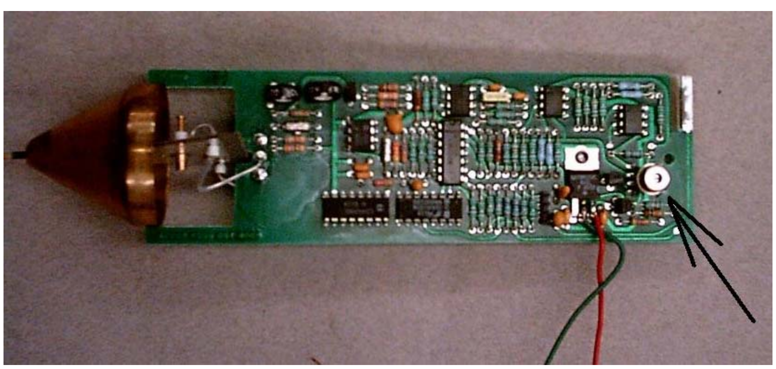
1.1.2. How Is Pressure Measured?

Evangelista Torricelli (1608 - 1647), a student of Galileo (one of my heroes), was the first person to demonstrate that the atmosphere exerts a pressure and to develop an instrument capable of measuring that pressure. Torricelli began with a very tall glass tube (over 34 feet long!) filled with water. He inverted the filled tube over an open pan of water and noticed that water drained out of the glass tube until the water height was 33.9 feet above the surface of the water in the opened pan. Torricelli reasoned that the atmosphere was pushing down on the pan of water and up into the glass tube with as much force as the weight of the water in the glass tube was pushing down. His device also measured changes the force that the atmosphere exerted. If the atmosphere exerts more pressure one day (pushes down harder on the pan of water), then the height of the column of water increased. If the atmosphere exerts less pressure on another day, then the height of the column of water decreased. The device Torricelli invented is called the barometer (from baro - pressure and meter – to measure).



Column Barometer

More recently barometers have measured air pressure by detecting changes in the volume of an aneroid barometer. The aneroid barometer is a sealed, flexible pair of bellows that changes its thickness as the air pressure outside the bellows changes. The aneroid barometer is the most popular style barometer seen in living rooms across the United States. Today the barometer is designed into solid-state electronics with a miniature version of the aneroid barometer. A sealed "pocket" in a silicon die flexes the tiny silicon disk covering the pocket. The silicon disk changes its resistance as it flexes. The change in resistance is subtle and must be measured in a Wheatstone Bridge, where it creates a current. The newer Viasala radiosondes use this solid-state barometer.



An Aneroid Barometer out of a Radiosonde

Silicon Pressure Transducer

1.1.3. Units Of Pressure

No matter what the diameters of the columns of water in the Torricelli barometer, the height of all columns of water is the same. A column of water 33.9 feet tall is too tall to be a practical barometer; so eventually a column of mercury was substituted for the column of water. Mercury has a density 13.6 times greater than water. So a column of mercury with the same weight as 33.9 feet of water would only be 1/13.6th as tall as the column of water, or 29.9 inches or 76 cm. After the transition to mercury-filled barometers, the unit of air pressure became the height of the mercury column supported by the atmosphere. Pressure is still sometimes given in inches or millimeters of mercury. One atmosphere of pressure in column inches of mercury is equal to 29.9 inches. In the metric system this is equivalent to 760 mm of mercury.

Using a length as a unit of pressure is not technically correct, as pressure is a force per unit area. The height of column of water typically supported by the atmosphere is 33.9 feet tall. A column of water this tall exerts a weight of 14.7 pounds for every square inch of surface covered by the column of water. Therefore 14.7 PSI is the measure of one standard atmosphere of pressure. In SI units the unit of pressure is the Pascal. One Pascal is equal to one Newton of force exerted over one square meter of area. A column of mercury one square meter in area and 76 cm tall exerts a force (has a weight) of 101,300 newtons. Therefore one standard atmosphere has a pressure of 101,300 pascals, or 101.3 kilopascals. Another SI unit of pressure is the bar. One bar equals one hundred kilopascals. Therefore one standard atmosphere equals 1.013 bars. The bar is broken into 1000 parts, called millibars. Therefore one standard atmosphere also equals 1013 millibars (mb). The millibar is the unit of pressure most often heard in weather. By the way, the average atmospheric pressure at the surface of the planet Mars is 7 mb which is the atmospheric pressure just above an altitude of 100,000 feet.

1.1.4. How Is Pressure Displayed?

In station plots, pressure is displayed as the number to the upper right. The value is in units of millibars and has the leading 10 or 9 removed along with the decimal point. In weather maps you will also find lines of equal pressure. These lines are called isobars (where iso mean equal and bars means pressure). If you follow an isobar, every point beneath the line has the same pressure as every other point beneath the line. Isobars over the launch site are more important to near space flights than the pressure at the launch site because they control the direction and speed of the wind (more on that in subsection 1.4.5).

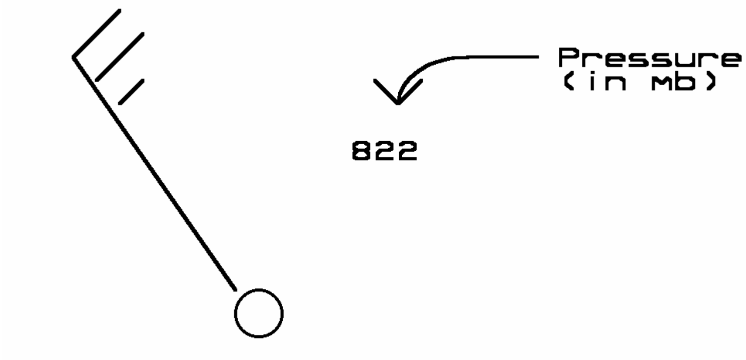
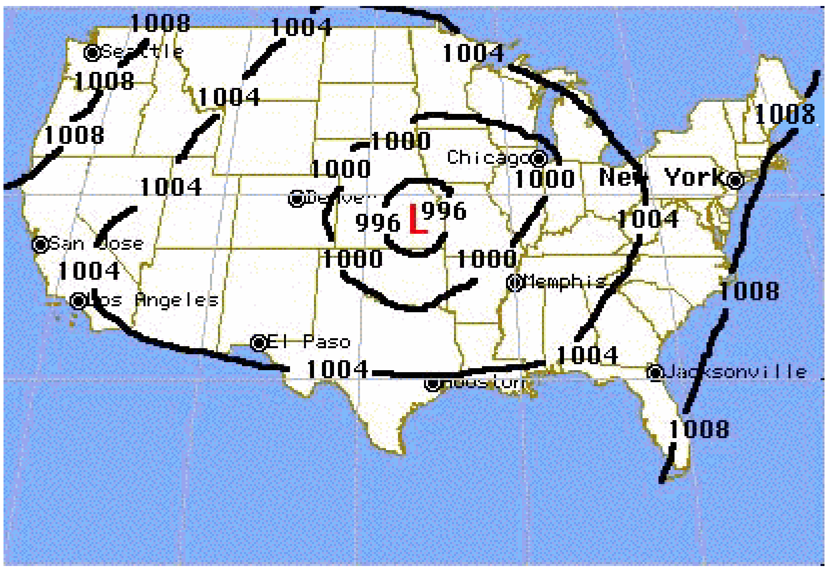


Diagram of Station Plot *- Pressure is marked with the "822"*

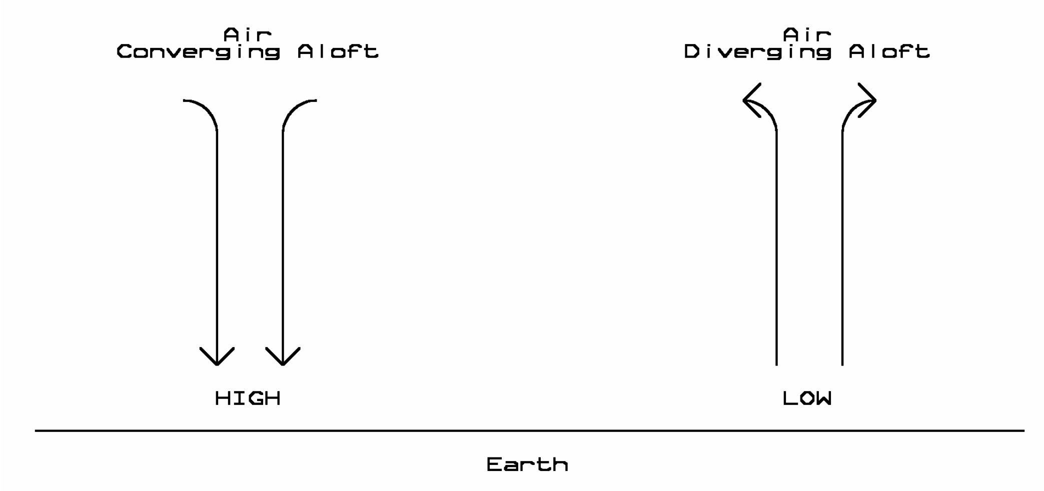


Isobar Diagram *- Courtesty of NASA*

1.1.5. Other Pressure Notes

Regions where the air aloft is diverging are called a low. When the air aloft diverges, it pulls air up from the surface to replace the air that is diverging above. As air rises, it expands due to the lower air pressure aloft and cools. As the air cools, its capacity to dissolve water vapor is reduced, increasing its relative humidity. When the relative humidity reaches close to 100%, clouds begin to form.

The opposite occurs when air aloft begins to converge. This creates a high where air aloft is forced to sink to the ground. The increasing pressure lower to the ground forces the air to compress, warming it. As the air warms, its capacity to dissolve water vapor increases, which lowers the air's relative humidity. Any clouds in the air convert back into water vapor leaving sunny skies.



Cross Section of High and Low Pressure

Ignoring other complicating factors, high pressure systems tend to have fair weather and light winds. Low pressure systems tend to have cloudy weather and stronger winds.

1.2. Temperature

1.2.1. What Is Temperature?

We all have a subjective feel for what temperature is as we can determine if something feels hot or cold. But we want to be more specific than that, so let's discuss just what temperature is. The energy contained within a body and that body’s specific heat determines the temperature of that body. If the energy contained within a body increases, so does its temperature. If the specific heat of a body decreases, then the same amount of energy contained within that body raises its temperature. The specific heat of a materials determines how much energy per unit of mass of the material is needed to raise that material’s temperature.

Two bodies made of different materials can have the same temperature when they contain different amounts of energy. When two bodies at the same temperature are brought into contact, the energy flowing out of the first body and into the second body is balanced by the energy flowing out of the second body and into the first body. This keeps the two bodies at the same temperature. When two bodies at the different temperatures are brought into contact, the energy flowing out of the hotter body and into the cooler body is greater than the energy flowing out of the cooler body and into the hotter body. This cools the hotter body and warms the cooler body.

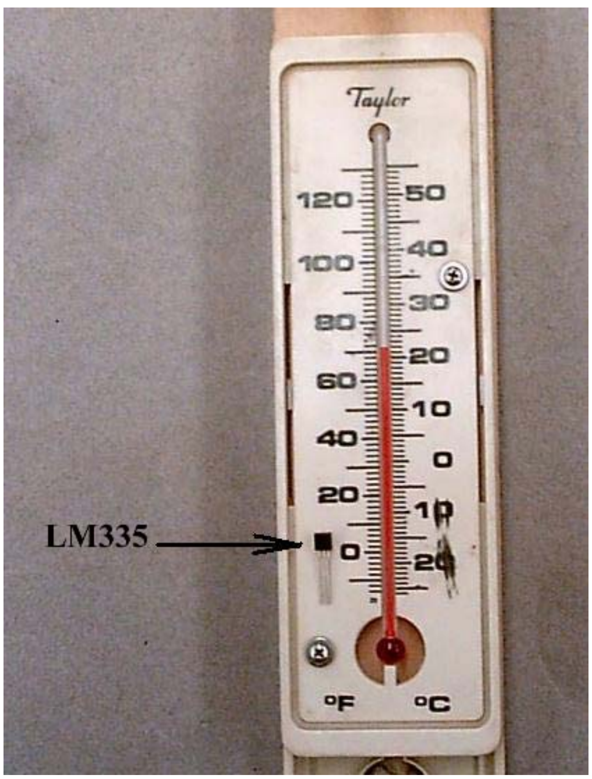
The amount of kinetic energy of a molecule or atom of a substance (which can be in the liquid, gas, or solid phase) determines the speed of that molecule or atom. As the temperature of the body increases, the average energy of the molecules or atoms of that substance increases, as does the average speed of those molecules or atoms. The opposite is also true. The lower the average speed of molecules or atoms within a substance, then the lower the temperature of that substance. The greater the average speed of molecules or atoms inside a body, the greater the average distance between those molecules or atoms. When the average distance increases, so do the physical dimensions of the body.

1.2.2. How Is Temperature Measured?

In principle, a thermometer is measuring the energy flow between a body and the thermometer. When the thermometer and body being measured have reached the same temperature, the net energy flow between them is zero (that is the energy flows are equal in both directions). As the temperature of the thermometer changes in response to the temperature of the body it is measuring, the volume occupied by the mercury or alcohol inside a thin capillary tube inside the glass thermometer changes. When brought in contact with a warmer body, the height of the alcohol rises and when brought in contact with a cooler body, the height decreases.

Another device for measuring the temperature of a body is the thermocouple. In a thermocouple, two dissimilar metals are brought in contact and exposed to a body whose temperature we want to know. At CSU Fresno, my physics labs used copper and Constantan wires twisted together. Heat applied to the junction of the two metals creates a potential difference. The voltage produced by the thermocouple is small and must be amplified with an operational amplifier.

A third type of device to measure temperature is based on the semiconductor diode. The breakdown voltages of P-N junctions are sensitive to temperature. This property of the P-N junction is used as the operating mechanism of the LM335, temperature controlled zener diode. The LM335 is used in this book as the primary temperature-measuring device.



Thermometer and LM 335

1.2.3. Units Of Temperature

There are three temperature scales in common use and one other that is not so common. The four temperature scales can be classified into two types. First are those with zero degrees as the lowest possible temperature (absolute zero). Second are those with zero degrees at some temperature above absolute zero. The two temperature scales in the first classification are the Rankine and Kelvin scales. The Rankine scale is an old engineering temperature scale with a degree of temperature equal to a degree in the Fahrenheit scale. The Kelvin scale is the current standard engineering temperature scale with a degree of temperature equal to the degree of the metric, Celsius scale. The Rankine scale is the Fahrenheit scale with its zero degree shifted to absolute zero and the Kelvin scale is the Celsius scale with its zero degree shifted to absolute zero. There are no negative temperatures in either the Rankine or Kelvin scale. By the way, never say X degrees Kelvins. The Kelvin scale doesn't use the unit, degrees. Temperatures in Kelvins are just listed as X Kelvins. As an example, water melts at a temperature of 273 Kelvins and not at 273 degrees Kelvin. The Rankine, Fahrenheit, and Celsius scales all use degrees.

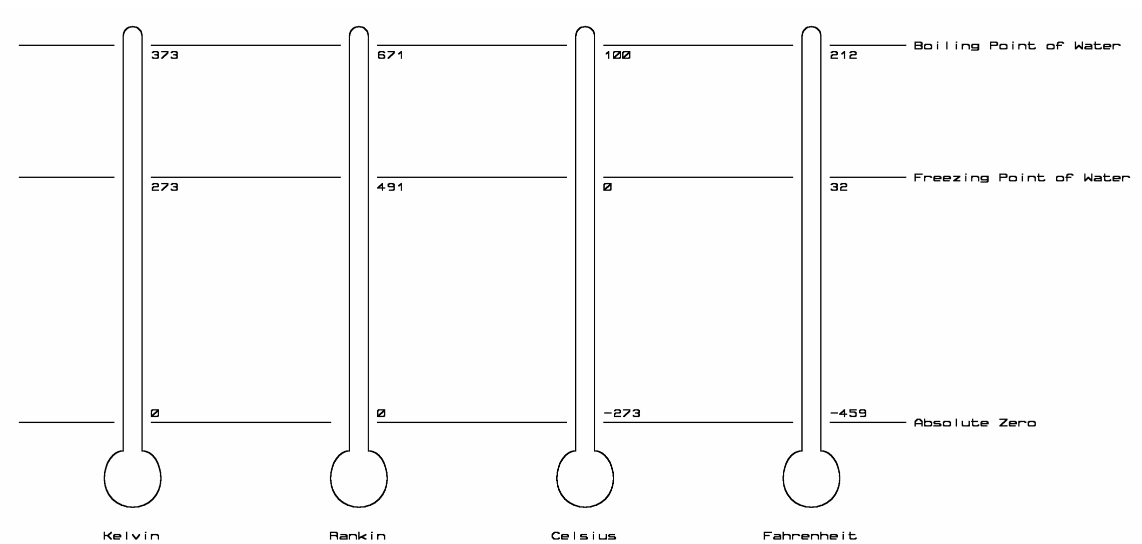
Conversions Between Temperature Scales

Convert the temperature in Celsius to Kelvins by subtracting 273.15 from the temperature in Celsius (and don't forget to drop the word, degrees). Convert the temperature in Fahrenheit to Rankine by subtracting 459.67 from the temperature in Fahrenheit.

There are 1.8 Celsius degrees per Fahrenheit degree. The Celsius temperature scale intersects the Fahrenheit temperature scale at –40 degrees. If you shift a temperature in either scale by –40 degrees, then you can either multiple or divide the temperature by a factor of 1.8 and shift back by 40 degrees to convert between the Celsius and Fahrenheit temperature scales.

The necessary equations are as follows.

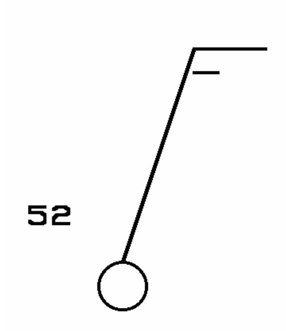
```
((Degrees-F – 40) / 1.8) + 40 = Degrees-C

((Degrees-C – 40) * 1.8) + 40 = Degrees-F
```



Aligned Temperature Scales - *(L-R): Kelvin, Rankin, Celsius, Fahrenheit*

1.2.4. How Is Temperature Displayed?

On station plots the temperature is listed in the upper right hand and is given in units of Fahrenheit. No decimal value is recorded. Isotherms are drawn in some weather charts. The shape of isotherms is useful for pointing out the locations of fronts.



Station Plot of Temperature

1.2.5. Other Temperature Notes

As an air parcel (like inside a helium balloon) ascends to higher altitudes, the air pressure around it drops, forcing the air parcel to expand in size. Air expands by converting the kinetic energy of its molecules to increase the spacing between the molecules. With lower average kinetic energy in its molecules, the air temperature cools. This cooling due to expansion is another factor in cloud formation and will be visited later in this chapter.

1.3. Humidity

1.3.1. What Is Humidity?

Water exists in three phases on Earth and no doubt you are familiar with them; solid (ice), liquid, and gas (water vapor). The only difference between the three phases is the average amount of energy in the water molecules in each of the phases. Water molecules in the ice phase have the lowest average amount of energy while water molecules in the water vapor phase have the largest average amount of energy. Water molecules are continuously making the transition between these three phases. If you could see at the atomic level, you'd see molecules of water in the atmosphere jumping between the solid, liquid, and gas phases. What percentage of the molecules is in each state depends on the temperature. As their temperature increases, the percentage of water molecules in the solid phase decreases while the percentage of molecules in the gas phase increases.

1.3.2. How Is Humidity Measured?

Hygrometers are the instruments used to measure relative humidity. The first ones where designed with human hair. As the relative humidity increases, so does the length of your hair. The changing length of the hair pulled or released a dial that was calibrated to the relative humidity. Radiosondes measure water vapor in the air by measuring the resistance of a salt, like lithium chloride. As the salt absorbs more water, it's resistance decreases. Many electronic weather stations measure the relative humidity with a capacitor that is sensitive to moisture. The sensor is connected to the 555 IC Timer where it affects the frequency of the 555. One other method is to measure the dry bulb and wet bulb temperatures of the air with a sling psychrometer. See Chapter Nine, Good To Know for information on building and using the sling psychrometer.

1.3.3. Units Of Humidity

The water molecules in the gas phase (water vapor) are dissolved in the air. The amount of water vapor in the air is called the absolute humidity or mixing ratio and is given in units of grams of water vapor dissolved in kilograms of dry air (g/kg). Mixing ratios typically vary within a range of about 2 g/kg to 30 g/kg. The maximum amount of water vapor capable of being dissolved in dry air is a function of the air pressure and air temperature. This maximum is called the saturation mixing ratio. Note that the mixing ratio does not have to equal the saturation mixing ratio of the air. In fact, most of the time, the mixing ratio is below the saturation mixing ratio.

The current mixing ratio compared to the saturation mixing ratio is a called the relative humidity. If the air temperature and pressure is kept constant while more water vapor dissolves into the air, then the relative humidity goes up. If the air's ability to dissolve water vapor goes up (by raising the air temperature), but the mixing ratio stays constant, then the relative humidity goes down. In conditions of low relative humidity, more water molecules in the liquid phase "want" to make the transition to the vapor phase, than "want" to make the transition from vapor phase to back to liquid or solid phase.

1.3.4. How Is Humidity Displayed?

The humidity itself is not listed in a station chart. Instead the dew point is listed in the lower left hand corner. The dew point is the temperature at which the local atmosphere would become 100% saturated, assuming the current mixing ratio and pressure does not change. The closer the air temperature is to the dew point, the higher the relative humidity. See Chapter Nine, Good To Know for more complete information on dew points.

1.3.5. Other Humidity Notes

Increasing the relative humidity of air by lifting and cooling it is one way to form clouds (as is seen as air moves into locations with mountains). Another way is to move (advection) humid air into regions of colder air. Cloud formation doesn't occur exactly when the temperature of the air reaches its dew point. Materials suspended in the air (condensation nuclei) help clouds (and rain) form at temperatures above the air's dew point.

Clouds are not made of water vapor, which is invisible, but are made of small droplets of liquid water suspended in the air. The tiny beads of liquid water are called droplets have diameters on the order of 0.01 mm in diameter. Being this small, they can be kept aloft by rising air. Being this large makes them scatter all colors of the spectrum. In large numbers they appear white in color.

The three basic types of clouds, those that are clumpy, those that are sheet-like, and those that are wispy. A clumpy or cotton ball type of cloud is referred to as cumuliform and is a sign of an unstable atmosphere and possible severe storms (especially when the clouds begin growing very tall). A sheet-like cloud is referred to as stratiform and is a sign of a stable atmosphere. When stratiform clouds create rain, the rain tends to be gentle. When the air temperatures drops below the freezing point of water, then the clouds that form are made of ice crystals rather than water droplets. The ice crystals form wispy clouds, like hair or horsetail, called cirrus. Cirrus clouds are higher than either status or cumulus clouds. There are many variations to the above cloud types based on their altitude and their ability to form rain. Most weather books explain clouds in greater detail.

Cumulus clouds

Cirrus clouds

Stratus clouds

A stratiform cloud in contact with the ground is called fog. Fog can form when either the air temperature has cooled enough at night to raise its relative humidity to 100% or when humid air moves onto cold ground. Fog in the morning is a good sign because it means there’s no wind at the surface, which makes it easy to launch balloons. It’s a bad sign because there's no ground to photograph, only cloud tops. Fog disappears when the air temperature warms up enough to lower its relative humidity. The air is warmed by its contact with the ground, and not directly by the Sun. However, white clouds reflect sunlight, preventing the ground from warming up as fast as it does when there are no clouds.

1.4. Winds

1.4.1. What Is Wind?

Wind is the movement of air from regions of relative high pressure to regions of relative low pressure. The greater the difference between the high and low pressure regions, the greater the wind speed between them. Ideally, winds blow straight from a high pressure region to a low pressure region. However, Earth’s rotation interferes with this simple picture. As the air moves under the influence of pressure, the Earth rotates, causing the moving air to change directions with respect to us who are stuck to the Earth’s surface.

1.4.2. How Is Wind Measured?

Anemometers measure the wind speed and direction where they are located. Balloons measure wind speeds aloft. Balloons are captive to the movement of air and cannot move independently of it. If the wind travels to the south at 15 knots, then the balloon must also travel to the south at 15 knots. Balloons carrying radiosondes are filled to a very precise amount of lift. The lift creates a known ascent speed for the radiosondes. A parabolic dish antenna tracks the radio signal from the radiosondes. Since the ascent rate for the balloon is well known, the azimuth and elevation of the radiosonde (found by the antenna’s position) indicates the three dimensional position of the radiosonde. Dividing the radiosonde’s position by the time of ascent gives the NWS the wind’s speed and direction along the radiosonde’s flight.

A radome (radar dome) - *a weatherproof enclosure used to protect an antenna.*

Balloon Carrying Radiosonde

1.4.3. Units Of Wind

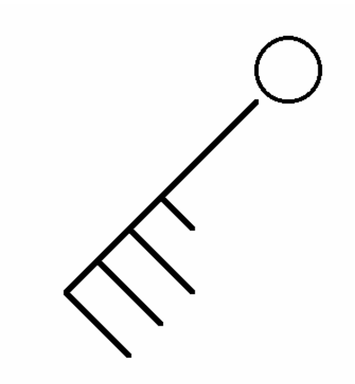
Wind speed is measures in knots, or nautical miles per hour. The nautical mile is a little over 6000 feet long. There are 1.15 miles per hour in one knot. The equations for converting between knots and miles per hour are given below.

```
MPH / 1.15 = knots

Knots * 1.15 = MPH
```

Wind direction is given by the direction the wind is coming from and not the direction t he wind is flowing to. So a southerly wind is coming from the south and going north. Wind direction is given by its position on the compass rose, with respect to true north and not magnetic north. Positions on the compass rose are those like the following, North, Northwest, and West- Northwest.

1.4.4. How Is Wind Displayed?

In station charts, wind speed and direction is displayed in a wind flag positioned over the station making the report. The direction of the tail indicates the wind is blowing and the number and length of the pendants indicates the wind speed rounded to the nearest five knots.



Wind Speed – *As denoted on station charts*

1.4.5. Other Wind Notes

The greater the change in air pressure over a given distance (pressure gradient), the greater the wind speed over that change in pressure. Higher pressure gradients occur where the isobars are the most narrow. Ideally, a high pressure system has wind blowing out radially from its center and a low pressure system has winds blowing radially into its center. The Earth's rotation curves the paths taken by these winds in what is called the Coriolis Effect. Winds spiral counterclockwise into low pressure systems and clockwise out of high pressure systems. When no other forces, like drag, are acting on winds, winds tend to flow parallel to isobars

The counterclockwise rotation of winds into a low pressure system pulls warmer air into the southeast quadrant of the low and colder air into the southwest quadrant of the low. Where warmer air is over taking cooler air in the southeast quadrant is a warm front. Where colder air is overtaking warmer air in the southwest quadrant is a cold front. Most low pressure systems have these two fronts associated with them and together they form what is called a frontal cyclone. Since frontal cyclones travel from west to east, a low approaching to the north of a site first sees the warm front. After the warm front and the low passes, comes the cold front.

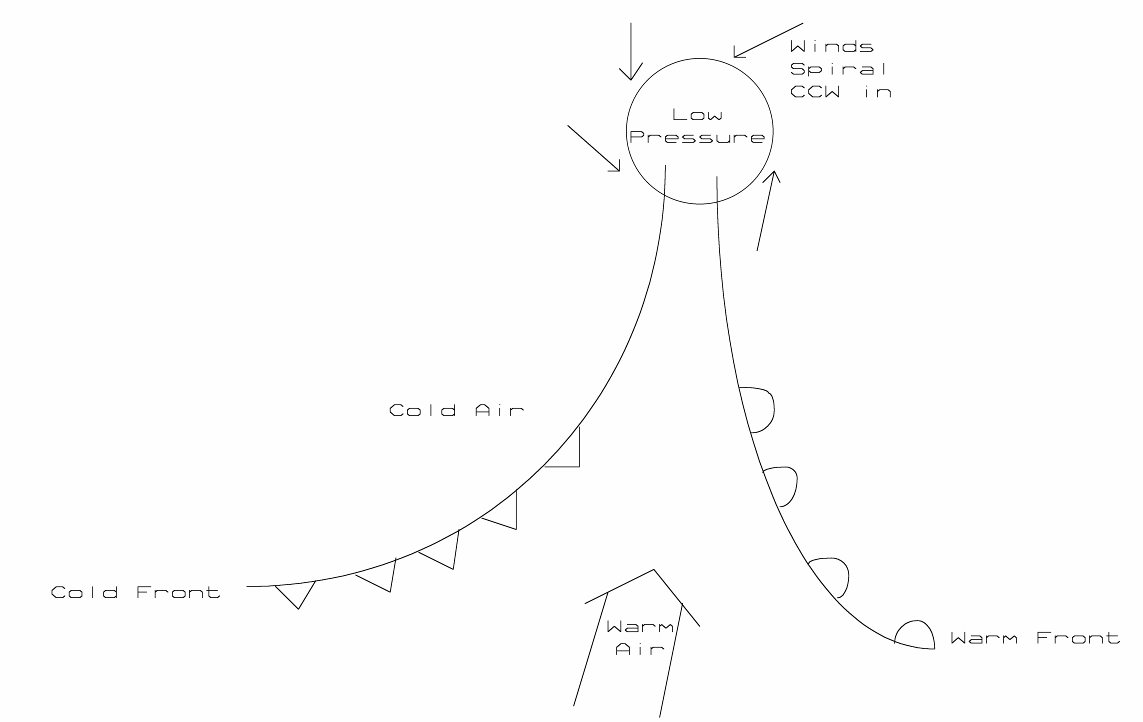


Diagram of Frontal Cyclone

If there is enough moisture, the approach of a warm front is first signaled by high cirrus clouds. As the warm front gets closer, the clouds lower, forming stratiform clouds. An approaching warm front typically means that the weather is warming up and rains tend to be gentle or non-existent. If there is enough moisture, the approach of a cold front is signaled by the quick appearance of growing cumuliform clouds. If there is enough moisture and energy in the atmosphere, the cumuliform clouds form thunderheads and severe weather. An approaching cold front typically means the weather is going to cool down and/or get drier (after the front passes). In the temperate zone of the Earth, the fronts are the major weather producers.

2.0 Weather's Influence On Flights

Here are several items to look for on a weather map or in a weather report when planning a near space launch.

2.1.1. Isobar Direction And Spacing

The direction and spacing of isobars indicates the wind speed and direction. The isobars plotted for 300 mb indicate winds near 30,000 feet (the altitude lowers in cold air and rises in warm air). The closer the isobars, the higher the wind speed indicated and the farther the near spacecraft will travel.

2.1.2. The Position Of The Jet Stream

Closely packed isobars at about 300 millibars indicate the position of the jet stream. If the jet stream is located over the launch site, then the near spacecraft is going for a high-speed ride and the Chase Crew is putting some miles on their cars. The longer the chase, the larger the recovery zone due to the imprecise nature of near space predictions. Launching through the Jet Stream is not a problem as long as the direction and distance covered in the flight is acceptable to the Chase Crew.

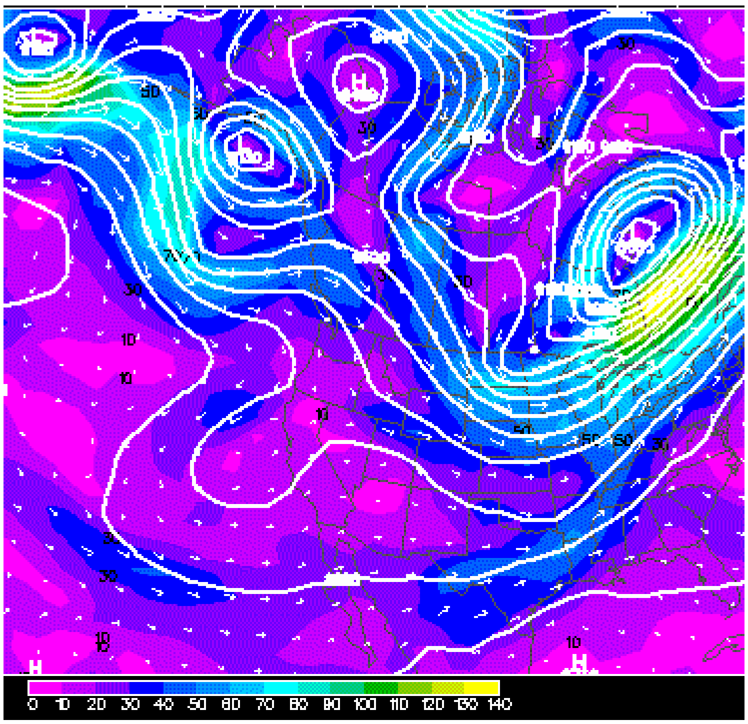


Image of Jet Stream *– Courtesy of Unisys*

2.1.3. Turn Around

During certain times of the year (Spring ?) the stratospheric winds turn around in direction. As they do so, they slow down in speed and reverse in direction. A mission launched during turn around does not recover as far from the launch site. KNSP Flight 99H which was predicted to land 40 miles away from the launch site (the Cosmosphere) landed less than ten miles from the launch site because these winds brought the balloon back (which is a bit funny as we were 40 miles away, waiting for the near spacecraft).

2.1.4. Approaching Cold Fronts

Typically an approaching cold front means there will be bad weather (high surface winds) before the denser (cooler or drier) air mass moves in. It's best to wait until after the cold front passes to plan a launch. The weather may be colder, but the air will be clear and usually much calmer. It's difficult to make accurate predictions during a front passage as the wind directions can dramatically change overnight.

2.1.5. Approaching Warm Fronts

An approaching warm front can mean extensive stratus cloud cover and gentle rains, if any. Wait until after the warm front passes for the rains to stop. Expect a warmer weather launch, but possibly more humid also.

2.1.6. No Surface Winds And Morning Temperatures At Or Below The Dew Point

When the air temperature reaches the dew point, you can count on dew in the morning (or frost if the temperature drops close to or below freezing). If there is no wind during the night, then fog also may develop as the relative humidity approaches 100%. If remote sensing is a part of the flight, then take into consideration that the flight may record cloud tops instead of the ground. You may want to launch later in the morning when the fog burns off.

2.1.7. High Pressure Systems

A high pressure system over the launch site typically indicates clear weather. What winds exist tend to be weak and disorganized inside a high pressure system. Expect flight not to travel very far in the first 30,000 feet. As long as there is not a jet stream overhead or high-speed winds in the stratosphere, high-pressure systems represent good conditions to launch.

2.1.8. Low Pressure System

A low pressure system over the launch site typically indicates cloudy weather. Winds in low pressure systems tend to be stronger than those in high pressure systems and more organized. Expect near space missions to travel farther if launched in a low pressure system. Approaching low pressure systems sweep a warm front across the launch site first and a cold front later.

2.1.9. Rising Air Pressure

This indicates an approaching high pressure system and possibly better weather (fair). The faster the air pressure rises, the greater the risk of high speed winds at the launch site.

2.1.10. Falling Air Pressure

This indicates an approaching low pressure system and possibly higher surface winds (stormy). Wait until after the weather settles down.

2.2. Weather Websites

Here are some URLs to use when predicting weather for a launch.

2.2.1. To Learn More About Weather

A site for an on-line weather course is located at
http://ww2010.atmos.uiuc.edu/

Another on-line weather course is available at
http://mammatus.plymount.eud/dstreme
I'd also recommend completing the Datastreme course. This is an excellent course given by the American Meteorological Society for teachers. In it, you'll cover as much material as some television meteorologists learn.

2.2.2. For Current Weather Predictions

For weather conditions in nearby locations (trying to get a peek at the weather coming you way), use The Weather Underground.
http://wunderground.org
Select your state and then home in on your region

For you region, use the local National Weather Service
http://www.wrh.noaa.gov/
Select your state and then find the closest reporting site.

For graphical displays of winds aloft, go to the Unisys Medium Range Forecast website.
http://weather.Unisys.com/mrf/index.html
Select four panel plots and the number of hours or days in advance you want to see the plots. The left plot is at a pressure altitude of 850 mb (less important for near space missions) and the right plot is for a pressure altitude of 300 mb (about 30,000 feet altitude and much more important for near space missions). Look at the position and direction of the isobars for a feel on the direction and distance for the first half of the near space flight.

3.0 Near Space Predictions

3.1. Amateur Near Space Software Lesson One

3.1.1. Goal

To Become Familiar With Amateur Near Space Software

3.1.2. Objective

To Learn How To Use LIFTWIN To Predict Balloon Ascent Rates, Burst Altitudes, And Needed Amount Of Helium

3.1.3. Software Notes

A. Where To Get A Copy Of The Software
The LIFTWIN software is available from http://www.eoss.org/balsoft.htm
LIFTWIN is a program written by Hank Riley. Originally written in BASIC, Hank has since written the Windows interface to the program. He makes updates to the program as needed. Download the Liftwin and VBRUN300 files from EOSS. They're both zipped files. After extracting the files, copy them to the same directory.

B. What Does The Software Do?
Given a balloon size, a payload weight (including parachute weight), a starting amount of helium, and additional increments in the amount of helium, LIFTWIN makes a prediction on the free lift of the balloon, its ascent rate, and maximum altitude.

C. How Does The Software Do What It Does?
The lift generated by a volume of helium in a balloon is determined by the amount of air the helium displaces (see Chapter Ten, Good To Know). From the lift generated by the helium, the volume of

the balloon, the balloon's drag, and the weight of the payload, and the ascent rate of the balloon can be determined. From the initial volume of helium, the pressure of the atmosphere at different altitudes, and the maximum volume of the balloon, the altitude at which the balloon bursts can be determined. The manufacturer specifies the maximum volume of each balloon they sell.

D. What Are The Inputs To The Software?

LIFTWIN needs the following inputs

- The balloon type
- The total weight of the payload
- The starting diameter of the balloon
- Diameter increments
- The maximum diameter of the balloon

The user inputs these fields as desired; no data needs to be downloaded.

E. Where Do You Get The Data To Input?

In the case of LIFTWIN, the user determines the conditions to test. LIFTWIN is a tool for satisfying the user's curiosity. The results indicate the appropriate balloon and volume of helium to use for a particular mission.

F. Inputting Data

After starting the program, the following fields are displayed. In these fields enter the data as explained.

Select from the menu item
Balloon Type
Select the manufacturer and balloon type in the pull down menu

Fill in the following fields
Min. Dia.
This is the minimum diameter of the balloon to begin the test with
Max. Dia.
This is the last diameter of the balloon to test
Dia. Increm.
This is the unit of increased balloon diameters to test
Total Weight
This is the weight of the near spacecrafts, any beacons, and parachute

Click the **Calc** button

G. Understanding Outputs

In the upper right hand, is a red window displaying specifications for the balloon selected.

The table generated by LIFTWIN has the following fields,

Dia. Vol. Noz. Lf. Alt. Range Asc. Burst

Field	**Definition**
Dia.	The diameter of the balloon
Vol.	The volume of the balloon, and therefore the helium being used

Noz. Lf.	The total lift generated by the balloon
Alt.	The predicted altitude at which the balloon will burst
Range	The distance to the horizon at the balloon's maximum altitude
Asc.	The predicted ascent speed of the balloon
Burst	The time to burst for the balloon

For each increment of balloon diameter greater than the minimum diameter, a new volume, nozzle lift, maximum altitude, distance to horizon, ascent speed, and time to burst is generated. From this table you can select the appropriate balloon and amount of helium needed for a near space mission. A minimum of one pound of free lift (or positive lift) is required. Take into consideration the time that is predicted for the balloon to ascend high enough to burst. The ascent rate and bursting altitude from Liftwin are used as inputs to the WBALTRAK program.

3.2. Amateur Near Space Software Lesson Two

3.2.1. Goal

To Become Familiar With Amateur Near Space Software

3.2.2. Objective

To Learn How To Use Balloon Track for Windows (WBALTRAK) To Predict Balloon Flights

3.2.3. Software Notes

A. Where To Get A Copy Of The Software

The WBALTRAK software is available from the EOSS website, http://www.eoss.org/balsoft.htm WBALTRAK was initially written as a BASIC program by Bill Brown and called BALLTRAK. Rick von Glahn designed a Windows interface to the program and has updated the interface on a regular basis. Download the full install of the program along with its manual (also written by Rick). The program is downloaded as a zipped file. After extracting it, the setup.exe file will install Balloon Track from the CAB file.

B. What Does The Software Do?

Given a pictures of the winds aloft (wind speeds and directions at various altitudes), the ascent and descent rate of the stack, and its maximum altitude, BallTrak makes a prediction on the flight path of the stack and its recovery location.

C. How Does The Software What It Does?

Based on the stack's ascent rate, WBALTRAK calculates how long the stack will traverse each layer of atmosphere for which it has the winds aloft. The stack is an unpowered device, so it moves according to the local wind speed and direction. The time spent in each layer is used to determine a new position for the stack. Displacements caused by the succession of local winds are added together, creating a picture of the stacks horizontal travels. At the predicted burst, the average descent speed is modified based on local air pressure. This modified descent speed is then used to determine the time of transit through the air layers documented in the winds aloft profile. The parachute, like the balloon, is an unpowered device; therefore it moves horizontally according to the local winds. The position of the capsule at its entry to each layer is modified by the wind's effect on the descending capsule, creating an exit position. The exit position is used as the entry position for the next lower layer of atmosphere documented in the winds profile. The process is repeated, with the capsule having a lower descent speed for each successive lower layer. When the capsule exits the lowest layer documented, or its altitude matches the predicted landing elevation, the process is stopped and the results displayed in one of several windows.

D. What Are The Inputs To The Software?
To make a prediction with WBALTRAK, the program needs at a minimum the following inputs

1. A winds aloft profile
2. Near space stack ascent and descent rates
3. Predicted maximum altitude of the stack
4. The program is more useful if given the latitude and longitude of the launch site

E. Where Do You Get The Data To Input?
An individual with a GPS receiver can determine the latitude and longitude of the launch site. Alternatively, mapping software like Street Atlas can be used to determine the position of the launch site without traveling there. However, this is not recommended, as launch crews should be familiar with the launch site before traveling out there for the first launch.

The stack's ascent rate and maximum altitude are determined with the Liftwin program. Eventually, launch crews should get a good idea of what to expect for a near space mission.

Descent speeds are determined with either software or by testing. Read Chapter Six, Recovery Systems, for procedures for determining the descent speed of a near spacecraft through testing. Alternatively, an estimate of 1200 feet per minute can be used for the first flight. After the flight, telemetry is used to refine the descent speed for future missions. In this case, use the landing speed of the N/C as the descent speed in future predictions.

Winds aloft profiles are available on the web.

F. Inputting Data
Initial Setup
The first execution of the program will report that a configuration file is not available. On the next window, fields for creating the WBALTRAK.INI file will appear. At a minimum, input data for the following fields.

Select **Flight Data** Tab
Under **Vertical Rates**
Enter an **Ascent Rate** (determined by Liftwin)
Enter a **Descent Rate** (determined by experience, use 1200 the first time)

Under **Burst Altitude**
Enter a burst altitude (determined by Liftwin)
Click the **Use Burst** box

Select **Location Data** Tab
Under **Launch Site** Data
Enter a launch site **Name**
Enter the **Latitude** of the launch site
Enter the **Longitude** of the launch site
Enter the **Altitude** of the launch site
Click the **Set** button

Click the **Save To Default Config File** button

Note that more launch sites can be created and saved under different names. Read the manual for more detailed information.

Now Balloon Track is ready to make predictions

Running Predictions
To run a prediction, you must first download a winds aloft report. After downloading the winds, the winds file is imported in to Balloon Track and a simulation is run.

Getting Winds Aloft Predictions
Winds aloft predictions are downloaded from the CMET website, at http://arl.noaa.gov/ready/cmet.html

Page down the web page to the **Forecast Models Graphics** section
Choose a forecast dataset in the **Forecast Soundings** field

Select one of the following models, based on the time until launch

Time Until Launch	Model
Up to 12 days	Medium Range Forecast Model (MRF 191 km Global)
Up to 3.5 days	AVN Short Range
48 hours	ETA Model (40 km Over US)
0 – 12 hours	Rapid Update Cycle (RUC 20 km Over US)

Click the **Go** button

There are three ways to select a location for the winds aloft, use the third option, and enter the latitude and longitude of the launch site. Use decimal degrees for the latitude and longitude. Also, use a negative longitude as you are making predictions for a location that is west longitude.

Click on the **Next**>> button

Select the following two options in the next window
- Plot 1 time period
- Text listing only

Choose the time. This field is a pull down menu, displaying the available times

Select the following option
- Full Sounding

Click the **Request Plot** button

The text report of the predicted winds is displayed

The latest winds aloft (collected every 12 hours) are available from:
http://weather.uwyo.edu/upperair/sounding.html

Click to select a text report

Click the WMO ID of the National Weather Service office closest to your launch site.

The text report of the predicted winds is displayed

Using your mouse, click and drag to highlight the entire report
Copy and **Paste** the text report into **Notepad**
Save the file under a name and location that you will remember, preferably under the Balloon Track directory. Be sure to save the file as a TXT file

Now you're ready to start Balloon Track

Start Balloon Track
Click **File**
Click **Open**
Click **Select File**
    This shows both DAT and TXT files in the Balloon Track directory
Select the latest winds aloft file
Balloon Track will convert the TXT file into a DAT file
    Balloon Track strips out the data that is not needed, converts the data from metric to imperial measurements, and formats the data into the proper fields
Balloon Track will then run a prediction based on the winds aloft and settings in the configuration file

Before accepting Balloon Tracks report, make sure the winds aloft were valid. Sometimes the winds aloft are not reported for altitudes high enough for the mission.

In the upper-right hand corner is a window of the current **Working Database**. This window displays the speed and direction of the winds aloft. Make sure the maximum altitude reported is at least as high as the predicted maximum altitude of the balloon. See notes at the end of this lesson for times when the predicted winds are not available for the balloon's predicted burst altitude.

At the bottom is a window displaying the following fields.

Time Alt Bearing Range Elevation Climb/Descent Latitude Longitude Distance to LOS

Field	**Definition**
Time	Mission elapsed time since the balloon was launch
Alt	Altitude of balloon
Bearing	Direction from launch site to balloon (true north)
Range	Distance to balloon, from the launch site
Elevation	Balloon's angle above the horizon
Climb/Descent	Ascent or descent rate of balloon
Latitude	Latitude of sub point of balloon
Longitude	Longitude of sub point of balloon
Distance To LOS	Greatest distance from balloon that a signal can be received (LOS means loss of signal)

At the end of the report you will find the Bearing, Range, Latitude, and longitude most important.

Click the **Flight Synopsis** button
Click the **Print Synopsis** button for a hard copy of this report

Close the Flight Synopsis window and click the **View Track** button for a graphic of the balloon's predicted track

Click the **Wind Profile** button to display wind speeds as a function of altitude. This graph shows the location of the jet stream and the highest predicted winds in it.

If any flight parameter is changed, clicking the **Force Calculation** button to force updates to the predicted flight.

Advance Notes

If you have a copy of Street Atlas running, perform the following steps to copy the predicted balloon track into Street Atlas. Save this file and you can compare the actual flight with the predicted flight.

Click **File**
Click **Export**
Click **Street Atlas**

In the Street Atlas Export Setup window, select the following options

Select an **Icon Shape**
Select on of the following **Plot Labels**
  Alt
  or
  Elapsed Time
Select an **Ascent Color** and a different **Descent Color**
Select an **Icon Size** of Small
Click the **OK** button

Enter a file name and directory for the Latitude and Longitude file (latlong.txt is the default)

Start Street Atlas
Click **File**
Click **Import Lat/Lon File**
Select your file
Click the **Open** button
Drag a box around the track to zoom in on it

Upon exiting Street Atlas, select to **Save Changes** so that you can display the track the next time Street Atlas is started.

G. Understanding Outputs

The first window displays an overview of the flight, divided into altitudes according to the altitudes of the predicted winds. Most useful is the synopsis report of the entire flight. The predicted latitude and longitude of the landing zone indicates if the mission is viable from the selected launch site. If not, then select a new launch site and rerun the prediction.

Run predictions daily, beginning one week before launch. The Street Atlas file displays the predicted track of the balloon. The ascent portion of the flight is displayed in a different color than the descent portion. Make note of hazards like towns and lakes that the capsule will descend over (and could potentially land in). Run other predictions with higher and lower predicted burst altitudes. This defines the zone of recovery. Ensure the zone of recovery is acceptable for the mission.

* Rick von Glahn (N0KKZ) and Mark Conner (N9XTN) recommended these websites.

When The Winds Aloft Report Is Incomplete

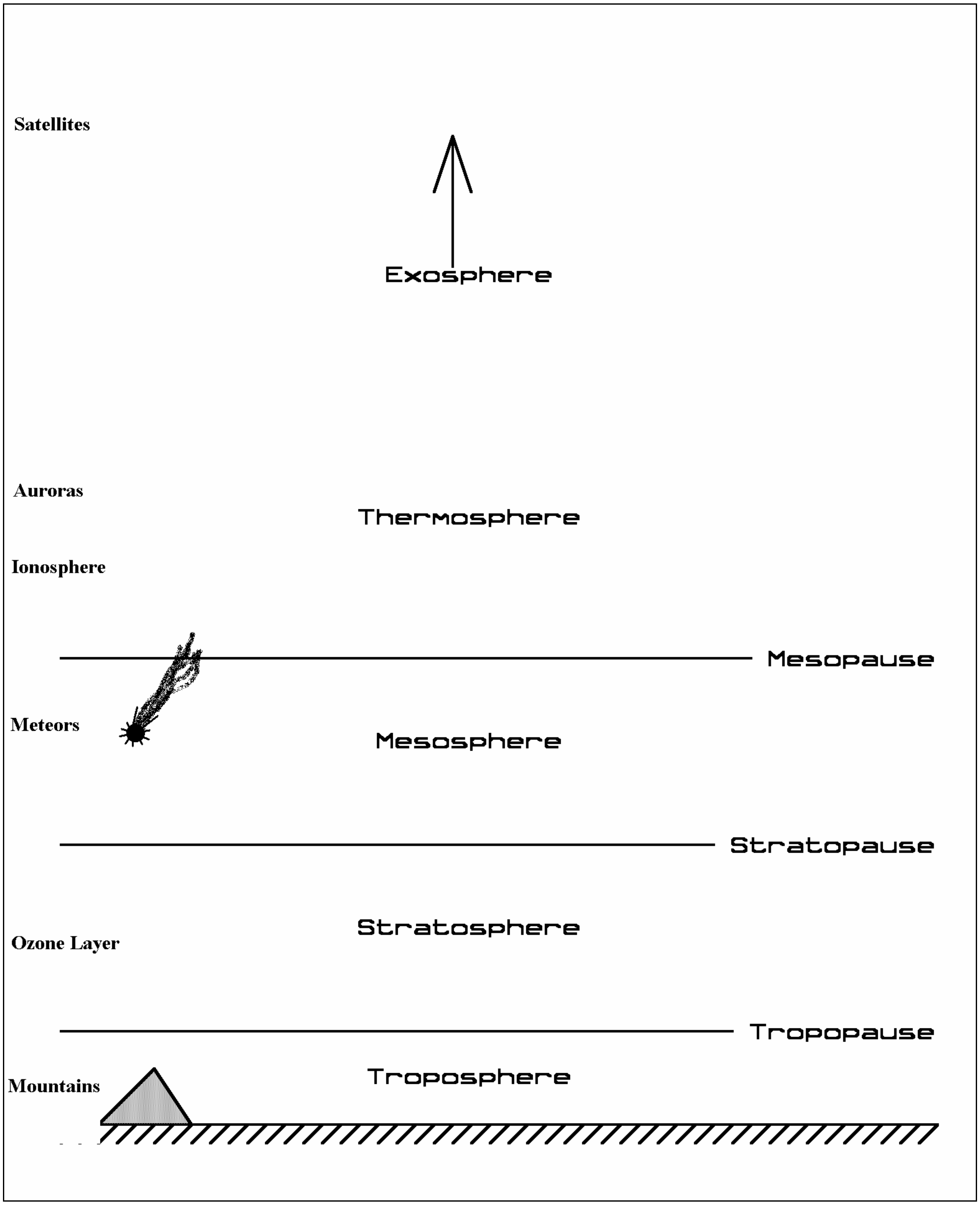
Occasionally, the winds aloft report will not be reported for as high as the balloon is predicted to reach. In this case, retrieve an older winds aloft report and copy the text for altitudes higher than those predicted. Above 60,000 feet, the winds aloft do not change frequently. Mark Conner recommends using the current wind aloft above 60,000 feet and tacking then on the predicted models as a means to make more accurate flight predictions. In this case, create a text file of predicted winds aloft. Save the results into a text file. Then download the latest winds aloft report from the Department of Atmospheric Sciences from the University of Wyoming and copy only the winds above 60,000 feet into the Windows Clipboard. Paste these winds into the predicted winds file and remove the predicted winds aloft that overlap with the current winds aloft above 60,000 feet.

Good To Know - The Atmosphere

The lower 90 miles of atmosphere consists of a homogenous mixture of gases. Of these gases, 78% is nitrogen, 21% oxygen, 1% argon, and 1% trace gases like water vapor and carbon dioxide. The amount of water vapor dissolved in the lower atmosphere however is variable and may reach as high as 3%.

Structure of the Atmosphere

The atmosphere is divided into layers. How the air temperature changes with altitude determines the boundary of each layer. From the bottom up, the layers are, the Troposphere, Stratosphere, Mesosphere, Thermosphere, and Exosphere. The boundary between each layer is called a pause of the lower layer. So located between the troposphere and stratosphere is the tropopause. Located between the stratosphere and mesosphere is a boundary called the stratopause. Typically the tropopause occurs at an altitude of 16 km or 10 miles. The stratopause occurs at an altitude of 48 km, or 30 miles, while the mesopause occurs at an altitude of 80 km or 49.5 miles. There is no thermopause as there is no clear transition between the thermosphere and exosphere.



Layers of The Atmosphere

The Troposphere

The lowest layer of the atmosphere is called the troposphere. It's the layer that contains most of our weather. The term Tropo comes from the word meaning turbulent and this layer of atmosphere is turbulent in nature. The troposphere is transparent to sunlight and therefore absorbs very little energy from the Sun. Instead, the air in the troposphere is warmed by its contact with the ground, which does absorb energy from the Sun. Once warmed by the ground, pockets of warm air rise due to their buoyancy. As these warm air pockets rise, the air pressure surrounding them drops, causing these pockets to cool. Eventually warm air pocket cool enough to lose their buoyancy and begin cooling. The constant rising and falling of air pockets is what makes the troposphere so "tropo".

The Stratosphere

At the top of the troposphere the temperature stops decreasing with increasing altitude and begins increasing with increasing altitude. This marks the boundary between the troposphere and the next higher atmospheric layer, the stratosphere. Located in the stratosphere is the Ozone Layer, which occupies a region between 16 and 60 km (10 to 37 miles) above the ground and easily accessible to amateur near space flights. This layer of ozone gas protects life on Earth's surface by absorbing the Sun's harmful ultraviolet emissions. Ozone molecules absorb UV light, eventually converting the UV photons into heat and warming the stratosphere. The combination of sunlight and ozone warms the stratosphere. As there is less ozone above you (and more ultraviolet) higher in the stratosphere, the stratosphere warms as the altitude increases. This creates a situation opposite of the troposphere where warm and unstable air can exist at the surface. The stratosphere is a very stable layer of air with the warmer air above cooler air and with very little mixing between layers. The prefix of stratosphere, strato means layered.

As a near spacecraft ascends, it experience decreasing air temperatures until it reaches the stratosphere. Then the air temperature of the near spacecraft begins increasing once it enters the stratosphere. The altitude of the stratosphere varies throughout the year. It's higher in the summer and lower in the winter. The altitude of the stratosphere also varies by latitude. The closer to the poles you launch the near spacecraft, the lower the altitude at which it detects the stratosphere.

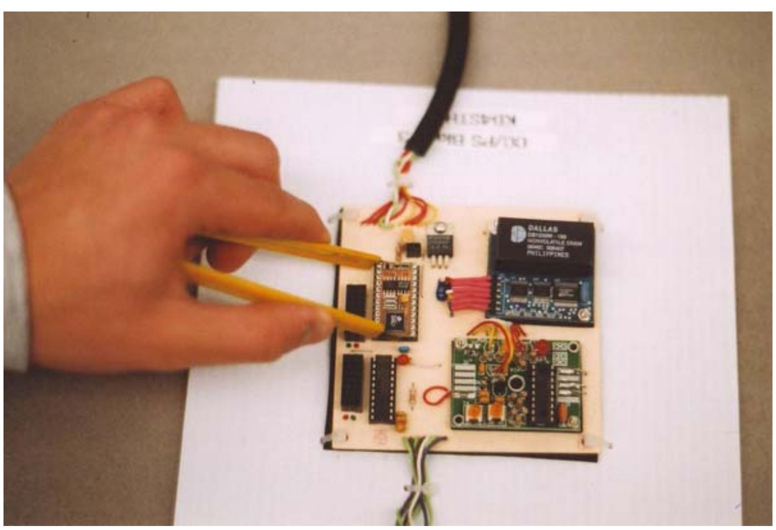
Above the Stratosphere

Since near spacecraft don't climb above the stratosphere, I'll only briefly discuss the structure of the atmosphere above the stratosphere. The mesosphere (Meso meaning middle) is the region of the atmosphere above the stratosphere where the temperature again drops with increasing altitude. The mesosphere is where most meteors burn up when they enter the atmosphere. Above the mesosphere is the thermosphere (Thermo meaning heat). In the lower thermosphere is located the ionosphere and the auroras. The temperature in the thermosphere is greater than the temperature of the mesosphere. The thermosphere is warmer because nitrogen and oxygen molecules in this layer absorb solar radiation. In fact each molecule acquires enough energy from the Sun to move at speeds indicative of molecules with a temperature or 2000 degrees Fahrenheit. However, since air molecules in the thermosphere are so far apart, collisions between them and objects in the thermosphere are infrequent. As a result, you would freeze to death rather than fry in the thermosphere. The exosphere is where satellites can be found orbiting the Earth. The eleven-year solar cycle warms the atmosphere which expands up into the exosphere. As a result, the amount of air drag on satellites in low earth orbits can change, bringing the satellites down earlier than originally desired.

Near Space Humor - Near Space Comix #2

Unfortunate Landing Spot – *Sign reads "DANGER Entering Idaho Army National Guard Firing and Maneuver Area. Do not salvage. Do not pick up unexploded ammunition."*

Bad Bacteria – *"Aiee, it's got my leg"*



I'm Just Going to Borrow This to Test my CC/PS – *How BASIC Stamp modules "Go Missing"*

Wow, I can see my house from up here! *– 11,454 feet*

CHAPTER THIRTEEN

Where To Go From Here

I think the folks doing "garage engineering for high tech" are the balloon people. They're the ones scrounging equipment, improvising environmental tests in their garage freezers, etc. and, most important, appearing to have fun.
- Jim Lux (W6RMK), a senior engineer at NASA/JPL
(This is not an endorsement from NASA/JPL)

Chapter Objectives

1.0 Some Suggested Future Experiments

Here's a list of twenty-five experiments I am either working on or would like to see developed. They range from the well thought out to the way out. The suggested directions for each experiment come either from experience, conversations with others, or in some cases, thinking about how I would approach them. Perhaps you can design one of them yourself. Or better yet, come up with an entirely different experiment. I suspect many of the results of these experiments may be found already published in the literature. This, however, is not the point or purpose of near space exploration. The purpose of near space exploration is to engineer a sensor, fly it into near space, analyze its data, and to discover the answer to the question; it's not to look it up answers in the encyclopedia. I believe there is something ennobling about finding out answers for yourself, by using your own hands and brains. Besides, making a really neat finding makes banging your head against the wall worthwhile. I've rated the following suggested experiments. Those with the H rating have some kind of hardware that I have built. Those with a P rating have parts that I have played around with. Those with the D rating are still in the dream stage.

1.1. Nephrometer (H)

1.1.1. Explanation

The nephrometer is a device to measure cloud opacity. The Galileo atmospheric probe carried one into the atmosphere of Jupiter in an effort to measure the altitudes and opacities of cloud layers during its descent. Nephrometers determine cloud opacity by measuring the cloud's effect on a beam of light. A light source in the nephrometer projects a fixed and known light intensity on a light sensor placed some distance away. The light detector continuously monitors the intensity of light reaching it from the light source. As obscuring material passes between the laser and the detector, the light intensity measured by the detector decreases. The greater the measured decrease in light intensity, the more obscuring (thicker) the cloud at the point of measurement.

1.1.2. Known Work In This Field

I know of no amateurs who are designing nephrometers at the time I am writing this book. I have a have completed design, but it isn't high on my to-do list at this time. I have often seen devices along military runways that appear to function as nephrometers, where they indicate the visibility at the runway for pilots.

1.1.3. Suggestions

Light Source
Probably the best source of light for the nephrometer is the laser diode. The collimated beam of a laser pointer simplifies the design of the nephrometer by doing away with the focusing lens and making it easier to exclude external light sources from interfering with the light sensors. Making the base line between the light detector and the laser source longer increases the amount of obscuring material between the detector and laser, thereby increasing its effect on the laser's intensity (which makes it easier to detect). A laser source will not spread it's beam over a significantly larger area as the base line of the device increases.

Light Detectors
Suitable light detectors for the nephrometer should be either the TSL230 Light To Frequency converter, a photodiode, or a LED wired in reverse. See Chapter Eight Section Five for instruction on these light sensors.

Potential Problems
The only thing changing the light intensity at the detector should be obscuring material between the laser source and the light detector. I can think of three factors that are independent of actual obscuring material that may affect the measurements returned by the nephrometer.

1. The laser source and the light detector may flex slightly, changing the amount of light reaching the light detector.

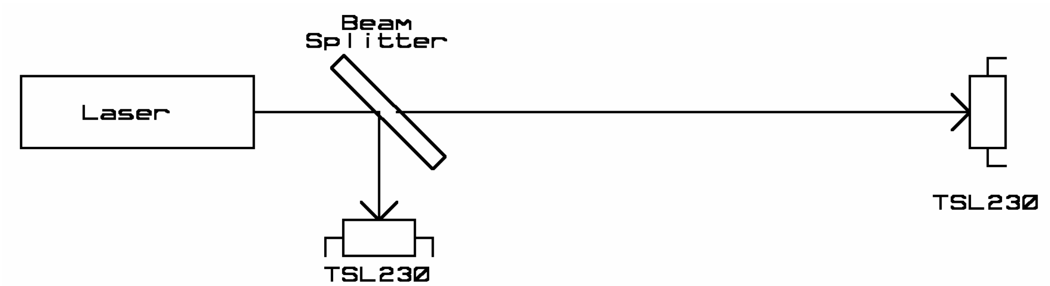
2. The laser's output probably varies with changes in temperature and battery voltage.

3. The sensitivity of the light sensor may change as the air temperature changes.

The first problem appears to be easily fixed by mounting the laser source and light detector to a base made from a wide beam of Styrofoam. When the beam is turned on its side (the wide side of the beam oriented vertically), the width of the base makes it difficult for the weight of the laser and light detector from flexing the beam. To prevent sideways forces from flexing the beam horizontally, glue one or two ribs to the base. The result is a T or C shaped beam. I don't think temperature changes can cause the Styrofoam beam to expand or contract significantly.

I know of no realistic way to prevent the laser source and the light detector from changing through the flight. Therefore I propose a second set of measurements be made during the flight to compensate for any changes in the system. First measure the laser's output without obscuring matter influencing the beam. This first measurement is the reference measurement that is used to determine the effects of the changing laser source and light sensor. Next a measurement is made of the laser's output with possibly obscuring matter can affect the beam. The first reference measurement is compared to the actual measurement. When the ratio of the second measurement compared to the first measurement differs from the first measurement, then obscuring material has been detected by the nephrometer.

I recommend the following design to implement the nephrometer. Place a beam splitter just in front of the laser to break the laser's beam into two separate beams. One beam travels the distance across the nephrometer, where clouds or dust can attenuate the beam. The second beam travels through a short blackened tube where it is sampled very close to the laser where obscuring material cannot interfere with the beam. Both light sensors are identical in design and exposed to the same temperatures and power source. Measurements of the two beams are made in quick sequence, before power fluctuations or temperature changes can affect the measurements independently of each other. Graph the ratio between the two measurements in relationship to the near spacecraft's altitude. The profile generated should indicate the altitude of clouds and their amount of obscuration.



Nephrometer Diagram

1.2. <u>Dust Sampling After Volcanic Eruptions (DH)</u>

1.2.1. Explanation

It's very difficult for dust to travel from the surface of the Earth into the stratosphere. Any dust launched only into the troposphere is quickly removed by weather, like rain. Once in the stratosphere however, dust should remain aloft for months or possibly even years as gravity slowly removes the dust. Remember, there is no weather, and especially rain, to wash dust from the stratosphere. High-energy events like big meteor impacts and volcanic eruptions can send material into the stratosphere. Launching balloons for several months after a volcanic eruption can record the progress of dust removal from the stratosphere.

1.2.2. Known Work In This Field

I know of no amateur program at this time making these measurements. I have experimented with using servo-operated petri dishes as a type of sampler, but still need to do more work. Perhaps photographs taken of the horizon at various altitudes may be used after-the-fact to make these kinds of measurements.

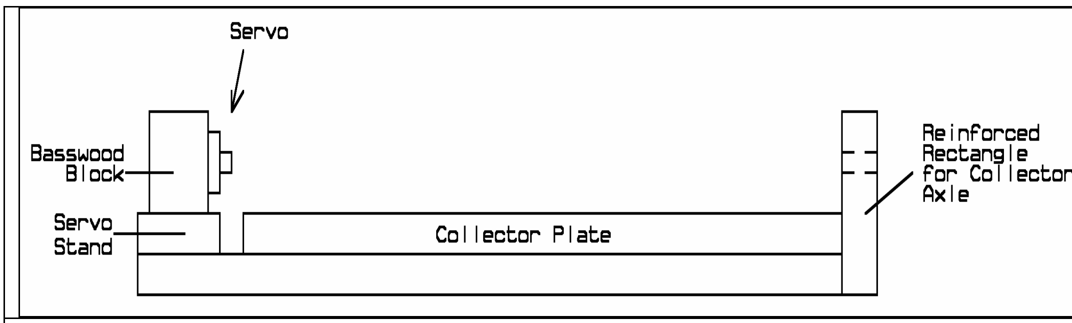
1.2.3. Suggestions

I can think of two ways of sampling the dust in the stratosphere. Either a large collecting plate can be carried on the near spacecraft or stratospheric air can be pumped through filter paper (this last idea comes from the GAINS project that EOSS is working with and from my email conversation with Dr. Brownlee of the University of Washington).

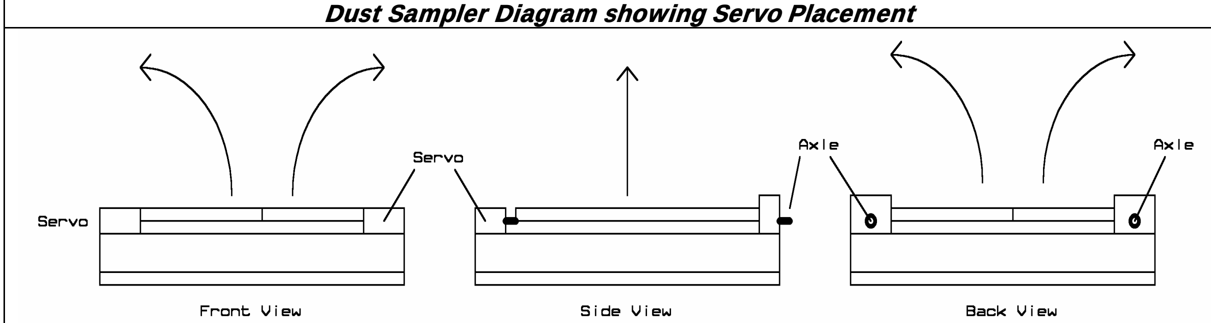
Sticky Plates As Dust Samplers

One way to collect materials in the stratosphere is to let them settle on a collection plate. The collection plate and its cover form the dust sampler. To increase the chances of collecting atmospheric dust, the sampling plate of the dust sampler must be large. To keep the weight of such a large plate low enough for a balloon and for a servo to open the cover, try making the dust sampler from a sheet of ½" thick Styrofoam. The dust sampler requires a sticky film on its plate to hold onto any material that settles on it.

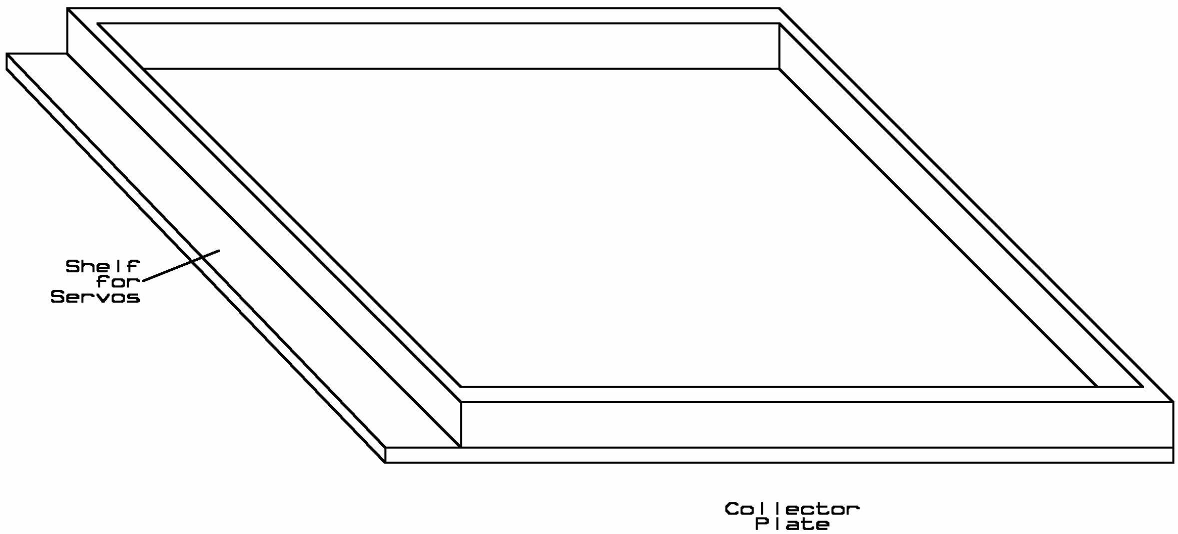
After reading *Sky and Telescope* magazine for October 2003, I discovered professionals use a film of oil on sheets of plastic to adhere any falling dust. With this in mind, a design for a dust sampler is shown in the following diagrams, with construction steps following.



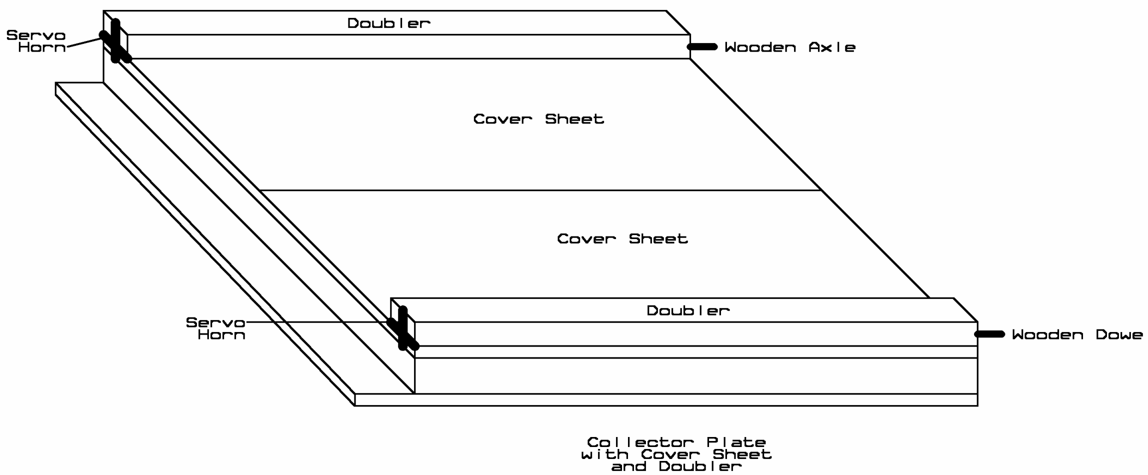
Dust Sampler Diagram showing Servo Placement



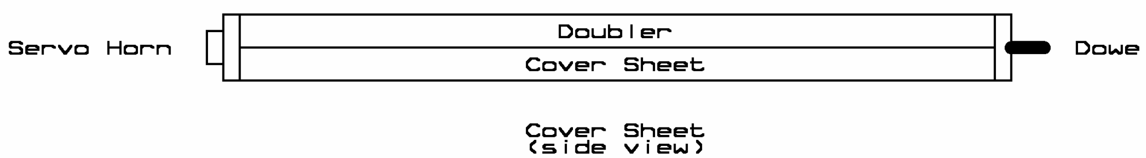
Front, Side, and Back View of the Dust Sampler



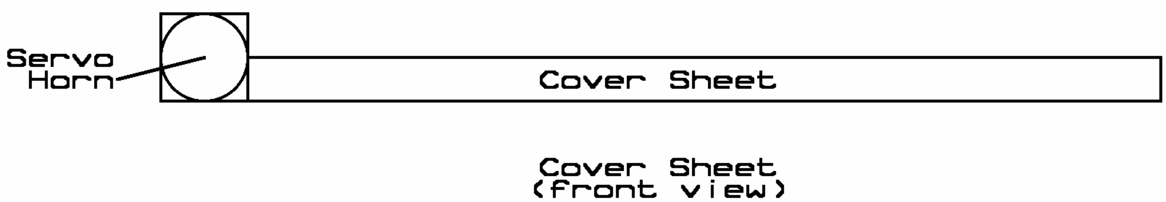
Collector Plate of Sampler



Collector Plate with Cover Sheet and Doubler



Side View of Cover Sheet



Front View of Cover Sheet

Materials

- ½ inch thick Styrofoam sheet
- Hot glue
- 1/8 inch thick plywood
- ¼ by ½ inch basswood strip
- ½ inch diameter dowel
- Servo mounting screws
- #0 or #00 hardware (1/4 inch long bolts, washers, and nuts)
- Two servos
- Three colors of #24 AWG wire (preferably red, black, and white)
- 1/8 inch thick heat shrink tubing

Procedures

√ Determine where the sampler will be carried on the near spacecraft. Perhaps it's easier if the dust sampler is suspended a ways below the bottom capsule in the near spacecraft.

√ Cut two identically sized sheets of ½ inch thick sheet of Styrofoam into a large square (the size depends on how large of a dust sampler your near spacecraft can carry)
√ Identify which cut sheet will be the collecting plate and which will become the cover
√ Cut six ¼ inch wide strips from ½ inch Styrofoam (four of these form the sides of the dust sampler and the other two form reinforcements for the cover)
√ Draw a line parallel to one side of the collecting plate that is two inches from the edge (this is the servo side)
√ Glue one strip to the collecting plate inside the two-inch line with hot glue
√ Glue the remaining three sides to the other edges of the collecting plate with hot glue
√ Cut the cover sheet of Styrofoam in half, down the center
√ Lay the covers on top of the collecting plate and cut off the overhang
√ Make notes on the covers so you cannot switch them around, as the covers are about to modified to the point where they cannot be switched
√ Trim about ½ inch from one end of each cover (this makes the cover about ½ inch narrower)
√ Glue one of each remaining strips to the outside edge of each of the covers (this doubles up the outside edge of each of the covers)
√ Cut four pieces of thin plywood into one inch squares
√ Rotate the servo to one of its fully rotated position

√ Note: The servo horn is to be mounted to the maxed out servo centered servo to form a cross, with arms that are diagonal to the square sides of the servo

√ Remove the servo horns from the servos and center them on two of the squares (to form an X across the squares)
√ Drill small holes for the #0 hardware through two opposite mounting holes in the servo horns and the thin plywood
√ Epoxy the bolts through the holes in the plywood squares (these are the bolted squares)
√ Epoxy the blank squares to the ends of the doubled up covers that are away from the servo side of the collecting plate
√ Epoxy the bolted squares to the ends of the doubled up covers that are on the side of the servo side of the collecting plate

√ Note: Now each cover has a blank square on one end and the bolted square on the other

√ Drill a ¼ inch (or slightly smaller) hole into the center of each of the blank squares

- √ Epoxy a length of ¼ inch dowel into the holes so that the dowel extends about ½ inch beyond the plywood
- √ Cut two pieces of ½ thick Styrofoam into a rectangle measuring one inch by two inches
- √ Cut two pieces of thin plywood to match and epoxy them to the Styrofoam rectangles
- √ Drill a ¼ inch diameter hole into the plywood face of the rectangles that is centered, but ½ inch from one edge (and 1-1/2 inches from the other end)
- √ Lay the covers over the collecting plate
- √ Slide the reinforced rectangles over the dowels in the cover
- √ Apply a thin layer of epoxy to the plywood faces where they make contact with the collecting plate and press them onto the plate and let the epoxy set

- √ Note: Be careful not to get epoxy on the dowels, the cover needs to rotate freely along the dowels

- √ Bolt the servo horn back onto the servo
- √ Rotate the servo to its maxed position
- √ Bolt the servo horn to the bolted squares
- √ Fill the space beneath the servo, but above the collecting plate with Styrofoam topped with a thin sheet of plywood

- √ Note: Cut the Styrofoam and plywood into a square measuring two inches on a side

- √ Use hot glue to glue the Styrofoam to the collecting plate and epoxy to glue the plywood the top of the Styrofoam

- √ Note: You'll need to get the servo out of the way when gluing the Styrofoam and plywood to the collecting plate. The square will fit up against the servo side of the collecting plate.

- √ Close the cover, laying the servo on the plywood face of the space filling Styrofoam and plywood
- √ Mark the outline of the servo
- √ Cut two pieces of the ½ by ¼ inch basswood to a length that fits under the servo mounting ears and against the servo body
- √ Place the basswood against the servo body and mark the location of the mounting holes in the servo ears
- √ Drill small pilot holes into the basswood
- √ Epoxy the basswood into place
- √ After the epoxy sets, bolt the servo to the collecting plate
- √ Place the cover axles into the axle holes in the collecting plate and push the cover up against the axle holes
- √ After the cover is laying flat on top of the collecting plate, push the covers into the servo horn
- √ Bolt the cover to the servo horn

- √ Note: The servo may not be exactly maxed at this point, but this will be corrected in software

- √ Cut the servo cable in half
- √ Split the servo cable back about one inch into three separate wires
- √ Strip about ½ of insulation from each of the three wires forming the servo cable

- √ Cut three lengths of #24 AWG wire long enough to extend the servo cable to the near spacecraft's flight computer
- √ Solder the wires to the servo cable, matching the colors
- √ Slide heat shrink tubing over the soldered connections and shrink
- √ Slide three more pieces of heat shrink over the extending wires
- √ Solder the remaining half of the servo cable to the extending wires
- √ Slide the heat shrink tubing over the soldered connection and shrink
- √ Plug the servos into the flight computer

Download code into the flight computer to position the servos and experiment with the proper settings. You want to position the cover in one of two positions, fully opened and fully closed. This means the servo must rotate 180 degrees with the code.

If the dust sampler is to be suspended below the near spacecraft, then cut two Dacron kite lines long enough to reach from the bottom of the near spacecraft, down to the dust sampler, across the sampler from diagonal corners, and back up to the opposite corner of the near spacecraft. Cut a second cord the same length and tie them together at their centers. Place the dust sampler into this harness and use a little duct tape to hold the dust sampler inside the Dacron harness. Let the harness come up from the sampler where it cannot interfere with the opening of the covers.

If the dust sampler is larger than the bottom of the near spacecraft, then make a spreader to keep the Dacron lines a part. To make the spreader, cut two lengths of dowel or fiberglass kite spars to a length just longer than the diagonal measurements of the dust sampler. Cut notches in the centers of both rods and epoxy them together to form an "X". Drill small holes near the edges of the arms of the X that are large enough to pass the Dacron cord through. Tie knots in each arm of the Dacron harness that the holes in the spreader cannot pass through. Tie these knots above the reach of the covers of the dust sampler. Pass the lines through the spreader and terminate the ends with bearing swivels. The spreader lets the Dacron harness widen from the bottom of the near spacecraft but remain out of the way of the opening covers.

Thoughts On Preparing The Dust Sampler

I don't know what kind of oil is used in dust samplers, but I imagine it is clear in color. There must be very little contamination from foreign debris in the oil or else it will be confused for near space-collected dust. Pouring the oil must be done in a clean location that will not add additional debris to the oil before the mission. So I imagine a process like this.

- √ Cut a sheet of Styrofoam large enough to cover the opened sampler, but sure to cleanly cut the edges so there is no Styrofoam flaking off the edges (I would recommend hot cutting the sheet)
- √ Set aside an area to pour the oil, it must have a table to work on and electrical power (this will be the clean room)
- √ Open the sampler and remove any dust with compressed air, then wipe down the surfaces with alchohol and lint-free paper towels (such as KimWipes™)[A]
- √ Hang plastic sheets around the work table, leaving enough space for you to work next to the table
- √ Blow as much dust out of the area as possible with fans or clean, compressed air
- √ Wipe down surfaces that seems to retain dust with lint free paper towels and alcohol
- √ Place a few fans on the table that point away from the center and far enough a part that the sampler can sit between them
- √ Run the fans until the sampler is closed

- √ Suspend the Styrofoam cover above the sampler in order to block any dust that may fall during the filling
- √ Wipe the bottom of the suspended Styrofoam sheet and let it dry before proceeding
- √ Open the sampler and wipe out the inside with alcohol-dampened lint free towels
- √ After it dries, pour a thin layer of oil into the sampler

- √ Note: I'd make the layer very thin, perhaps around a 1/16th of an inch or less

- √ Rock the sampler to spread the oil evenly
- √ Close the sampler covers as soon as possible
- √ Consider covering the closed sampler inside a plastic bag to prevent contamination before launch (add directions to remove the plastic bag covering to the pre-launch checklist).

Program the flight computer to open the sampler at an altitude above aircraft and before the balloon bursts. It opened too early, particulate matter from jet exhaust may contaminate your sample and if closed after the balloon bursts, latex and talcum power from the burst balloon may contaminate the dust sampler's plate. Immediately upon recovery, cover the petri dish with a plastic bag. Keep the plate closed and do not open it until it is inside the clean room. Thoroughly clean the exterior of the dust collector before opening it. Pour off the oil from the opened dust sampler into a petri dish. Note that any glassware used in this process must be free of dust. View the collected dust under a microscope.

The amount of atmosphere sampled is determined by multiplying the surface area of the plates by the change of altitude during the time the sampler is opened. The length of time the sampler is opened is another important thing to know. Samplers covering the largest volume of air for the longest period of time have the greatest exposure to dust. Complicating this is the fact that the air pressure drops as the balloon ascends. Lower air pressures are less capable of keeping dust aloft. So the "effective" volume sampled is not simply the volume of air the sampler plate passes through.

A control sampler must be constructed along with the actual sampler. The control is a sample of the same oil that has never been sent up. Another good control is to use oil that has been poured into sampler, but removed before closing up the sampler. The dust collected from the control sampler is compared to the dust from the actual sampler. It looks like a lot of fun is to be had perfecting this process.

Air Pump Samplers

A second option is to pump a high volume of air through a sheet of filter paper. By using a high volume air pump, more atmosphere is sampled. The benefit of using an air pump to sample the atmosphere is that a clean room and large collection plates are not needed.

Potential Problems

Air pumps are rated in cubic feet per minute (CFM) for one standard atmosphere. As the air pressure drops in near space, the pump is less effective at pumping air. High volume air pumps require more power to operate that low volume air pumps. Increased power implies more weight is required in batteries.

Potential Air Pump Designs

Because of current requirements, a relay or MOSFET is required to turn on and shut off the air pump. Orient the air pump horizontally, rather than vertically, so dust cannot fall on the filter paper during the initial ascent. Use a funnel to concentrate airflow into the air pump. Make the funnel with smooth sides and joints so turbulent airflow doesn't cause pockets of air to slow down. When any medium, including air, carrying materials slows down, it loses it ability to keep those materials suspended in the medium. Use smooth surfaces in the funnel to prevent suspended dust from settling out and onto the funnel surface. At the exhaust port of the sampler, suspend a sheet of paper from its top edge to monitor the effectiveness of the air pump to create airflow. The greater the volume of air flowing through the pump per unit time, the greater the deflection it creates on the paper. Use a camera to photograph the position of the paper sheet. I suspect the effective CFM of the air pump decreases just as the air pressure deceases. As an example, when using an air pump with a rating of 100 CFM at a pressure of 500 mb (about ½ of the air pressure at sea level), the effective CFM of the pump is only 50 CFM.

Turn on the air pump once the near spacecraft is above the troposphere and off before the balloon bursts. To prevent contamination upon landing, a door should close over the filter when the air pump shuts off. Use two covers, one on the inflow side of the filter and the other on the outflow side of the filter. If the covers are mounted inside the funnel of the sampler, and next to the filter paper, then the doors can be kept small. Use a servo to open and close the doors. After the flight the filter paper is removed and examined under a microscope. Create a control by launching a second filter paper that is not exposed to airflow from the pump. Orient the control with its face pointing horizontally, like the filter paper in the air pump.

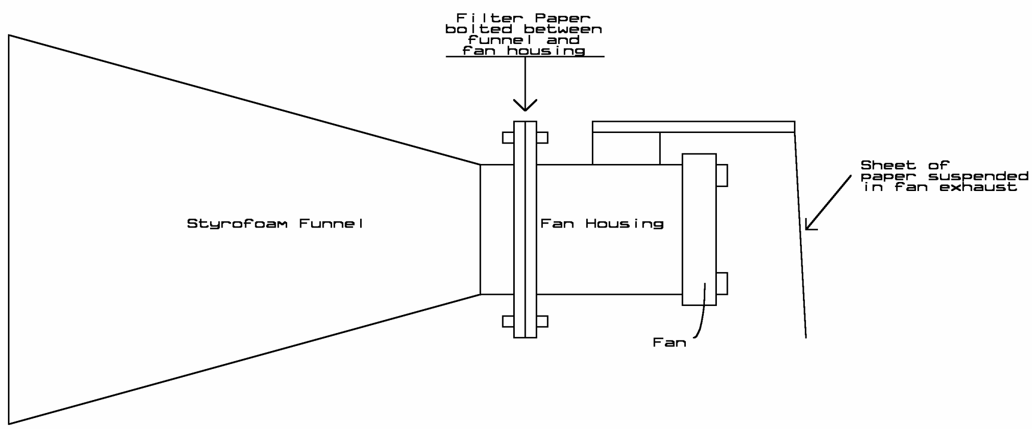


Diagram of Pump Sampler

Because of the changing altitude of the air pump during the flight, the volume of air sampled cannot be determined simply by multiply the CFM of the air pump by the length of time the pump was operated. Normally calculus is used to calculate something like this. It may be too difficult to determine a mathematical function describing the air pressure as a function of time. If such a function can be determined, then the function is integrated over the length of the time the filter was operated. Here are two other ways to make the calculation.

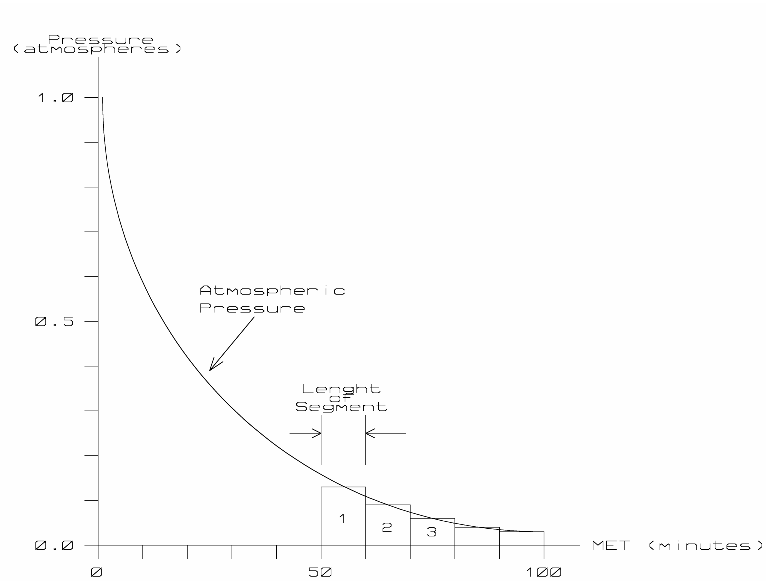
Graphical Approach

- √ Multiply the CFM of the air pump by the length of time (in minutes) it was operated to calculate a total volume of air in cubic feet
  (This is the uncorrected volume value)
- √ Determine the altitudes at which the air pump was operating

Use a sheet of fine square graphing paper to perform the next steps

- √ Graph the air pressure versus the time during which the time pump operated

- √ Note: The resulting graph looks like a pressure versus altitude graph, but the altitudes have been converted to the MET the experiment operated at that altitude
- √ Draw a rectangle on the above graph where:
    - o The top side of the rectangle is the air pressure at the start time of the experiment
    - o The bottom side of the rectangle is at the origin of the graph
    - o The left side of the rectangle is the start time of the experiment
    - o The right side of the rectangle is the stop time of the experiment



Graphical Approach to CFM

Now the calculus step, sans the calculus

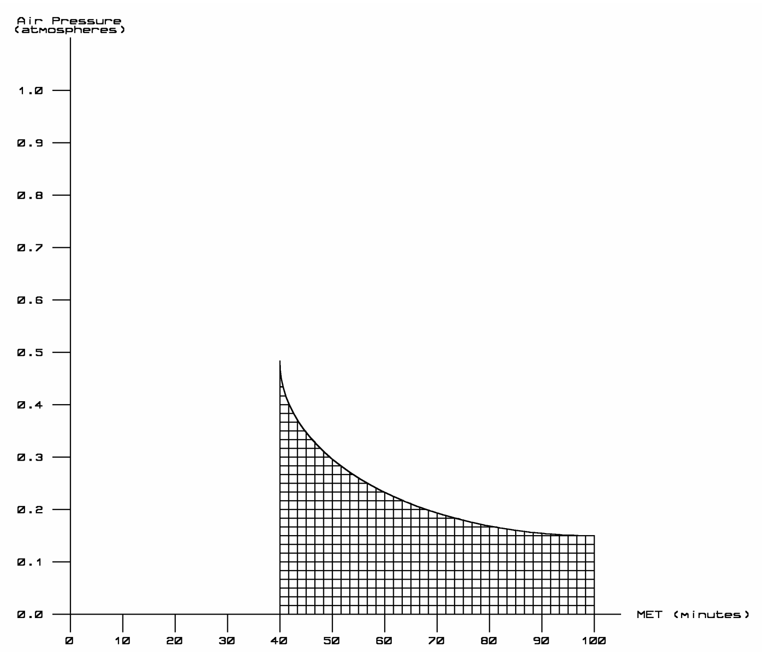
- √ Count and record the number of squares inside the original, uncorrected rectangle
- √ Count and record the number of squares beneath the curve of pressure versus time graph
- √ Calculate the correction ratio by dividing the number of squares beneath the pressure versus time curve by the number of squares in the original rectangle
- √ Note: The result of this division is less than one
- √ Multiply the uncorrected volume value by the correction ratio

The result should be close to the actual volume of air sampled
Note: The finer the squares on the graph paper, the more accurate the results of the calculations

Sampling Approach
This method divides the sampling time into segments. The average pressure during each segment is used as a correction factor for the volume of air sampled during that segment.

- √ Divide the time the experiment was run into a number of equal width segments of time (I recommend at least ten segments)
- √ Determine the altitude at the beginning and ending of each segment
- √ Determine the length of time required for the balloon to pass through each segment (This is the time spent at each segment)
- √ Average the altitude at the beginning and ending of the segment to determine the average altitude during each segment

- √ Determine the air pressure at the average altitude of each segment (This is the average air pressure of each segment)
- √ Divide the average air pressure of each segment by the sea level air pressure at the time of launch (This is the correction factor for each segment)
- √ Note: Because of the great change of pressure experienced during the flight, 1013 mb can probably be used without creating significant errors
- √ Multiple the time at each segment by the CFM of the air pump (This is the uncorrected volume of air sampled)
- √ Multiple the uncorrected volume of air sampled by the correction factor of each segment (This is the averaged volume sampled as each segment)
- √ Sum up all the averaged volumes sampled for all the segments



Sampling Segments

The result should be close to the actual volume of air sampled
Note: The greater the number of segments created, the more accurate the results of the calculations

1.3. Aurora Studies (D)

***Aurora over Idaho** - November 2003*

1.3.1. Explanation

Auroras are an inspiring sight. After seeing my first one in Idaho, I immediately wanted to send a near spacecraft up to photograph it from the darkness of near space.

1.3.2. Known Work In This Field

There is no amateur work in this area that I know of. Satellites have been launched to study auroras, however.

1.3.3. Suggestions

Since auroras are not predictable in the long term, experiments for an aurora flight must be designed in advance and be ready to launch in a few hours notice and at night. Don't forget that this means tanks of helium must be on hand. While this is not difficult for professionals who get paid to do studies in the middle of the night, it's difficult to arrange for amateurs. Possible aurora experiments include the following.

- Measure cosmic rays fluxes during an aurora and compare the results to a flight shortly after the aurora
- Measure ionization levels in the atmosphere (see section 1.5)
- Record images of aurora on videotape

Since auroras are caused by storms of charged particles from the Sun, larger cosmic ray fluxes should be detected during the mission. In this case, most of the additional flux is due to the Sun. The increased number of cosmic rays detected can be correlated to the solar wind measurements as determined by the ACE satellite. See the ACE website at http://www.sec.noaa.gov/ace/ACErtsw_home.html for the current solar wind measurements.

Some newer CCD cameras are sensitive enough to record faint stars. A suitable CCD camera is the PC 164C available from Super Circuits. This CCD camera has a lux rating of 0.0003 lux, letting it see in near darkness. For color images of aurora try using the PC 165C CCD camera. However, this camera only has a lux rating of 0.05 lux. Live images of the aurora can be transmitted over ATV, but for the best quality of images, use a camcorder with A/V input or a portable, battery operated VCR to record the images from the CCD camera onboard the near spacecraft. CCD cameras need an optical system to create images. Don't use a pinhole; instead use a wide-angle camera lens for the CCD camera optics. Auroras are large beasts; to see them requires large angles of view, so don't use anything like a telephoto lens.

Do not attempt to use a film camera in place of the CCD camera. A film camera requires about 15 seconds to record a descent aurora photograph. The capsule's spinning and swinging will not allow good still images of an aurora from near space using film cameras.

For the best images, position the CCD camera to point above the horizon but below the balloon. Placed at a 45 degree angle above the horizon might make a good compromise. Positioning the CCD camera at a 45 degree angle prevents city lights below from entering into the camera. It also prevents city light reflected off the balloon from entering into the camera. For additional protection, make a light hood to go over the camera lens and extends several inches beyond the end of camera lens.

1.4. Measuring Cosmic Ray Energies And Directions (H and D)

1.4.1. Explanation

A Geiger counter is good at counting the number of cosmic rays during a near space flight, but it can't determine the energies of the detected cosmic rays. A single Geiger counter also can't determine the direction of the radiation.

1.4.2. Known Work In This Field

There is none that I know of. I have heard of only two amateur flights even measuring cosmic ray fluxes in near space.

1.4.3. Suggestions

There are two measurements I want to make in regards to cosmic rays. The first is their energies and the second is their source (direction).

Cosmic Ray Energies

In one of my Physics classes in college, we used a multichannel analyzer to measure the energies of x and gamma radiation. The detector consisted of a doped silicon crystal or a crystal of sodium iodide (scintillators) place in front of a photomulitplier tube (PMT). When radiation slams into the scintillator it creates a small flash of light, which is too faint to be seen with the eye. The brightness of the flash is determined by the energy of the particle slamming into the crystal. A PMT amplifies the tiny flash of light. Photons from the flash strike the face of the PMT liberating electrons (in some cases, a single photon of light can be detected). Several charged grids inside the PMT accelerate the freed electrons. Each collision between one of the grids and an accelerating electron creates more free electrons, amplifying the original signal. At the end of the tube, the PMT creates a voltage pulse that is linearly related to the size of the original flash of light. The signal from the PMT is digitized by an I/O card in a PC and graphing software then plots the results.

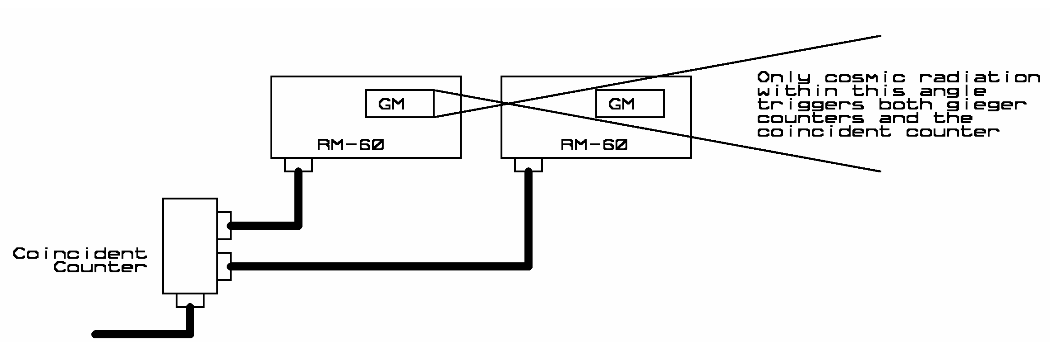
Unfortunately, a PC is not a realistic item to carry on a near spacecraft. But a PC does exist in a single board computers (SBC) form factor called the PC104. Several CPUs, like the 80486 and Pentium can be found in this PC104 form factor. It may take some effort to physically interface a

PMT A to D board to the I/O slots of the PC104. Use a solid-state hard drive to store the multichannel analyzer software and the results from the flight. If the PC104 route is too difficult, then another possible option is to record data from the PMT on an audiotape and analyze it after recovery.

Another suggestion, and one should be easier to implement, is to send materials into near space that physically record nuclear tracks. Materials like acrylic plastic are damaged by the impact of subatomic particles. Etching the acrylic plastic with suitable chemicals changes the damaged regions into tracks visible in simple microscopes. The size and orientation of the tracks indicate the energy and path of each particle. Dr. Fleischer's book, *Nuclear Tracks In Solids*, explains which materials are suitable and the proper etchants to use. It's quite amazing what he and others have done with the clear plastic visors of the Apollo astronauts.

Cosmic Ray Direction

Cosmic ray detectors have already determined that galactic magnetic fields hopelessly scramble the flights of cosmic rays. There is no way to determine the original direction and source of cosmic rays, unless a statistical study of a large number of cosmic rays can sort it out. But this fact does not prevent us from determining the direction of cosmic rays in the atmosphere. Recall that a Geiger counter only measures the presence of ionizing radiation, and not the direction of its travel. But there is a way around this. When two Geiger counters are placed in close proximity, cosmic rays traveling in the direction aligned with both Geiger counters can be sorted out from those that do not travel in the same direction. The coincident counter is an AND gate with inputs from two Geiger counters. Only when both Geiger counters produce a detection at nearly the same time, does the AND gate produce an output. The time available to detect a coincidence is the length of time it takes for ionized gas inside the GM tube to recombine. The length of time for a quenching gas to recombine the ions inside the GM tube is referred to as the tube's dead time. The dead time is shortened by the presence of a quenching gas inside the GM tube, usually an inert gas like Argon. During the dead time, no further detection of radiation is possible. This creates an incentive to design GM tubes with very short dead times. In the case of the RM-60, the dead time is on the order of 20 microseconds. Since cosmic rays travel at relativistic speeds, two RM-60s within 20,000 feet of each other can detect coincidences. Two RM-60s and a coincident counter electrically connected between them makes a Cosmic Ray Telescope (CRT). To make the CRT more effective, mount the CRT to a servo-operated scan platform, as outlined in Chapter Seven, Section Four. During a near space mission, take several measurements at each altitude, with the CRT positioned at a different azimuth.



***Two RM-60 Geiger Counters AND a Coincidence Counter** – Only cosmic radiation within the angle shown will trigger both geiger counters and the coincident counter*

A more pressing problem than the time it takes cosmic rays to travel the length of the CRT is that as the distance between the GM tubes is increased, the beam diameter of the telescope decreases. As the area of the sky being viewed decreases, so does the cosmic ray flux entering the CRT. Improvements in resolution are offset in decreases in sensitivity. Also, as the beam diameter, or field of view of the CRT decreases, rotation and rocking of the near spacecraft smears out the CRT's field of view. For amateur near space, it's only realistic for us to measure cosmic ray fluxes where, we use short length CRTs, with the RM-60s are positioned next to each other, and at large changes in elevations. My first and only CRT test, which appears to have recovered in a reservoir, attempted to measure cosmic ray fluxes at three elevations, 0 degrees, 45 degrees, and 90 degrees. With the RM-60s mounted next to each other, the beam diameter of the CRT was 7.5 degree. Depending on the results of the experiment (which I never got back), I was going to attempt other elevation measurements on the next flight. Perhaps you can have better luck than I did. I'd like to add one more point about finding sources of cosmic rays by determining their direction. If a nearby star goes supernova, it may be a source of increased cosmic ray flux. In that case, the CRT should be able to determine that the supernova is a source of cosmic rays. However, if the supernova is really close and powerful, chances are we'll be more interested in avoiding the cosmic rays than measuring them!

1.5. Atmospheric Ion Measurements (P)

1.5.1. Explanation

Cosmic ray collisions with molecules in the atmosphere break a part those molecules and create atmospheric ions. The movement of these charged ions can be detected with resistors and an operational amplifier
.

1.5.2. Known Work In This Field

I know of no one making this kind of measurement.

1.5.3. Suggestions

The Society of Amateur Scientists, operated by Shawn Carlson, has developed a atmospheric ion-measuring device which is simple to construct. The plans were initially published in the September 1999 issue of *Scientific American* under the Amateur Scientist. Kits may still be available from the SAS. If not, there is sufficient information in the Amateur Scientist article to build the atmospheric ion counter.

Once I complete my kit, I plan to compare the ion count at various altitudes with the cosmic ray counts my RM-60 measures. Perhaps measuring ion concentration is one way to measure cosmic ray energies.

1.6. UV and Ozone (H and D)

1.6.1. Explanation

Ozone in the stratosphere prevents most ultraviolet radiation from the Sun from reaching the Earth's surface. Ultraviolet radiation is divided into three bands, called UVA (320 to 400 nm), UVB (290 to 320 nm), and UVC (100 to 290 nm). UVA is not absorbed by ozone as both UVB and UVC are. The amount of ozone in a column of air can be determined by measuring the UV flux. Alternatively, the concentration of ozone can be measured by an instruments carried aloft by balloons. A device to measure ozone, an ozone sounder, is called an ozonesonde.

1.6.2. Known Work In This Field

Ozonesondes are launched daily by professional organizations. I know of no amateur near space groups launching their own ozonesondes. Ground-based UV measurements are taken through telescopes pointed at the Sun and carrying special UV filters. By taking into account the elevation of the Sun, the amount of ozone in the column of air above the telescope can be determined. The units of ozone are given in Dobsons.

1.6.3. Suggestions

Ozonesondes pump air through a cell containing a solution of sodium iodide. The chemical reaction between the ozone and sodium iodide creates a small current. The amount of current generated is measured and compared with the airflow of the pump or fan pulling ozone-containing air through the chemical cell. The ozonesondes create a signal that is the standard for radiosondes, allowing to be interfaced to a standard radiosonde. Ozonesonde kits are manufactured and are available over the Internet. Refill kits are available to refurbish and refly the same ozonesonde. However, I found the cost to be prohibitive.

An alternative is to use a light detector sensitive to ultraviolet radiation. One method is to use a broadband light detector and cover it with a UV filter. A second method is to purchase a UV photo-detector. Hammamatsu is one manufacturer of these devices. Do not use a flame detector. Flames give off UV radiation and the flame detector is used in fire-fighting robots. My research has uncovered that these flame detectors do not create a signal that is linear with UV flux. They produce a signal when the UV flux is intense enough to trigger them. Recently I have come across UV and violet emitting diodes (UVEDs). Wiring them backwards creates a UV sensitive photodiode. Refer to Chapter Eight, Section Five for using LEDs as photodiodes.

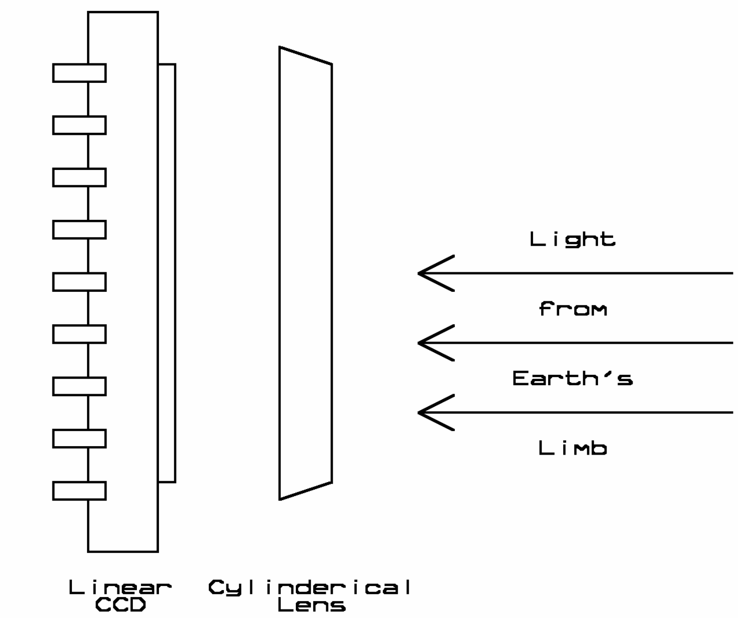
To get a reading of the absorption of UV by ozone, the UVED must be sensitive (emit) in at a wavelength below 350 nm, which is the lowest end of the UVC band, and all of the UVB and UVC bands (100 nm to 320 nm). After finding a UVED sensitive to that region of the spectrum (they don’t exist now, but they may exist soon), the UVED detector must point to the Sun to get the most accurate reading. There are a couple of approaches to solving this problem. One is to build a despun section for the near spacecraft. As the near spacecraft rotates on ascent, the despun section rotates in the opposite direction, keeping every instrument on the despun section in a fix position. Either the flight computer must be located on the despun section or command and control between the flight computer and instruments on the despun section must be accomplished by a radio link. The second suggestion would necessitate a slave flight computer on the despun section. Perhaps a RC helicopter gyroscope could be used to determine how fast and in what direction to rotate the despun section. These gyros output a PWM signal that changes as the direction and amount of rotation of the gyro changes. A second option to determine the spinning of the near spacecraft is to detect the position of the Sun, which changes very slowly during the ascent (roughly one or two RPM as experienced by past missions). Another option is to take measurements only while the Sun is drifting through the UV sensor’s field of view. This method requires the construction of a sun sensor to detect when the Sun has entered the field of view of the UV detector. See this chapter, Section 1.14 for notes on the Sun Sensor.

A third option to record the output of the UVED for an entire rotation of the near spacecraft is not a viable solution, because the rotation of the near spacecraft changes, sometimes speeding up, other times slowing down or even reversing directions.

1.7. Limb Sounding (D)

1.7.1. Explanation

Satellites measure atmospheric structure and gas concentrations by limb sounding. As the Sun sets in relationship to a satellite, the Sun passes through more atmosphere until it passes behind the limb of the Earth. Special filters or spectrometers determine the composition of the atmosphere at various levels.



Limb Diagram

1.7.2. Known Work In This Field

Near spacecraft are not suitable for measuring the composition of the atmosphere by observing the Sun rise or set. However, the brightness of the atmosphere as a function of elevation above the Earth's limb can be measured. I know of no one doing this sort of measurement.

1.7.3. Suggestions

The best idea I have had on this topic is to use a linear CCD chip at the focus of a lens, perhaps a cylindrical lens, since the measurement in only one dimension is needed. A CCD is needed, as many measurements over a small angle are required to sound the atmosphere above the Earth's limb. If an array of photodiodes were used in place of the linear CCD, the resolution of the array would not be as great as it would be with a linear CCD. At Kansas State University In the late 1990's I was shown a linear CCD with a sample and hold feature. After the array is signaled to make a measurement, the results from each element in the CCD array was stored until read out, one element at a time. This feature is needed as by the time the results from one end of the array was readout, the other end of the array would be experiencing a different amount of light. Take multiple limb soundings and compared them to each other as the altitude changes or to soundings at the same altitude but recorded on different days.

Potential Problems In Limb Sounding

Not taking limb soundings at the same azimuth or the same elevation confounds comparing different soundings. Variations in elevation may be the easiest to correct, as the increased in brightness of the Earth's limb may be easy to pull out of the data. The detection of Earth's limb in each sounding becomes the pixel to align other limb soundings. The remaining problem with this method is the missing data that results. Some limb soundings will start sampling at a lower elevation while other limb soundings will begin sampling at higher elevations. Data on the extremes of the CCD will be lost in the alignment process.

I can think of two ways to get around the azimuth problem. Either mount a limb sounder to a despun section or take a limb sounding only when the Sun is in the correct location with respect to the limb sounder. This requires the use of a sun sensor. It's really beginning to look like the development of the sun sensor would be a good idea.

To compare limb soundings, load the results from each limb sounding into columns of a spreadsheet. Align the columns until the Earth's limb in each column is located in the same row for each column of data. Then graph the results by plotting light intensity vertically and the altitudes horizontally. Draw lines across each column in the graph connecting equal light intensities, called isophotes (equal light brightness)

1.8. Passive Thermal Tests (H)

1.8.1. Explanation

Near spacecraft risk getting too cold rather than getting too hot, unless, that is, the electronics inside the airframe generates a great amount of heat. The temperature in near space can drop below –60 degrees Fahrenheit -- not a good temperature for many devices! Systems that actively heat the interior when it gets too cold can be designed, however, they require batteries to operate the heater. The drain on the battery from an electric heater is quite substantial, necessitating a separate battery for the heater than is independent of main battery power for the avionics. To save weight and make use of the solar heater always present in near space, the Sun, passive heating methods are preferred over active ones.

1.8.2. Known Work In This Field

Several TVNSP experiments have been designed to determine which construction techniques are best for airframes. Other than TVNSP, I'm not aware of any other near space groups performing these experiments.

1.8.3. Suggestions

The following conditions are a few suggestions of the many possibilities available for testing passive warming of near spacecraft.

- Construction Materials
- Insulation Materials
- Insulation Techniques
- Airframe Color

For example, other materials may insulate near spacecraft better than ¾" thick Styrofoam. If such a material is identified, it needs to be lightweight and easy to build with. Is space blanket effective enough to justify using it? Perhaps wrapping the airframe in a different material will retain interior heat. What about how the space blanket is used? Materials may be more effective at insulating an airframe when used in a particular way. Materials with the lowest albedo should keep the airframe warmer by absorbing the greatest amount of solar radiation. Aside from absorbing radiation, materials also emit radiation. An ideal material has a high absorption of solar radiation external to the airframe but low emission of infrared radiation from inside the airframe.

1.9. Gas Measurements (D)

1.9.1. Explanation

Explorer II made attempts to determine the gases and their ratios in the stratosphere (the collected air samples were analyzed in laboratories after the flight). Atmospheric probes dropped by spacecraft into the atmosphere of the planet Jupiter and soon the moon Titan, also attempt to measure gases in the atmosphere (but of other planets or moons).

1.9.2. Known Work In This Field

Ozondesondes are one sensor used to measure atmospheric constituents that are used regularly. There may be other programs to measure gases in the atmosphere by balloon. Aircraft are used regularly to measure levels of pollution above cities.

1.9.3. Suggestions

I have two suggestions for measuring gases in the atmosphere. The first involves in-situ measurement and the second involves sampling for later analysis. Carbon monoxide and oxygen sensors are available to the public. However, as I understand, their output tends to be more digital than analog. That is, they are used to indicate whether conditions regarding oxygen into an engine are acceptable or if carbon monoxide levels are too high. A second option to purchasing ready-made sensors is to construct one on the workbench. Like the ozondesonde, ambient air can be pumped into a chemical cell where the gas of interest chemical reacts inside the cell. One example is carbon dioxide gas pumped into a solution of sodium hydroxide. A precipitation is produced that clouds the liquid inside the cell. A LED and photodiode together can measure the resulting cloudiness.

The second option is to carry sampling bottles onboard the near spacecraft. At a programmed altitude, the bottle is opened to the air. Afterwards, the bottle is closed, sealing the air sample inside. Servo controlled valves are available at hobby shops that cater to RC aircraft hobbyists. The valves are used to control the deployment of pneumatically operated landing gear. The one problem preventing this from being a simple method is the lower air pressure in near space. When the sample returns to the ground, the increased atmospheric pressure will attempt to crush the bottle. So it may be necessary to pump sampled air into the sample bottle. Alternatively, a stronger, perhaps thin walled aluminum, sampling bottle can be used. Gas ratios should not change between the ground and near space, but let's try measure it.

1.10. Repeaters And Digipeaters (H)

1.10.1. Explanation

The higher a VHF, UHF, or microwave antenna is above the ground, the greater the range of the radios using that antenna. Lower frequencies like HF make use of the ionosphere to bounce and skip radio transmissions around the world, so they don't benefit from higher antennas like higher frequencies. Adding a repeater to a near spacecraft makes the near spacecraft look like a commsat. Though not official, this form of communication is termed, Earth-Balloon-Earth (EBE). One of the near space records Ralph Wallio maintains is the record for the longest distance communication via EBE.

1.10.2. Known Work In This Field

Many groups have carried voice repeaters into near space. I wouldn't be surprised if every program hasn't carried a repeater at some time. Voice repeaters appear to be very popular with non-participants who can use them to make long distant contacts with a Handie-Talkie. Less frequently, digipeaters are launched into near space.

1.10.3. Suggestions

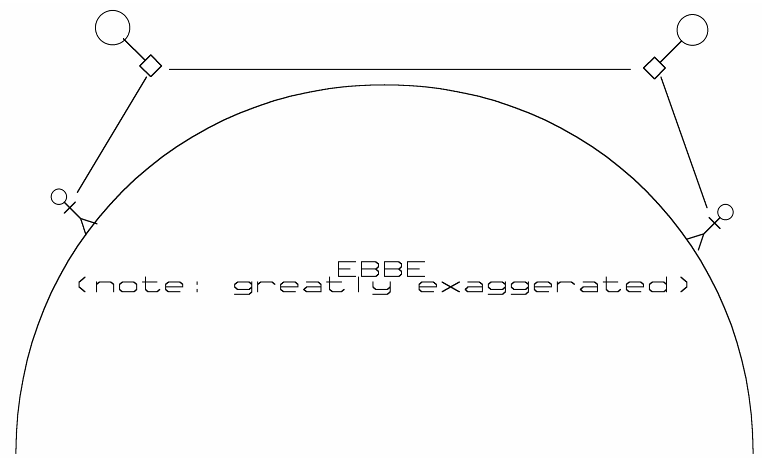
The easiest way for a near space program to get into voice repeating is to use the simplex repeater sold by Radio Shack. Their repeater records up to 30 seconds of conversation, keys the radio, and retransmits the recorded signal. The repeater operates on "AAA" batteries and only requires a handheld radio. An external antenna is preferable, but one TVNSP flight successfully flew a handheld with its rubber ducky antenna. The shortcoming of the simplex repeater is that it transmits on the same frequency that it receives. Unless repeater users understand this and the delay between transmission and reception, they will double with each other. One way to reduce doubling is to transmit on one frequency and receive on a different one. Frequency splits can be programmed into most HTs for this purpose.

Some dual band radios are capable of performing as repeaters, but repeaters with a frequency split on located different bands. The shortcoming of this repeater design is that anyone without a dual band radio or two separate radios is incapable of listening into conversations.

To make the repeater strictly legal with the FCC, a means of shutting off the repeater must be incorporated with the repeater. One way is with the Flight Termination Unit (FTU) used to separate the balloon from the load line. Instead of activating the relay to heat the nichrome coil, the relay is used to provide power to the repeater. When the repeater must be shut off, the signal to the FTU is brought to ground, opening the relay and shutting off the repeater. I have personally made this minor modification and programmed a flight computer to turn the repeater on and off. Now you only need to find a means to signal the FTU from the ground. This last requirement is left as an exercise for the reader, as the author has not had the time to experiment sufficiently with DTMF decoders.

If a digipeater is on the manifest for your near space launch, be sure to use a second radio and TNC (unless the flight computer uses a MIM or Tiny Trak). Do not digipeat on the tracker frequency or use the same TNC as the tracker. As the near spacecraft ascends, the amount of packet data is will hear increases. With digipeating turned on, Chase Crews may lose tracking and status data from the near spacecraft as the TNC spends more time digipeating traffic than sending position reports. .

Another exciting event is to attempt communication hops through several balloons carrying repeaters. This EBBE method of communication has only recently been attempted and promises to allow communications over nearly half the United States. To attempt EBBE communication requires coordination for the times of the launches, the distance between launches, and the frequencies used by the repeaters onboard the near spacecraft. The launches must place the near spacecraft within each other's communication footprint long enough to allow sufficient communications. The farther the launch sites are from each other, the higher the balloon must rise and the shorter the allowed time for communications. Of course, the greater the distance between the balloons, the greater the range allowed between two amateur radio operators using the system. Of course once EBBE becomes more commonplace, there will be attempts for EBBBE! I can just see the fun that will entail.



EBBE – *Earth → Balloon → Balloon → Earth communication*

Be sure to pass the word if you plan to launch a repeater on your near space mission. Let those in the predicted footprint of the signal know what frequency to communicate with and the time to expect the launch. This is especially true if EBBE is to be attempted.

1.11. Long Duration Missions (D)

1.11.1. Explanation

Currently, most near space missions use latex balloons that are guaranteed to burst. These flights are limited in duration unless measures are taken. Carrying two balloons is one such way. Longer flights allow more amateurs to work balloon-based repeaters and more terrain below to be photographed. By drifting neutrally buoyant, ground photographs are taken at uniform altitudes, making comparisons between photographs easier.

1.11.2. Known Work In This Field

HABET has experimented with making neutrally buoyant balloons using two latex weather balloons. The first balloon is filled to the point that it just about lift the near spacecraft. The second balloon is filled with a few pounds positive lift and carries the balloon into near space. At the proper altitude, the second "grape balloon" is cut free, leaving the first balloon with the near spacecraft. Ballast is released from the near spacecraft to trim its ascent rate. Mark Caviezel (KC0JHQ) of ES-OS is developing his own affordable zero pressure balloons that allow long duration flights.

1.11.3. Suggestions

The suggestions in this sub section are divided into those focused on the near spacecraft and those focused on the ground. In the near spacecraft issues of flight termination, power systems, flight path, and mission manifest are important. On the ground issues of logistics and public outreach (which is partly governed by the mission manifest) are important.

Flight Termination Systems

Either way, with multiple latex weather balloons or ZPBs, cutdowns and cutdown systems must be perfected before attempting a long duration near space mission. When the cutdown system of a near spacecraft doesn't function, the near spacecraft is left aloft for its batteries to fail. Once the batteries fail, the near spacecraft can no longer send telemetry. At that point the FAA declares the near spacecraft derelict. The location of a derelict near spacecraft is unknown and represents a risk to air traffic. Being responsible for a derelict near spacecraft makes you very popular with the FAA. The solution is to use multiple, redundant cutdowns. Each system must include it's own power, antenna and receiver or timer. Design cutdowns to use multiple frequency bands, rather than just one. Another option is to include a pager controlled cutdown. Using a stopwatch-operated cutdown should be the ultimate failsafe. Before using a flight termination system, cold soak it in dry ice for 24 hours to make sure it will properly function in the chill of near space.

Power Systems

Consideration should be given to meeting long term power needs with solar cells and rechargeable main batteries. Because of the prolonged cold soaking, battery chemistry is another important issue. This is especially true during the night when internal temperatures are expected to drop to their lowest point when there is no sunlight to warm the exterior of the near spacecraft. Non-rechargeable batteries have an ultimate limit at which they will no longer produce enough power for the near spacecraft. Using solar power and rechargeable cells gets around this limitation.

Flight Path

For the simplest flight prediction, fly the mission in the stratosphere where winds tend to remain at the same heading. If flown lower, the location of moving lows and highs complicates the flight path. Besides, floating above 60,000 feet keeps the near spacecraft above controlled airspace, simplifying any possible planning with the FAA. Be aware that when the Sun sets, the helium inside the balloon cools and contracts, lowering the altitude of the near spacecraft. In the morning as the helium warms, the near spacecraft will rise, but not as high as the day before. This is because over many hours, the small helium atoms leak from balloons, reducing the balloon's lift. So use more helium that is needed for a short duration mission..

Mission Manifest

Three important tissues here are redundant tracking, the power budget of the near spacecraft, and how the flight manifest relates to the planned public outreach.

Carry multiple tracking systems on the near spacecraft to lower the risk of it becoming derelict, even when the flight termination works properly. Each tracker needs its own power supply, GPS, HT, and antenna.

Determining the power budget of a near spacecraft is not much of an issue when the flight only lasts for three hours. On long duration missions, the capacity of the batteries and their recharge rate (if solar cells are used) must be balanced with the current draw of devices onboard and their duty rate. If using multiple sources of power, then each bus is consisted independently of the others. Don't forget to factor in the fact that batteries cannot be recharged at night in your calculations of the required total battery capacity.

Monitor the current on each power bus as a part of telemetry. Op-amps can be configured to act as current to voltage converters and the result fed into a ADC channel for monitoring. High-risk items can be off-loaded to power busses that are considered non-critical. Another option is to design latching relays into power circuits. This allows ground crews or even the CC/PS to take devices off-line should it appear they have failed and are exceeding their power allotment or battery levels have dropped low enough that non-critical items must be taken off-line. Onboard devices may be at a higher risk of failing because of their long-term exposure to cold temperatures.

Logistics On The Ground

There are two groups of people to be concerned with; those in fixed locations like Mission Control or Tracking Posts and the Chase and Recovery Team

A Mission Control is much more important for long-term missions that it is for our typical four hour near space mission. First, Mission Control is the liaison with the FAA. If there's any question about the mission, the FAA needs a single phone number to call. Mission Control provides a location to get weather updates for new flight predictions off the web. They can generate new flight predictions every three hours when updates to the models are made available. Mission Control is also a way to gather many experts together for monitoring the progress of the flight. When the near spacecraft is out of range of Mission Control, they will depend on support sites located along the flight path to forward information. Doesn't this sound just like Mission Control back in the beginning of the Space Age? Since a long duration mission may require 24 hours, a schedule to relieve crews in Mission Control is needed.

For the Chase and Recovery Team, a long duration mission can be thought of as a twenty-four hour road rally. Cars making the entire trip need to be inspected before launch to make sure they're up to the driving. Each vehicle needs more than one occupant, even if the car is not actively tracking. Drivers need to take turns driving to prevent fatigue. Some chase vehicles will not need to make the entire trip, as they can start the chase when the near spacecraft passes close to their homes. As a result I would expect the number of cars in the Chase Team to increase as the mission progresses. Depending on the winds aloft, there may be no need to drive the entire time. If the Chase Team can get ahead of the near spacecraft they may be able to get some sleep during the night. A KOA® Kampground or such location may be an ideal place to wait the night as it's easier to set up antennas at a campsite then at a motel. This adds another responsibility to Mission Control, calling ahead and making reservations. When the Chase Crew does stop for the night, someone should be tasked with monitoring communications and near spacecraft telemetry.

Public Outreach

If going to this much trouble for a long-term mission, then get some outside attention for it! The media should be notified and asked to attend the launch and recovery. Between the launch and recovery ask them to visit with Mission Control. Because of liability issues, the media may not want to go on the chase. However, there's no reason they can't interview members of the Chase Team via cell phone.

Because of the large swath of country a long duration mission covers, get amateur radio clubs involved to set up public tracking posts. Locations where large numbers of people who are not in a hurry, like shopping malls and parks, to are good places to set up tracking posts. Carrying items like SSTV and repeaters on the flight manifest is a good way to interest the public. At the tracking post they can watch as live images as they are transmitted or talk to other observers in another state through the near space repeater. As for a launch date, perhaps Field Day would be the best time. On Field Day many hams have already planned to be out and showing amateur radio to the public.

1.12. High Altitude Rocket Launches (P)

1.12.1. Explanation

A portion of the thrust of a rocket motor is used to overcome drag and does not accelerate the rocket. The force of drag on a rocket is related to the density of the air the rocket must pass through. If the air density decreases by a factor of two, then the amount of drag the motor must overcome decreases by a factor of two. Predictions made by the Idaho Tripoli indicate that a rocket launched at 100,000 feet, where the air density is only 1% of that at sea level, would go some 2.5 times higher than it would launched at sea level. The reduction of drag at 100,000 feet means more of the motor thrust goes into accelerating the rocket to high speeds and that there is less drag to slow down the rocket once the motor cuts off. The drag issue at engine cut off gets better because the air density is decreasing with increasing altitude. Just where drag begins to slow down the rocket (at motor burn-out), there's less air to help drag do it.

Before the beginning of the Space Age, physicists like James van Allen were launching rockets from balloons, called rockoons, to study cosmic rays.

1.12.2. Known Work In This Field

On the amateur side, Bill Brown in conjunction with the Huntsville, Alabama L-5 (HAL-5) Society has developed HALO, High Altitude Lift Off.

Website: http://hiwaay.net/~hal5/HALO/index.shtml

1.12.3. Suggestions

There are several issues to resolve. For instance, what is entailed with launching rockets above controlled airspace (60,000 feet)? What is the requirement to carry rockets through controlled air space? What safing mechanisms are required to ensure there is no premature rocket launch? What safing mechanisms are required to bring a rocket back down to the ground should the launch be aborted?

Launch Issues
From HALO's experience, it appears that there is less trouble if the launch takes place over the ocean. As far as mechanisms to prevent launch, several switches (relays) should be used in the launch chain. For instance, an altimeter switch could be used to prevent a launch until the balloon is above the specified altitude. Switches to detect when the launch rail is properly oriented (like the old mercury switches) should also be included. A timer is another switch in the launch chain to prevent unauthorized launches. One last switch is the fusible link. The fusible link breaks the launch chain of switches when a launch abort of balloon burst is detected. Since no system is prefect, it is preferable that the launch chain fail by preventing a launch, rather than initiating one.

Rocket Issues
High power rocketry has certification levels that are administrated by amateur rocketry societies like Tripoli and NAR. Be sure that certified individuals with up to date memberships to organizations like Tripoli and NAR are involved with the project. Launching a rocket at 100,000 feet involves entirely different solutions to stability. On the ground, fins and the distribution of weight in the rocket are the primary means of insuring stability. Amateur rocket designers ensure their rockets have a center of

pressure about one caliber behind the rocket's the center of mass. In near space, with its low air density, there is much less air to produce pressure on the rocket when it pitches or yaws. One way to address this issue is to use larger fins. However, in near space the fins rapidly become very large and a waste of mass. A large and heavy gyroscope that maintains stability through angular momentum is unsuitable because of its excessive weight. However, a lightweight gyroscope used as input to a guidance system is a possibility. Actively gimballing the motor is a difficult proposition. Gimballing requires servos under the control of a microcontroller getting it's input from the Sun or a piezo gyro. While the weight may not be much, the space required inside the rocket tube for gimballing is best left to more propellant. In place of gimballing the engine, thrust vectoring with graphite vanes (like the V-2) may be possible. Perhaps the best guidance method is to launch the rocket out of a rifled barrel. The spin up of the rocket as it leaves the launch tube may be able to keep it straight. In essence, the rocket becomes its own gyroscope.

According to the International Aeronautical Federation (FAI, from the French – go figure), space begins at an altitude of 100 kilometers. This is equivalent to 62.5 miles or 330,000 feet. If launched from 100,000 feet, a rocket need only make an additional 230,000 feet. With the reduced drag of near space, a rocket capable of making 100,000 feet at sea level should make an additional 250,000 feet if launched at an altitude of 100,000 feet. A rocket performance program run by a member of Idaho Tripoli at my request calculated this improved altitude. Currently, most rockets I have seen capable of making 100,000 feet are very large and heavy. It is necessary to design a minimum mass rocket if a near space launch to space is to be attempted. A back of the envelope calculation by the author indicates a rocket capable of achieving a speed of one kilometer per second at motor burn out should touch space if launched at 100,000 feet. This brings to mind the question, what does it take make a rocket capable of going into orbit? To achieve an Earth orbit requires a rocket to reach a speed of seven kilometers per second. The kinetic energy of such a rocket is 49 times greater than a rocket only capable of traveling at one kilometer per second (kinetic energy scales with the square of the speed). Forty-nine times more kinetic energy means there must be 49 times more propellant onboard the rocket without increasing the rocket's mass, including fuel weight. While rockoons make great sounding rockets, they make lousy orbital vehicles.

1.13. Near Space Return Vehicle (NSRV) (D)

1.13.1. Explanation

Why chase when you can have the near spacecraft come to you? Currently Chase and Recovery Crews drive after every near spacecraft launched. While most of us enjoy the road rally, there are times when it would be better if the near spacecraft would return to a predetermined safe location. There can be other reasons to control the descent of a near spacecraft. Perhaps an experiment calls for photographs to be taken at particular locations. Or just perhaps the mission profile requires that the flight not recover in the bottom of a canyon or the top of a snow capped peak. For times like this, a near space return vehicle (NSRV) operating similar to the Space Shuttle would be ideal. Besides, creating a NSRV adds another challenge to anyone's near space program.

1.13.2. Known Work In This Field

In Canada, Art Vanden Berg has had success with a NSRV design. See his webpage at http://members.shaw.ca/sonde/index.htm

1.13.3. Suggestions

There are two design approaches to the NSRV. One design utilizes a vehicle flown on wings and the other utilizes a vehicle flown on a parafoil (used in place of standard hemispherical recovery parachute). If the winged vehicle approach is selected, then experiments must be designed to fit inside the glider. If the parafoil approach is used, then experiments and airframes remain as they are for the near space program outlined in this book. Most likely the weight of the control mechanisms, like servos, is similar between the glider approach and the parafoil approach. The major difference between the approaches is regards to dead weight. The weight of NSRV wings becomes part of the payload weight under FAR 101. As a result, the weight of the wings is weight that cannot be utilized for experiments. In the parafoil approach, the weight of the parafoil, like the standard hemispherical recovery parachute, is not a part of the near spacecraft. As a result, changing a hemispherical parachute to a parafoil does not effect the weight available to experiments as much as using wings.

Glider Approach

A release mechanism must be designed that cleanly separates the NSRV from its balloon. Because of the thinner air in near space, the glide speed of the NSRV is initially higher, but slows as the NSRV approaches landing. Steering is accomplished by more than turning a rudder. When the rudder turns, it creates drag, making the glider slow down and descend faster. When steering the glider, turn the elevators up a little to counteract the descent caused by the rudder's drag.

Wing Cautions

The concerns regarding wings are different, but still important. Airfoils develop lift when air passes over them. The amount of air passing over the airfoil determines the lift generated (assuming the same airfoil is used). The greater the air speed or the air density, the greater the lift developed. At high altitudes, where the air density is very low, the wing must pass through the air much faster. As the air density increases, the airfoil travels slower while still providing the same amount of lift. At high speeds, wing tip flutter, a rapid vibration of the wings, places stress on the root of the wings. When enough flutter, one or both of the wings can rip away from the fuselage. At this point the controlled aspect of the recovery is over. There are several ways to avoid this. Strengthening the wing roots is one approach, but it adds weight to the NSRV. Another approach is to use wings with a longer root. The delta shaped wing like those used in the Space Shuttle is an example of this approach. However, delta wings develop less lift that traditional straight wings. Going from straight wing to delta wing changes the NSRV design from that of a long glide ratio slope glider with conventional straight wings to more of a delta wing with its shorter glide ratio. The shorter glide ratio reduces the range of the NSRV, possibly requiring the NSRV to land at a location other than the launch site. At a minimum, a GPS receiver and electronic compass are required inputs to the flight computer to guide the NSRV. Program the final destination of the glider into the GPS and rely of the GPS receiver to calculate the range and bearing to the destination. A compass is required to indicate the heading of the NSRV, which may not be the direction it is gliding. An additional input that may be desired is an artificial horizon to keep the glider level. Dan Paulson (KD7OST) of TVNSP is working on these issues.

Parafoil Approach

The same items in regards to guidance of a winged NSRV are issues for the parafoil approach. However, instead of steering the NSRV with a rudder and two ailerons, steering the parafoil is accomplished by pulling on a single Dacron line attached to the ends of the parafoil. Each end of the Dacron line is attached to one point on the outside edges of the parafoil. The middle of the Dacron line is wrapped a couple of times around a spool. The steering servo rotates the spool to steer the parafoil. When the spool is rotated clockwise, one end of the parafoil is pulled down and the other end is slack. When rotated counter clockwise, the opposite end of the parafoil is pulled down, steering the parafoil in the opposite direction. The larger the spool's diameter or the greater the spool's rotation, the greater the steering effect.

Parafoil Cautions
Slow rotation of the balloon relative to the NSRV during an ascent risks twisting the shroud lines of the parafoil. A method to prevent the parafoil shroud lines from twisting into a knot is paramount to a successful recovery. One method to prevent tangling of the parafoil shroud lines is to stow the parafoil during ascent. This solution creates two new concerns. First, the parafoil must deploy with a high level of reliability. Second, the parafoil must be oriented correctly during deployment such that airflow opens the parafoil. NASA's X-38 approach to parafoil recovery is to use multiple sets of parachutes or parafoils, each designed for a different speed and pressure regime. Of course relying on multiple recovery devices multiples the reliable deployment concerns.

1.14. Sun Sensors (P)

1.14.1. Explanation

Many experiments I am contemplating require some sort of steering or at least an awareness of the Sun's position. A sun sensor is one solution to this need.

1.14.2. Known Work In This Field

The only sun sensor I have heard of is marketed by AeroAstro and is designed for microsatellites.

1.14.3. Suggestions

Any electronic component capable of detecting light should be able to form the basis of a sun sensor. The one design I have in mind uses photocells (photoresistors). The resistance of photocells depends on how much light is falling on them. One way to detect this change in resistance is to connect a photocell in series to a second, fixed resistor. Connecting a voltage source to one end and ground to the other forms a voltage divider. As the light intensity changes, so does the voltage drop across the photocell. The Basic Stamp can detect a change in voltage when the voltage increases above or below 1.4 volts. Changing the fixed resistor to a trimmer pot allows you to adjust the sensitivity of the photocell to sunlight. Now when the light intensity increases to a certain point, the logic state of the I/O pin changes from low to high or from high to low. Place the photocell into end of a opaque tube, and the photocell will not change states until the tube is pointed close to the Sun. This design is limited to telling the CC/PS when the Sun is pointed in a particular position. Finer position sensing is possible if several sun sensors are used, with each pointed at a slightly different direction.

Instead of placing the photocells into the bottom of tubes, place a fence between the photocells. The shadow cast by the fence indicates which photocell is not pointed directly at the Sun. The fence is less sensitive to azimuth pointing errors that the tube design is.

Instead of programming the flight computer to measure the voltage from each photocell voltage divider, input the voltages from each photocell voltage divider into a series of comparators. Instead of checking the entire set of sun sensor I/O pins for their logic state, the CC/PS only needs to check the output of the correct comparator to be sure the Sun is located in one particular direction.

An alternative to photocells is to use phototransistors. The benefit of using phototransistors is their increased speed over the photocell. Phototransistors control the current flowing through them based on the amount of light shining on their base. The greater the light intensity, the greater the current they let flow through them. Connecting a phototransistor in series with a resistor between five volts and ground creates a "pseudo" voltage divider. The current that the phototransistor lets flow to ground creates a voltage drop across the resistor. Measuring the voltage drop across the resistor indicates the light intensity on the phototransistor. As with the photocell sun sensor, you may want to use comparators to indicate which sensor is most closely pointed towards the Sun.

1.15. Sounds In Near Space (H)

1.15.1. Explanation

Except for special cases, as in the case of light, waves require a medium to exist. As an example, water supports and carries a water wave. Air is the medium that carries the sound wave. Sound waves are compression waves, so they're not like water waves that travel as rising and falling water. Tiny compressions and rarefactions of air are waves of sound. When you hear a sound, your ears are detecting tiny bursts of high and low pressure in the air (the changes in pressure are very small). Remember that all waves have a characteristic called wavelength. High pitch tones or frequencies have a shorter wavelength than low pitch sounds or tones. As the air pressure drops, the average distance between the air molecules gets greater. We can calculate the average distance between air molecules as a function of the air pressure. We refer to this average distance between air molecules as their mean free path. So as the altitude increases and the air pressure drops, the mean free path between molecules increases. Thinner air also doesn't carry sound very well. So as the air pressure drops, what frequencies that can be carried are not carried with sufficient energy, so they get fainter.

1.15.2. Known Work In This Field

Some of my former students at Nampa High School designed a near space beeper experiment using a BS-1 IC, LEDS, and a piezo speaker. Sounds in near space have been measured indirectly by KNSP and TVNSP on missions flying camcorders and audio locator beacons.

1.15.3. Suggestions

It should be the case that air molecules can only carry sound waves with wavelengths longer than the mean distance between the air molecules (I have yet to verify this). Recall from your physical science courses that the longer the wavelength of a sound wave, the lower its pitch, or frequency. The distance between molecules determines how far molecules can move before colliding with each other, or their mean free path. As the air pressure drops, there are fewer molecules in a volume of air and therefore their free mean path increases.

As a near spacecraft ascends and the air pressure drops, the highest frequency tones are affected first. The increasing mean free path between molecules means it's difficult to carry high pitch sounds effectively. As the capsule continues to climb, lower and lower frequency sounds begin to fall off in volume.

To determine near space's effects on sound, Nampa High School students designed a sound and light circuit with the Basic Stamp 1-IC. Seven LEDs and a speaker where connected to the BS1-IC. Seven tones were programmed in the BS1-IC. When a tone was played, its LED was illuminated as a visual indicator (in case the tone couldn't be heard, we would know it was being produced). The assembled circuit was positioned in front of a camcorder. Throughout the mission, the camcorder recorded the LED and sounds of the circuit, with the edge of the Earth as a backdrop to the experiment. From the results of the experiment, we determined frequency is a large factor in whether a tone is heard or not in near space. But my calculations of mean free path and wavelength at altitude do not predict which tones are affected at each altitude.

Two Useful Equations
The mean free path of air molecules is determined using the following equation.

```
L = 1 / (pi * sqrt(2) * N * D^2)
```

Where
L = the mean free path
N = number of molecules per cm3
D = average diameter of molecules (2 x 10^{-8} cm)
pi = 3.14159

The number of molecules in a cubic centimeter of air at sea level is equal to 3×10^{19}.
At lower pressures, the number of molecules per unit volume drops off linearly with pressure. So if the pressure is reduced by half, there will only be half as many molecules per unit volume.

The wavelength of a sound wave is determined the equation,

```
Wavelength = velocity/frequency
```

The speed of sound changes as the altitude changes.

Altitude (feet)	**Speed (cm/sec)**
Sea level	33500
10,000	
20,000	
30,000	
40,000	
50,000	29500
60,000	
70,000	
80,000	
90,000	
100,000	30200

1.16. Tethered Capsules (H)

1.16.1. Explanation

On two occasions, the Space Shuttle attempted to deploy tethered satellites. The satellites were connected to a conductive tether that was wound around a winch. Astronauts on board the Space Shuttle unreeled the satellite from the shuttle for a distance of some miles. Twice the experiment has failed. When it works properly, the tether between the satellite and the shuttle will cut through the Earth's magnetic field, creating a current. This current can be used as a power source or be used to do work and raise or lower satellite orbits.

How about if amateur near space giving tethered satellites a try?

1.16.2. Known Work In This Field

Twice KNSP operated a tethered capsule (flights 98A and 98B). The first time the capsule deployed properly, but the camera failed, so no photographs where recorded. The second time the flight computer glitched, preventing the experiment from taking place. I have not heard of any other attempts.

1.16.3. Suggestions

The KNSP Tethered Capsule Experiment relied on a servo modified to be a winch.[B] Many robotics websites explain how to modify a servo for continuous rotation, so it is not covered in this book, or you can buy pre-modified, continuous rotations servos directly from Parallax, Inc. A reel was attached to KNSP's modified servo and approximately twenty feet of 50 pound test Dacron was wound around the reel. The tethered capsule was attached to the end of the Dacron kite line. The servo and reel were housed inside the docking unit and the tethered capsule was pulled tightly into the face of the docking unit. During the mission, the flight computer was programmed to operate the modified servo as if it where a regular servo. But instead of placing and holding the servo in one specific position, the servo spun continuously when instructed to position itself away from neutral. In response the servo began spinning and unwinding the tether and lowering the tethered capsule. A number of seconds later, the flight computer instructed the flight computer to place the servo into the neutral position, stopping the servo's rotation. At the end of the experiment, the flight computer instructed the servo in a new position that was opposite of the first position. The new position reversed the servo, winding the tether back onto the reel. By experimenting on the ground, it was determined that the rewinding required more time that the unwinding. At the programmed time, the servo was instructed to place itself back into the neutral position, stopping the rewinding of the tether. To ensure the tethered capsule remained firmly against the docking unit, occasionally momentary commands were given during the remainder of the mission to rewind the tether. During descent, at approximately 500 feet above the ground, the servo was again instructed to unwind the tether. This kept the near spacecraft from landing on top of the tethered capsule and also allowed Recovery Crews to observe the deployed tethered capsule.

Future Plans

I have three changes I would like to make the first KNSP attempt at tethered capsules. First, I would like to place a small digital camera and RF link into the tethered capsule and return images of the underside of the near spacecraft when the tethered capsule is deployed. Parallax has the perfect 433 MHz RF modules for this. Second, the Earth's atmosphere develops an electrical charge (the fair weather field) of on the order of 100 volts per meter. A tethered capsule placed five meters below a near spacecraft should experience a voltage potential of 500 volts between the near spacecraft and itself. It may be possible to use a conductive tether to measure this potential. The near spacecraft would seem to be an ideal platform for measuring this charge as a function of altitude. Note that this fair weather field is not related to the potential difference the Space Shuttle sees when its tethered satellite cuts through lines of the Earth's magnetic field. Third, to ensure the tethered capsule remains firmly attached to the docking unit, a servo-operated latch should be implemented. Before the tethered capsule can be lowered, the docking latch must be released. After being rewound, the docking latch is locked.

1.17. Satellite Testing (D)

1.17.1. Explanation

The use of pico and nano satellites is somewhat popular with universities. For $75,000, they can build and launch a one-pound satellite measuring four inches on a side. These pico-sized satellites are called CubeSats. The CubeSat concept was developed at Stanford University. One Stop Satellite Solutions (OSSS) inn Utah is one distributor of the kits, and they will arrange to launch your CubeSat once you complete it. Another nanosatellite idea is the CanSat concept by Dr. Twiggs at Stanford. The CanSat uses a pop can as the airframe. Once a student finishes building their CanSat, it is launched on an amateur rocket. Finally, the Colorado Space Grant along with others has designed the BalloonSat program. In BalloonSats, college students design a functioning nanosatellite model and attach them to near space trackers.

Because of the costs involved, it's highly desirable to test even CubeSats before their launch. Some tests, like vibration and acoustical testing, which simulates a rocket ride into orbit, is best performed on the ground in test chambers. However other tests can be performed in near space at very reasonable cost. Aside from testing complete CubeSats in near space, portions of microsatellites occasionally need to be tested independent of the rest of the satellite. Here again, balloons can perform a valuable service. Because of weight constrains, its more difficult to test anything larger than a complete nanosatellite.

Satellite testing is one of many functions of the National Scientific Balloon Facility (NSBF). Once you develop a proven program, you can offer to test CubeSats and satellite components for less than the equivalent test on the ground. In addition, your test can return photographs of the CubeSats with the Earth's horizon at 100,000 feet as a backdrop. However, remember that we are using amateur radio for telemetry. As a result, we cannot make a profit testing satellites.

1.17.2. Known Work In This Field

EOSS is working with the Colorado Space Grant to test BalloonSats. GPSL 2003 took place in Colorado to support the BalloonSat program that year.

1.17.3. Suggestions

BalloonSats, CubeSats, CanSats, or portions of satellites can be tested inside a near spacecraft or mounted as part of the stack for greater exposure to the near space environment. This section explains how to make a harness for BalloonSats and CanSats and a bumper for CubeSats, and discusses an idea to carrying CanSats.

BalloonSat Harness

This is how the author built a harness for the BalloonSats launched at GPSL 2003 in Deer Creek, Colorado. The harness will work for CanSats also, since both BalloonSats and CanSats have a single tether point (in the case of the CanSat, the tether point is for its parachute) The harness is designed to integrate a BalloonSat or CanSat into the near space stack just like another module. It's made up of a Dacron cross and a length of dangling Dacron that attaches to the chain of BalloonSats or a single CanSat.

Materials

- 150 pound test Dacron kite line
- Five #0 bearing swivels

- Split ring
- Heat shrink tubing large enough to cover knots in the Dacron (3/16”)

Procedure

√ Cut three lengths of kite line, at least four feet long

√ Note: two lengths make the Dacron cross and the remaining length is the dangling Dacron. The cross pieces must be the same length, but the dangling Dacron can be a different length.

√ Mark the center of two of them with a permanent marker
√ Pass both of them through a ring in a bearing swivel
√ Align their center marks and center the bearing over the mark
√ Tie a knot in the Dacron, trapping the bearing swivel in the knot and centered over the centering marks in the Dacron
√ Mark six inches from the ends of the Dacron with a permanent marker
√ Slide a short length of heat shrink over the Dacron if you want to cover the knots
√ Slide a bearing swivel over the Dacron line (four swivels total)
√ Center the marks in the Dacron inside the ring of the bearing swivel and tie an overhand knot in the doubled over line
√ Heat shrink the knot if desired
√ Mark six inches from both ends of the remaining length of Dacron
√ Slide one end of the Dacron through the open ring of the bearing swivel in the center of the crossed Dacron lines
√ Tie an overhand knot in the doubled over Dacron
√ Slide a length of heat shrink over the knot and shrink, if desired
√ Slide a second piece of heat shrink over the dangling Dacron
√ Slide the remaining free end of the dangling Dacron through a ring of the last remaining bearing swivel
√ Center the mark inside the bearing ring and tie an overhand knot in the doubled over line
√ Slide the remaining heat shrink over the knot and shrink
√ Put a split ring into the open ring of the swivel bearing on the dangling Dacron

Using the BalloonSat Harness

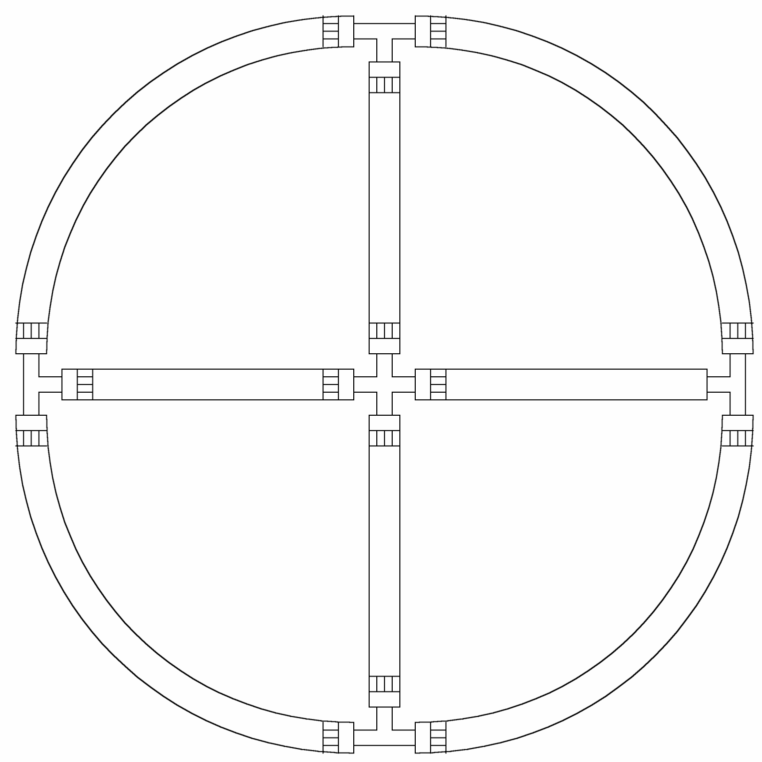
The BalloonSat harness is designed to suspend BalloonSats beneath the last module in the near space stack. The four bearing swivels in the Dacron cross connect to the lift rings in the bottom of the last module in the near space stack. The Ballonsats have a metal post through their center(s) that attach to the split ring in the end of the dangling Dacron. The harness basically makes the BalloonSats a part of the near spacecraft.

The CubeSat Bumpers

A sample satellite bumper is described in this section. This is a simple design that should work with the lightweight CubeSats. Use this design as a beginning and modify it as needed. Unlike the BalloonSat harness, this design has not been tested yet.

Materials

The following materials are bent into a spherical frame made up of octants.



CubeSat Bumper

- Fifteen feet of stiff poly hose
- Three plastic barbs
- One package of hot water pipe insulation tubing
- Twenty-four inches of three-inch diameter heat shrink tubing
- Eight pieces of one-inch long, 3/32” diameter heat shrink
- Four lengths of 24” long Dacron, 200 pound test
- Six small hose clamps
- Eight #3 or larger barrel swivels
- At least eight inches of heat shrink tubing
- Eight one-inch split rings
- Scissors and a lighter

Procedure

√ Melt the ends of the Dacron line with a lighter to keep the lines from unraveling (Use just enough heat to seal the ends, but not to change their lengths significantly)
√ Mark three inches from each end of a link line with a laundry marker
√ Cut eight pieces of one-inch long 3/32” diameter heat shrink tubing.
√ Slide two pieces of heat shrink tubing onto the link line
√ Slide two barrel swivels onto the link line
√ Center the loop of a swivel over a 3" mark on the link line and tie an overhand knot with the doubled over string
√ Trim up the excess string from each knot. Melt the new ends of the nylon string
√ Slide a piece of heat shrink tubing over the knot and center it.
√ Slide the second piece over the knot at the other end.
√ Apply heat with a heat gun and shrink the tubing securely over each knot.
√ Repeat the above process with the other three link lines

- √ Make three marks on both ends of the link line, each mark three inches further in from the knot (3”, 6”, and 9” from the knot)
- √ Double the link line at the 6” mark and knot the line on the 3” and 9” marks

- √ Cut the poly tubing into three lengths, five feet long
- √ Cut the heat shrink into one-inch long pieces (24 bands)
- √ Bend each length of tubing into a circle
- √ Slide eight pieces of heat shrink bands on each tubing
- √ Select one tubing piece to be the equator and set it aside for a moment
- √ Slide the loops of one of the link lines through the circular tubing
- √ Slide the loops of the second link line through the second circular tubing
- √ Insert a barb into all three poly tubing circles and lock the ends together
- √ Combine the rings into a sphere with mutually perpendicular great circles formed by the rings
- √ Position the bands of heat shrink so that two bands are in each 90-degree segment
- √ Clamp the intersections of the great circles together with the hose clamps
- √ Cut the hot water pipe insulation tubing to fit each 90-degree segment
- √ Slide the tubing over the segments, making sure the heat shrink bands and the link line loops are placed over the tubing
- √ Gently heat the heat shrink, do not crush or melt the tubing
- √ Slide on the split rings to the link line loops

Using The Bumper

One way to protect an externally mounted CubeSat during landing is to surround the satellite with bumpers and mount the bumper frame above the top module. Mounted above the top module, the recovery parachute slows the final landing of the satellite even more, as the weight of the lower modules is taken off the parachute by their landing on the ground. Attach the satellite bumper below the parachute ring and above the top module in a stack. The satellite bumper does not support the weight of the near space capsules below it. Instead, it hangs suspended inside the loops in the link lines. A different set of lines attaches the CubeSat-mounting frame to the split rings of the satellite bumper. The lines need to be reasonably tight to keep the CubeSat from swinging outside the bumper. The bumper flexes on landing and keeps the CubeSat from making contact with the ground. A camera mounted to an E-Quad of the top module can photograph the CubeSat during its flight.

1.18. Photovoltaic Systems (P)

1.18.1. Explanation

For long duration flights where a sufficient amount of primary batteries weighs too much, photovoltaic (PV) arrays may be the solution. Even when PV arrays are not strictly necessary, experimentation with them can be valuable. Remember, it’s always a sunny day in near space, so take advantage of the free power.

1.18.2. Known Work In This Field

The Voice Of Idaho Amateur Radio Club tested a PV array on their first near space launch. TVNSP has designed a PV array suitable to operate an Alinco DJ-S11. However, at this time, it has not been tested in a mission.

1.18.3. Suggestions

There are at least three major types of silicon solar cells on the market (in the past a very inefficient selenium based solar cell was available and today more efficient gallium arsenide cells are used on some satellites). The first silicon type is the single crystal solar cell and is the most expensive type. These have a uniform texture and color to them. Not all single crystal solar cells are created equal, as the most efficient ones are also the more expensive ones. The next type is the polycrystalline solar cell. These solar cells have a cracked appearance to them. As they are rotated, different crystals in the cell reflect more brightly. These solar cells are less costly than single crystal solar cells and produce less power. They also are more fragile than the crystalline. The last type of silicon solar cell is the amorphous solar cell. These are the least expensive and produce the lowest power. They are a fairly uniform purple color to them. Amorphous solar cells are always found mounted to a frame or base. Their low power probably makes them unsuitable for near space use since much more efficient solar cells are not so expensive as to make them unavailable. One area where amorphous solar cells shine however is in their ability to bend. If a curved surface must be covered in solar cells, then amorphous solar cells are the choice.

Solar cells are constructed of very thin disks of doped silicon. As a result, they are very fragile. As a result, most commerically available PV arrays are mounted to glass covers and metal frames. Since amateur near space faces severe weight constraints, these PV arrays are unsuitable. Instead, purchase individual solar cells and make your own PV array. To make a PV array for amateur near space use, the individual solar cells must be soldered together to create the voltage and current levels needed, then mounted to a lightweight and durable backing to prevent them from breaking.

Solar Cell Electrical Characteristics

Solar cells, like photodiodes (which they are related to), are not voltage sources. Instead, solar cells are current sources. The typical solar cell produces 0.5 volts, regardless of the dimensions of the cell. The size of the cell (that is its surface area) determines the amount of current it produces (the load the solar cell is under does vary their voltage, but we are assuming a constant load). The greater the surface area, the more current produced by the cell. Solar cells that produce several volts are actually many cells wired together (so shouldn't we be calling them solar batteries?). The face of a solar cell is crisscrossed with a metal grid, forming the positive electrical connection for the cell. Along the edge of the solar cell's face is a border of silver. Solder to any point on the border to make an electrical connection. The back of the solar cell is coated in a thin layer of silver. Solder to any point on the back to make the negative connection to the solar cells. Before soldering wires to the solar cell, pre-tin the wires. Pre-tinning the wires speeds the process of soldering wires to the solar cells, reducing the chances of damaging them. Use stranded wire to connect solar cells. Solid wire is too stiff, risking breaking solar cells or soldered connections (but probably solar cells first). It's not difficult to solder to solar cells, but be quick so the heat of the soldering iron does not damage the solar cell. Use a DMM set to DC voltage to verify the solar cell's terminals and polarity.

To electrically assemble the PV array, first determine both the current and voltage requirement needs of the near spacecraft subsystem in question. Solar cells are connected in a combination of series and parallel. Connecting solar cells in parallel (soldering back to back and front to front) increases their current capacity. Connecting solar cells in series (soldering front to back) increases their output voltage. To create a PV array, first create a series chain of solar cells to meet the voltage requirement. Then make several chains and wire them in parallel to meet the current requirement.

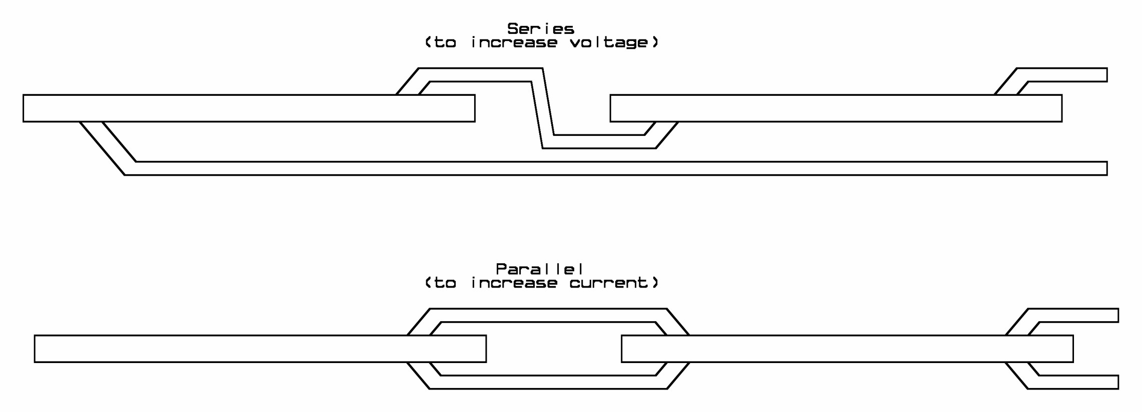
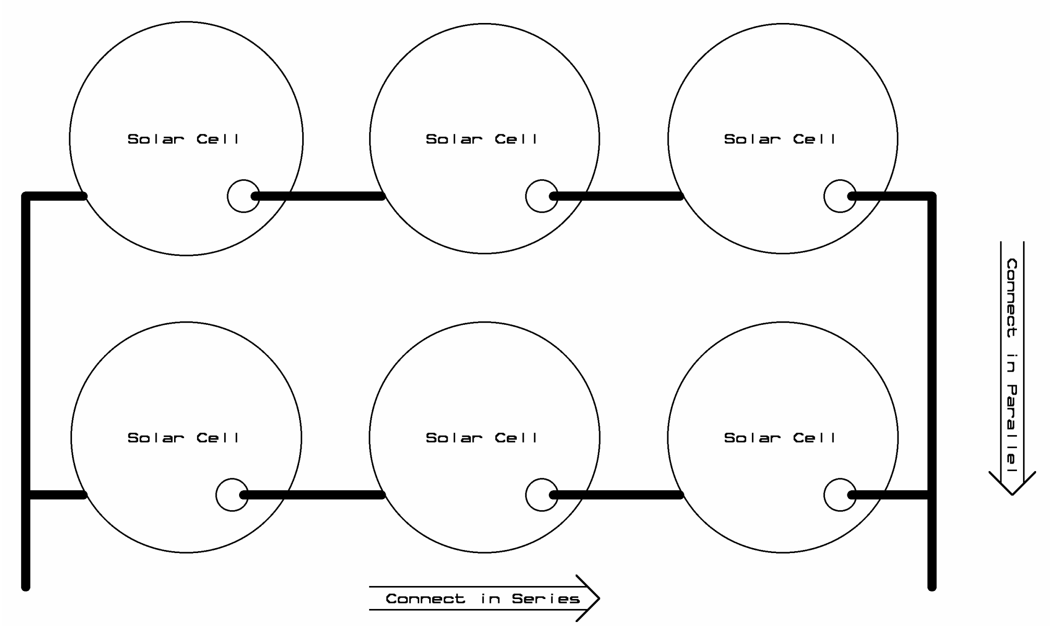


Diagram of Series and Parallel Combinations *– Series to increase voltage (top), Parallel to increase current (bottom)*

A PV array can be used as the primary power system for a device (preferably a non-critical one) or as a trickle charger a battery during a mission. To recharge a battery, the voltage of the PV array must be at least two volts greater than the battery voltage. To get the longest lifetime out of a battery, use a smart charger to control the recharging of the battery. If the battery cost is not great, and the recharging system is to be kept simple, then a trickle charger is suitable. If used to recharge batteries during a mission flown partially at night, the PV array requires a blocking diode to prevent the battery from discharging into the solar cell during the night (ummm, wouldn't running current back into a PV array make it emit light?). Keep in mind that the blocking diode drops the voltage output of the PV array by 0.7 volts. Two benefits of flying a PV array into near space is that the colder temperatures in near space increase the output current of the PV array as well the increased intensity of sunlight. If you will be using a diode in the PV array, then solder it into the array near the end of the power cable. Since the current and voltage are not very great, a 1N4001 diode should be good enough. If you are designing a larger array, then read the voltage and current limits of the diode before soldering it into the PV array. Measure the voltage of the PV array with a DMM set to voltage before proceeding. Record this value, as you will measure the PV array again shortly. Cut the leads of a diode to a length of about ½ inch. Strip about ½ inch of insulation from the positive wire in the PV array. Wrap that bare lead around the lead of the diode that is not closest to the band around the diode. The band (the cathode side) is to be connected to the most negative terminal in order for current to flow. Use a DMM set to voltage and measure the voltage of the PV array a second time. It's best if the second measurement is made at close to the same time as the first measurement and in the same lighting conditions. You should see that the voltage of the PV array is about 0.7 volts lower. If you measure no volts, then the diode is in backwards. Now slide a length of heat shrink tubing over the diode and its soldered leads and shrink it, covering the diode completely.

Mounting Solar Cells

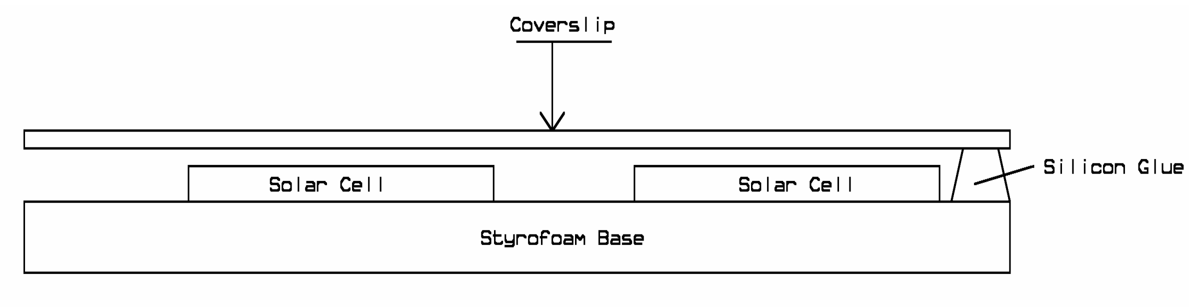
Two characteristics are important when mounting the soldered solar cells to form a near space PV array, weight and rigidity. The PV base material cannot be so heavy to make the near spacecraft overweight. Also, the material needs to resist flexing or the solar cells will break. One ideal material that meets both of these requirements is the same Styrofoam used in the module airframes.



Photovoltaic Array (PV) *– Solar Cells chained in series to meet voltage requirements, then in parallel to meet current requirements.*

Position the soldered solar cells next to each other on your workbench. Measure the dimensions of the array and add then a border to the final size (try a one inch border). Cut the Styrofoam sheet to this dimension. Mount each solar cell to the Styrofoam base with a small dab of silicone glue. Do not coat the entire back of the solar cell with a layer of silicone glue or any other adhesive. Using a single dab insures each solar cell is free to expand and contract at a different rates than the Styrofoam. I have seen differential expansion between a basswood backing and a silicon die shatter the silicon. You may have to cut a small trench into the Styrofoam backing to mount the diode (you want the diode to rise no higher than the top surface of the solar cells. To prevent movement of the PV array wires from breaking their connection to the solar cells, put a dab of silicone rubber over the cable to attach them to the Styrofoam backing. This acts as a strain-relief. During landing there is a risk that the solar cells may be damaged.

The one-inch border around the PV array backing is to reduce this possibility, but if you are still concerned, than make a cover slip for the PV array. Cut a very thin sheet of clear plastic to the same dimensions as the Styrofoam base. If possible, use something other than 1/8" thick Plexiglas, as it's heavy for it's size. Place thin spacers (thin cardboard or plastic strips) on the surface of several of the solar cells in the PV array. Make the spacers long enough that their ends extend beyond the edge of the Styrofoam base. This way they can be pulled out after making the cover slip. The spacers keep the cover slip off the surface of the solar cells in the PV array. Apply dabs of silicone glue to the corners of the Styrofoam. If the PV array is large, then consider applying silicone glue to places in between the solar cells, also. Place the cover slip over the solar cells and let the silicone glue set. After the adhesive sets, carefully pull the spacers out from the PV array.



PV Array *– Details of Coverslip*

Since uniformity is one concern with amateur near space, use the same connectors on your batteries for the PV array. So for instance, if you use Anderson Powerpole® connectors[C] (as I recommend), for the batteries, then terminate the PV array power cable with Powerpoles also.

1.19. Bolometers (D)

1.19.1. Explanation

A bolometer is a device that measures small amounts of radiant heat. Typically they consist of a heat-detecting element with a resistance that that varies as its temperature changes. The Wheatstone Bridge is used to measure the tiny changes of resistance in circuits, so I think it would be appropriate for the bolometer. Satellite-based bolometers are used to measure the heat emitted from the ground and from astronomical sources.

1.19.2. Known Work In This Field

I have found no one experimenting with building a bolometer for near space use.

1.19.3. Suggestions

There are two approaches I would like to investigate. The first is to design a bolometer similar in fashion to the traditional bolometer in which the temperature-sensing element changes its resistance. The second approach uses a passive infrared (PIR) sensor (which may be very difficult to implement) or a thermocouple and produces a voltage that changes as the bolometer detects differing amounts of heat.

Resistance Output Approach

Here I would plan to use a thermistor as the temperature-sensing element. As the temperature of a thermistor changes, so does its resistance. Jameco sells a line of thermistors for fifty-nine cents each. Their temperature coefficients are on the order of 4 ohms per degree Celsius. I would try a smaller value thermistor since they experience the greatest percent change in resistance with changes in temperature. The amount of radiant heat impinging on the thermistor from sources on the ground is miniscule. So a means to amplifying the amount of radiation is required. For this, optics is used. A small telescope gathers more radiation from the source and focuses it on the thermistor. There are two ways to increase the radiation gathered by the telescope. One is to increase the field of view of the telescope. The larger the field of view of the telescope, the more radiation gathered. But as a consequence, the resolution of the instrument decreases. The second way to increase the radiation collected by the bolometer is to increase the diameter of the telescope's objective. The objective is either the main lens of a refracting type telescope or the mirror of a reflecting type telescope.

Increasing the diameter of the objective increases the weight of the optical system, which is a problem when your module goes over six pounds in weight. There is a relationship between the diameter of an optical system, its focal length, and its field of view. For a fixed diameter of objective, the shorter the focal length of the objective, the wider its field of view. However, a shorter focal length implies a shorter length telescope, making it lighter and easier to mount to the airframe.

In any case, the thermistor must be a part of a Wheatstone Bridge. As the thermistor's resistance changes, it unbalances the bridge, letting current flow through the bridge. The direction of the current flow depends on which element of the Wheatstone Bridge is the thermistor and the direction the resistance of the thermistor changes (whether it increases or decreases as it gets warmer). A fixed resistor across the outputs of the Wheatstone Bridge generates a voltage drop according to the amount of current flowing through it. Before the voltage drop of the current sensor in the Wheatstone Bridge can be connected to the ADC, the ADC and resistor must share the same ground and the direction of current flow, known. I will leave these as an exercise for the reader, since I have not played with it myself.

Voltage Output Approach

Passive Infrared

The passive infrared (PIR) based motion detector contains a sensor with two crystals of a heat sensitive material. Each crystal generates a tiny charge when radiant heat impinges upon them. However, the amount of generated charge is very tiny. It's so small that random fluctuations in the crystal and air will swamp any signal generated by the presences of body heat. The purpose of the frensel lens in front of the motion sensor is break the view of the sensor into segments, where each segment sees a different portion of the field of view. As long as nothing in the field of view changes, then there is no change in the outputs between the two crystals of the motion sensor. When a warm object walks into range of the motion sensor, only one of the crystals is initially affected. The crystals begin generating a different amount of charge, which is detected by the electronics inside the sensor. When the difference between the two crystals is great enough, electronics inside the motion sensor trigger an alarm.

To use a PIR, I see two modifications that must be made. First, a new output from the motion sensor must be found. Perhaps even connecting directly to the PIR sensor itself since a motion sensor with only two digital states (ON and OFF) will not work as a bolometer. The bolometer must have an analog output that varies with IR striking it. Second, the second crystal of the PIR must be exposed to a constant temperature reference to compare to the other crystal. The reference crystal is insulated from the radiation entering the bolometer and is kept at a constant temperature. Perhaps a heat pipe immersed in LN2 would make a good reference source.

Thermocouple

A thermocouple consists of two dissimilar metal wires twisted together. As the temperature of the thermocouple changes, the voltage generated by the thermocouple also changes. The voltage generated is very small (on the order of microvolts per degree), so an amplifier is required to use the thermocouple. To use a thermocouple, place the tip of the thermocouple at the focus of the telescope used in the bolometer.

Would the thermocouple-based bolometer be more accurate with a constant temperature reference? If so use a second thermocouple kept at a constant temperature as the reference. Place the outputs from both thermocouples into the inputs of a differential amplifier (diff-amp). What constant temperature source would I recommend? I believe liquid nitrogen (LN2) should be used as the reference. LN2 is the lowest easily available constant temperature sources for the amateur. As long as the LN2 is available as a temperature reference, it maintains the same low temperature of 79 kelvins, or –315 degrees Fahrenheit. Styrofoam containers insulate well enough to keep nitrogen liquid for hours. Make the cold cup by carving up a thick piece of Styrofoam. Place the reference thermocouple inside and fill the cup with. Leave the lid of the cold cup loosely fitting because as LN2 boils off, the nitrogen gas must be free to escape. The exterior of the cold cup should be covered in MLI to reflect solar radiation. To be honest, the greatest reason I wish to build this instrument is that I think a gold or silver color instrument requiring me to pour LN2 into it just before launch is a really cool thing to build. Seeing one of my near spacecraft lifting off, trailing a cloud of cold nitrogen gas is an appealing notion.

1.20. Radiation Budget Experiment (P)

1.20.1. Explanation

A planet's radiation budget is the measure of the radiation absorbed by the planet from space compared to the radiation emitted by the planet back into space. As a near spacecraft ascends, the amount of air below it (a source of heat) increases as the air above it decreases. Making measurements of heat emitted above and below the near spacecraft indicate how much heat is emitted at different levels of the atmosphere.

1.20.2. Known Work In This Field

No one I know is investigating this. I have never read whether there is a change in the radiation (mostly infrared, I believe) emitted at various layers of the atmosphere. However, I would expect that since the Stratosphere is warmer than the Troposphere, the radiation emitted by the atmosphere below the near spacecraft will change significantly once the near spacecraft reaches 50,000 feet.

1.20.3. Suggestions

In a past issue of the astronomy magazine, *Sky and Telescope*, an article in the Amateur Telescope Making section discussed an automated observatory capable of determining if it was cloudy that night. If it was cloudy that night, then the computer-controlled observatory wouldn't bother opening the observatory and making observations with the telescope that night. The computer located at the observatory made the cloudy sky determination by measuring the voltage created by a Peltier junction.

Peltier junctions are semiconductor thermocouples operated in reverse. As a voltage is applied to them, one side get colder and the opposite side gets warmer. There's no violation in thermodynamics here. The warmer side gets much warmer than the colder side gets cold. Peltier junctions are great cooling systems when it's not practical to pump freon or chilled water over a warmer surface.

The Peltier junction can operate backwards like a standard thermocouple. The difference is that the Peltier junction is made up of many semiconductor thermocouples, which increases the voltage generated by the Peltier junction. In the automated observatory example, the Peltier junction is mounted outside the observatory. One side of the Peltier junction faces the ground and the other side faces the sky. Clouds retain heat emitted by the Earth at night. Without clouds overhead, the warm ground emits infrared radiation into the black (very cold) skies. When clouds are overhead, the sky appears to the Earth to be warmer, so the Earth emits less infrared radiation. Remember, heat can only flow from a warm location to a cooler location, unless work is performed to move heat backwards across this temperature gradient. The maximum difference of temperatures between the ground and the sky occurs on cloud-free nights. The least difference in temperatures occurs on cloudy nights. When determining if the nighttime sky is cloudy, the automated observatory measures the voltage generated by the Peltier junction. When the voltage is too low (not enough difference between ground and sky temperatures), the computer determines it's too cloudy to open the observatory.

As the Peltier junction sensor of the mission ascends, the temperature difference between the two faces changes. However, I believe the changing air temperature will make interpretation difficult. I can think of two ways that may get around this. The first uses two Peltier junctions and the second places a constant temperature reference in contact with one of the faces of the Peltier junctions (yep, you guessed it, LN2).

One Peltier Junction

In this method, the Peltier junction is given a constant temperature source on one face. Just like the bolometer in subsection 1.19, I think LN2 would make the ideal temperature reference. With such a cold reference, the voltage generated by the Peltier junction is greater, increasing the precision of the measurements. To create a liquid tight seal (so the LN2 doesn't leak out), use a metal cup. The bottom of the cup is place in contact with the Peltier junction and then filled with LN2. Now there's a problem with this design. Anyone touching the cup will receive frostbite very quickly. So the metal cup must be surrounded with a Styrofoam cup. A loose fitting lid tops it off. The Peltier junction is mounted to the end of a boom to give the bottom face of the junction an unobstructed view of the ground. Which side is exposed to LN2 must be determined before hand. I believe measuring the voltage produced by the Peltier junction when the junction is placed on a warm surface and touching the top surface with an ice cube in a plastic bag can determine the correct orientation. As long as a positive voltage is produced, then you have the correct orientation of the Peltier junction. If a negative voltage is produced, then switch the leads or flip the junction over.

Two Peltier Junctions

In the second design, two junctions are assembled into the experiment. However, the junctions must be turned with opposite faces pointed at the ground and at the sky. The effects of cold air on the faces of the junctions are identical in this configuration since they are both exposed to the same air temperature. The effect of colder sky (in relation to the ground and air mass below) does vary, as opposite faces of the junctions are oriented to the ground. As one junction decreases the voltage it generates, the other increases the voltage it generates. Instead of using the voltage generated by one junction, use the difference between the voltages of the two junctions as a measure of the heat coming from the ground and air mass below the near spacecraft. I believe this is sufficient to remove the effects of air temperature on the Peltier junction without relying on a constant temperature reference.

Processing Radiation Budget Measurements

After recovery, the radiation budget measurements are charted with the altitude from the GPS receiver. If two Peltier junctions are used, then the difference between the two junctions is used as the radiation measurement. If a single junction is used in the experiment, then only the absolute voltage as determined by a single channel of the flight computer's ADC is used. Unfortunately, I don't of a good way to convert the measurements into some kind of absolute units (I haven't researched this project very much, yet). So the radiation emitted at different layers of the atmosphere is compared and graphed. As the altitude increases, the radiation emitted by the atmosphere increases as the mass of atmosphere below the near spacecraft increases and the blacker, or colder the air above appears. The increase in heat emission with altitude may not increase linearly with altitude. In fact, some altitudes may not experience a significant increase in emission with increasing altitude. After processing the data from the flight and graphing it, compare the results to the same measurements taken at a different time of the year, as there may be a seasonal change. Perhaps this experiment will only be able to determine the altitude of the Stratosphere.

1.21. Blood On Near Space Demonstration (D)

1.21.1. Explanation

As stated in Chapter Six, Good To Know, the ambient air pressure affects the boiling point of liquids. Lower the pressure enough and liquids, including blood, at body temperature will begin to boil. This demonstration is designed to illustrate this fact very dramatically.

1.21.2. Known Work In This Field

I know of none at this time.

1.21.3. Suggestions

Some large scale RC aircraft use pneumatic systems to deploy landing gear (it makes the deployment of landing gear look more realistic than the instant snap that a servo creates). The RC aircraft company, Robart, manufacturers an entire line of pneumatic systems, under the name of Air Control. One component of Air Control is the Speed Control valve, a servo operated valve. The Speed Control valve exhausts air from a reservoir when a servo sets the valve. It can also vent air overboard when the speed valve is set to a third position. The speed valve is the heart of this demonstration. There are three major topics to discuss in this demonstration, the liquid, the container and getting an airtight seal, and doing the demonstration.

The Liquid

To demonstrate the lowered boiling point of liquids in near space, a speed control valve must exhaust the air inside a container filled with a red liquid that will pass for blood. As a substitute for real blood (which would coagulate anyways), use either red-dyed water or alcohol. Alcohol has the higher vapor pressure, so it should begin boiling at a higher air pressure. Using alcohol in place of water may be cheating, but remember, it's the effect we're after. The effect will be more dramatic if the liquid is hot to begin with. This is especially important, as the liquid will cool during the mission. Be very careful if you heat the alcohol. Never directly apply a flame to alcohol to warm it. Inside use a water bath. Get the water boiling hot first, remove it from heat, and then place the alcohol container inside the hot water to warm. Keep the cap on the alcohol container so it doesn't evaporate away from the heat.

The Container And An Airtight Seal

To increase the safety of this demonstration and to reduce its weight, use a plastic container, rather than a glass container, as the blood bottle. It would be ideal to use a plastic version of a chemistry flask, but I don't know if anything like that exists. The next best option is to use a plastic bottle with a screw-on cap.

This demonstration requires that the blood bottle remain out of view of the camcorder until it is time to open the speed valve. I recommend placing the blood bottle on the end of a boom that is mounted to a quad panel next to the camcorder's view. A rotating mirror is used to change the camcorder's perspective. Read Chapter Seven, Section Five for information on building a rotating mirror for a camcorder. The boom holding the blood bottle must be wide enough to secure the container. The means to secure the bottle to the boom cannot interfere with the view the camcorder has of the red liquid in the bottle. Perhaps a bed of hot glue will be enough.

A means of sealing the blood bottle airtight is required. The air inside the blood bottle must be exhausted on command as a slow air leak in the blood bottle will weaken the impact of the demonstration. A possible solution is to seal the blood bottle with a screw-on cap and to wrap the threads of the container with Teflon tape. The cap must have a port in it so that an air hose can be attached to it. The port must have a hollow tube attached to it so the air hose can be secured to the cap. If the cap doesn't include a tube, you'll have to drill a hole in the cap just large enough to pass the tube through. Seal the tube to the cap with hot glue or epoxy so it remains airtight. If air does still leak, then use a little vacuum grease inside the cap to seal the air leak. As a final guard against air leaks, you may want to wrap the cap and top of the container with duct tape.

Now it's time to build the blood bottle's pressure control system. Attach an air hose to the cap of the blood bottle and route the hose along the bottle arm and into the airframe at the bottle arm's quad panel. Terminate the hose at the Speed Control valve. To operate the Speed Control valve, it must be securely mounted to a frame that also securely mounts the valve's servo. If the servo and valve are free to shift positions, the servo will not open the valve reliably. A sheet of 1/8" thick plywood and basswood blocks suffices as the frame's base. Epoxy the basswood such that the servo mounting flanges can be screwed to the basswood. In RC aircraft, the Speed Control valve is secured to a bulkhead. Attach and brace a second sheet of 1/8" thick plywood to the frame base as the bulkhead. Drill a large enough hole in the bulkhead to mount the valve. A link rod connects the servo horn to the valve's arm. The link rod assembly is the traditional RC aircraft method for connecting servos to airplane control surfaces.

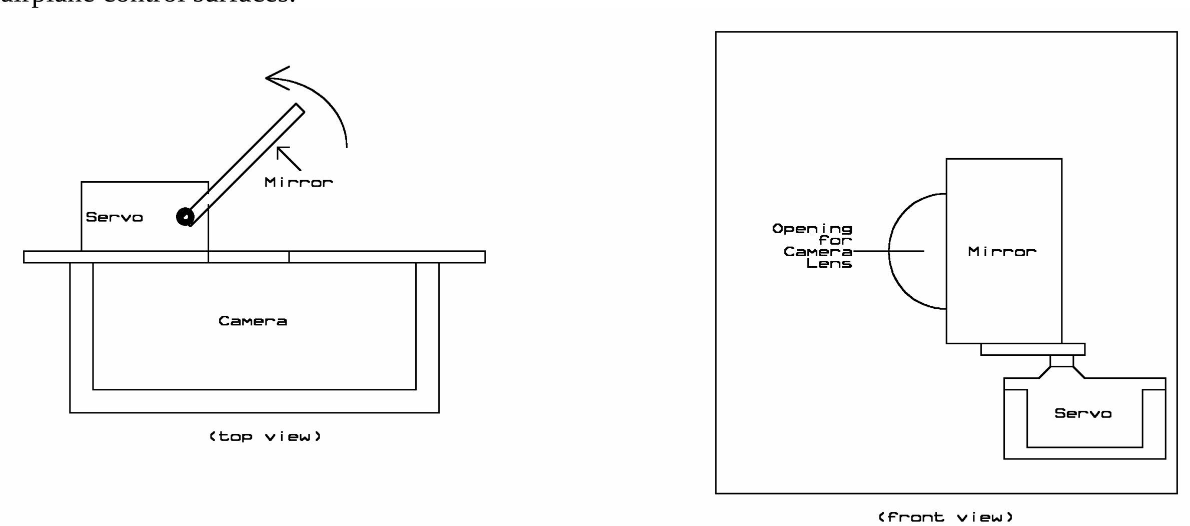


***Diagram of capsule with mirror, camcorder, and bottle on boom** – Top View (left), Front View (right)*

Doing The Demonstration

Write flight code to operate the demonstration. The code must rotate the mirror into place once the near spacecraft is above 75,000 feet where the skies are black. After a short pause the open the Speed Control valve with its servo. I recommend the following script be added to the video as a voice over.

"This is near space"
Short pause, then the mirror rotates the camera's view into position
"This is your blood"
Short pause, then the Speed Control valve is opened
"This is your blood on near space"
"Any questions?"

Preflight Checklist

- √ Fill the blood bottle with the hot red liquid
- √ Note: Start with hot liquid, as it will cool during the ascent
- √ Seal the container airtight
- √ Confirm the Speed Control valve is in the closed position
- √ Start the camcorder and launch the near spacecraft

1.22. Gravity In Near Space (D)

1.22.1. Explanation

Due to the $1/R^2$ nature of gravity, the Earth's radius, and its mass, the acceleration due to gravity decreases by just over 1% at an altitude of 100,000 feet.

1.22.2. Known Work In This Field

No one that I know of is attempting this measurement

1.22.3. Suggestions

To detect the reduction in Earth's gravity compare the weight of a test mass at the ground before launch and once again when the near spacecraft is above 100,000 feet. If the test mass weighs one pound at sea level, then its weight at 100,000 feet is about 4.5 grams less, or just under the weight of a nickel. A means to weigh a test mass is required to perform this demonstration. Perhaps a digital scale can be modified for this purpose. The output of the scale must be made available to the flight computer, or other microcontroller, which records the results. However, the small accelerations experienced by the near spacecraft as it ascends become a source of error in the measurements. The magnitude and direction of the error varies constantly throughout the flight and appear as "noise in the signal". The noise may even swamp the effects of reduced gravity in near space. I can think of two methods to reduce the "noise in the signal".

First, the scale test mass and scale must be isolated from as much balloon and wind induced acceleration as possible. The experiment can be mounted inside a mini-airframe that rides within a real airframe. Shock cords suspend the min-airframe inside of the real airframe, absorbing some of the acceleration. Also consider mounting the scale on a bed of foam rubber or other shock absorbing material. Look at what material is used to cushion laptops that are used inside automobiles.

A second means to decrease the effects of this "noise in the signal" is to make weight measurements of the test mass frequently during the mission. Over the entire flight, the residual errors in the measurements should be consistent. A trend in reduced weight should show up in a graph of the weight of the test mass versus the altitude of the near spacecraft. Have the flight computer take many measurements during the flight. Measurements taken during the mission must include, the current altitude and the current weight of the test mass. After recovery download the data and import the data into a spreadsheet. A graph of altitude versus weight should show a jittery weight that decreases in step with increasing altitude. Add a trendline to the graph, selecting linear regression. With such a small increase in altitude (100,000 feet isn't very significant to the radius of the Earth), the graph may appear linear.

1.23. Landing Bags (D)

1.23.1. Explanation

The Mars Pathfinder Lander relied on airbags to cushion its final impact with the Martian surface. While the Earth's atmosphere is dense enough to aerobrake a near spacecraft with parachutes, the idea of deploying a landing bag during descent is too appealing to ignore.

1.23.2. Known Work In This Field

The only organization I know attempting this is the Jet Propulsion Laboratory (JPL). But then, they hardly count as amateurs, do they?

1.23.3. Suggestions

JPL designed the Mars Pathfinder to deploy air-filled landing bags shortly before impact with the ground. The landing bags were made of a durable material that resisted abrasion and bursting during the landing. In our case, since landing bags are not the primary recovery system of near spacecraft, they can be a simpler design. I think a toy vinyl flotation ring[D] would be sufficient. The ring cannot be inflated prior to launch or else it will burst in the near vacuum of near space. Instead, inflate the ring prior to landing, say 5,000 feet above the ground. Two ways to inflate the landing bag are with a source of compressed air or with an air pump.

Compressed Air
Robart RC equipment is the source of compressed air in this suggestion. A Speed Control valve is connected to an aluminum reservoir (bottle). Prior to launch, the air reservoir is filled with air through a check valve. The Speed Control valve is kept in the closed position. The hose from the Speed Control valve is routed to the filler of the vinyl ring through a quad port. Leave the reservoir inside the airframe and route the check valve to the exterior of the airframe through the same quad port as the check valve. During descent, the flight computer when the altitude is low enough to deploy the landing bag and opens the speed valve, filling the donut.

Air Pump
In place of a source of compressed air inside the airframe, a small air pump can be used to inflate the vinyl ring. The pump will require more time to inflate the ring than the compressed air. So run a test on the ground to determine the time required to fill the donut and add an extra minute. Then determine at what altitude filling must begin by assuming a constant descent rate of 1200 feet per minute (so multiply the time required to fill the flotation ring by 1200 and the result is the altitude to begin filling). One source of an air pump is the air pump used in automatic blood pressure monitors. I purchased one through a surplus catalog and they still may be available. Route a hose from the input side of the air pump to the outside of the airframe through a quad port. Do not try to pump air from inside the airframe to the vinyl ring, as the input port of the air pump may be covered with a Styrofoam peanut during the flight. So route a hose from the output side of the air pump to the filler of the vinyl ring through the same quad port as the output side of the air pump routes.

Attaching The Vinyl Ring To A Module
Loosely mount the vinyl ring to the outside of the airframe with Dacron cord. The Dacron must keep the deflated ring in place, but not bind the ring as it inflates. It's easier to let the vinyl ring hang limply from the bottom of the airframe. However, for a more professional look, consider giving the vinyl ring a covering of aluminized Mylar. Cut a single sheet and tuck it around the edges of the deflated ring. The Mylar must be wrapped loosely enough not to bind the inflating vinyl ring. To

prevent the Mylar from falling free of the airframe, tack the Mylar at one point to the airframe or the ring.

Note that a landing bag also works in cases of unplanned water recoveries. The ring becomes a floatation device should the near spacecraft recover in a lake.

1.24. Rocket Assisted Landing (D)

1.24.1. Explanation

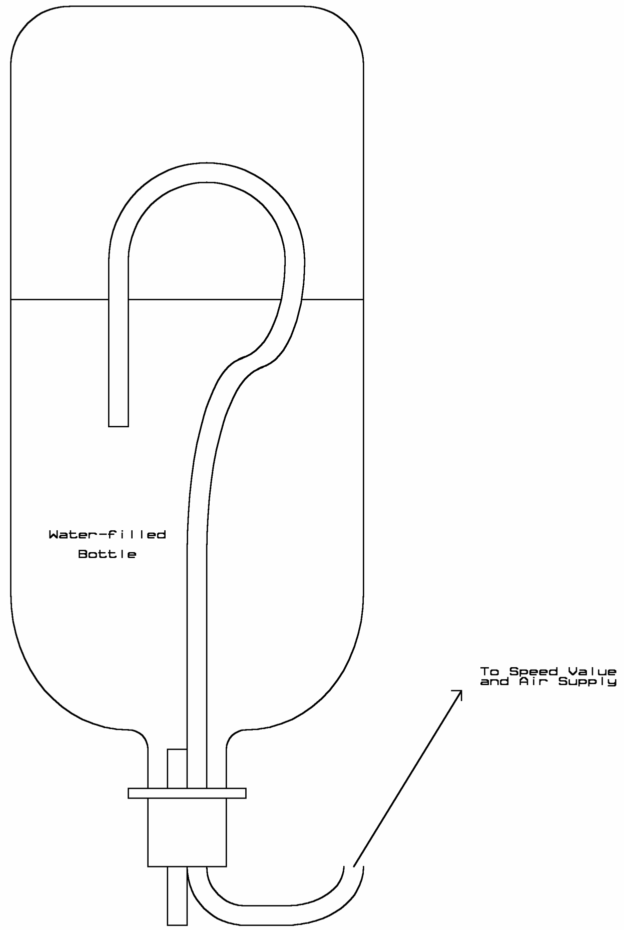
Before the Mars Pathfinder was released from its parachute to bounce like a Martian beach ball, it fired a solid fuel rocket mounted just below the parachute shroud lines. This rocket thrust was the last blast of deceleration before the Mars Pathfinder impacted the ground. Something similar can be attempted with amateur near spacecraft, but not with rocket motors that generate hot thrust.

1.24.2. Known Work In This Field

Except for experimental glider programs, no program attempts to land the near spacecraft with anything but a passive parachute.

1.24.3. Suggestions

Setting a field on fire when the near spacecraft lands aids in locating the recovery site. However, the costs of such a landing far outweigh the benefits. Here's a better idea. Almost everyone has at one time or another played with toy rockets that develop a cold thrust. I'm referring to water rockets. The technically inclined people have developed water rockets from two and three liter pop bottles. One such two-stage water rocket has reached an altitude of 1000 feet. These are not your father's toy water rockets. Toy water rockets require a pressure chamber partly filled with water and a source of compressed air. Having not tried this yet as a near space application, I recommend using two bottles.



Cold Thrust Rocket Assisted Landing Motor – *The Pressure Chamber*

The first bottle is the pressure vessel and is sealed with a servo-operated valve. The second bottle is the pressure chamber and is partially filled with water. The pressure vessel connects to the pressure chamber with a hose that connects to its screw-on cap. A second hose forms an inverted "U" inside the pressure chamber before exiting the pressure chamber through its screw-on cap. The inverted "U" prevents water from leaking out of the pressure chamber until the servo-operated valve is opened and the pressure chamber is pressurized from the pressure vessel.

Note that one end of the "U" extends to the bottom of the tank and its other end loops out of the water and terminates below the water level. If the tube is filled with water, then a siphon forms, draining the water out of the tank. During ascent, air pressure inside the tank will eventually begin pushing water out of the tank through the tube. To prevent the slow draining of the tank during ascent, plug the end of the nozzle with a rubber cap, wax, or clay. You want to use a material that will resist the gradually increasing difference between tank and atmospheric pressure, but not the rapid rise in pressure when the motor is fired.

There are two hoses then that pass through the screw-on cap, one for the pressure delivery hose from the pressure vessel and a second for the exhaust of the pressure chamber. There's no reason the motor hose can't terminate in a T or other junction to create multiple mini-motors. Multiple motors are useful in avoiding problems where a single motor is not aligned with the center of gravity of the near spacecraft. The motor should be fired when the near spacecraft is near the ground. If the motor exhaust is located in the bottom capsule, then the result of firing the motor is to offset only the weight of the bottom capsule, letting the parachute slow the capsules even further. However, if there is too much thrust, the motor lifts the bottom capsule up into the capsule above it where the collision may damage the capsules. If the motor exhaust is placed inside the top capsule, then firing it will soak the bottom capsule. In that case the top of the bottom capsule requires a plastic roof. When acting on two modules, the motor has more difficulty trying to lift both capsules up, so there's less risk of taking the weight off the parachute and collapsing it.

One issue that needs to be addressed is making sure enough air can flow through the pressure delivery hose to make the motor effective. Because of the requirement for high thrust, a Speed Control valve and its tubing may not be large enough to let air flow fast enough to pressurize the pressure bottle effectively. However, do not think of this as an obstacle to success, rather, think of it as an opportunity to launch more near space missions in support of an experiment. One last idea. In place of a second pop bottle to provide pressure, consider using a CO_2 cartridge from a pellet gun. A servo can be used to operate the gas release mechanism from the pellet gun.

1.25. Reefed Recovery Systems (D)

1.25.1. Explanation

A reefed parachute has a cord running around its perimeter that prevents it from opening fully. As a result, its descent speed is increased. A faster drop to the ground reduces the drift the recovering near spacecraft caused by the wind. At a lower altitude, the reefing system allows the parachute to open more fully, slowing the near spacecraft to a safe landing speed.

1.25.2. Known Work In This Field

I know of no amateur group experimenting with this, however, reefing parachutes are popular with professional recovery systems.

1.25.3. Suggestions

Here's how I plan to approach reefing parachutes some day.

- √ Sew Dacron loops to the bottom of the parachute that are independent of the shroud line loops
- √ Note: The loops are how the reefing line keeps the parachute from opening fully
- √ Build and test two FTUs (Chapter Six, Section Six)
- √ Note: The FTUs are used to cut the reefing line
- √ Build a case for each FTU

FTU Case Notes:

- The FTU case keeps the reefing line from tugging on their nichrome coils and insulates the coil from cold temperatures
- The cases must have mounting tabs to secure them and the FTU to the canopy
- The FTU and cases are mounted such that their nichrome coils extend below the bottom edge of the canopy where the reefing line can pass through them
- The cases must have a closure that allows access to the nichrome coil and the reefing line

- √ Place the FTUs on opposite sides of the parachute canopy and mark their location

- √ Sew reinforcing panels (Dacron?) to both sides of the parachute canopy where the FTUs are to be located
- √ Make the reinforced panels a little larger than the FTU cases
- √ Punch holes in the canopy reinforcement for the mounting tabs of the FTU cases
- √ Secure the cases to the canopy with nylon wire ties
- √ Route cables for triggering the FTUs along shroud lines

Using Reefing Lines

- √ Determine the circumference of the opened parachute
- √ Cut two 50 pound test Dacron kite lines
  One to a length 1/3 the parachute circumference (short reefing line)
  The second to a length 2/3 the parachute circumference (long reefing line)
- √ String the long reefing line through the reefing loops and one of the FTUs
- √ Tie the ends of the long reefing line together, forming a loop
- √ String the short reefing line through the reefing loops and the remaining FTU
- √ Tie the ends of the short reefing line together, forming a loop
- √ Connect FTU triggering cables to the flight computer when the stack is assembled
- √ Launch the near spacecraft
- √ Monitor the near spacecraft's altitude during descent with the GPS receiver and use a back up software timer in the flight computer in case the GPS stops sending data

At this point, the short reefing line prevents the canopy from opening fully, so the near spacecraft descends faster than usual and drifts less

- √ At some point during descent, trigger one FTU to cut the short reefing line

Now the long reefing line prevents the parachute from opening fully, but now the near spacecraft descends slower than before the short reefing line was cut

- √ Later in the descent, trigger the second FTU to cut the long reefing line

Now the canopy is fully opened, the near spacecraft descends at its normal speed

It goes without saying that this process must be tested thoroughly. Also, launch the first test of any modification to the recovery system in a region where there is no private property to possibly damage.

2.0 Developing A Program

These suggestions come from my experience forming two near space programs (KNSP and TVNSP) and helping others begin their own near space programs

2.1. Read

The more, the better. There's a wealth of information out there waiting to be applied to amateur near space. Some sources apply directly to amateur near space, while other sources are only indirectly applicable.

As an example, a book on parachute design will give you ideas on making or modifying your recovery system. Robotics books can be applied except for the parts about wheels, since a near space capsule is a robot on a balloon.

2.1.1. Sources

Here are some of the references I have read over the last seven years I have been involved with amateur near space.

- BASIC Stamp Programming Manual, Parallax Inc.
- Computers In Space, James E. Tomakyo, Alpha Books
- Engineer's Mini-Notebook (all of them), Forest Mims III, Siliconcepts
- Meteorology, Danielson, Levin, and Abrams, WCB McGraw Hill
- Micro Spacecraft, Rick Fleeter, The Edge City Press
- Mobile Robots, Joseph L. Jones, Bruce A. Seiger, and Anita M. Flynn, A. K. Peters
- Parachute Recovery System, T. W. Knacke
- Practical Electronics For Inventors, Paul Scherz, McGraw Hill
- Research Balloons, Carole S. Briggs, Lerner Publications
- Space Mission Analysis And Design, Wiley J. Larson and James R. Wertz, Space Technology Library
- The 6.270 Robot Builder's Guide, Fred Martin, Pankaj Oberoi, and Randy Sargent, MIT
- The Idiot's Guide To Meteorology,
- The Mars Pathfinder, Price Pritchett and Brian Muirhead, Pritchett and Associates
- The Pre-Astronauts, Craig Ryan, Naval Institute Press
- The Satellite Experiment's Handbook, Martin Davidoff, ARRL

As you can see, some of these books are only indirectly related to near space. Some of the books listed above are more motivational or historical. Some of the experiments I try today are derived from what was attempted in the past.

2.2. Crew Training

This cannot be stressed enough. To be successful, your crews need to know what they're doing. You will be stopped constantly during a launch for further instructions when you are the only one who knows what is going on. Launches go much faster when your crew is knowledgeable. When you're the only knowledgeable person, flight predictions are only made when you have time. When many people are making predictions errors can be identified, preventing a launch in questionable wind conditions. TVNSP tries to meet at regular intervals (sometimes every two weeks) for training and review. If you are the program manager, then see the following items are done.

- Document your procedures
- Teach everyone how to perform all the steps of launching a near spacecraft
- Practice launch procedures at the beginning of each year's launch campaign
- Help trackers set up their equipment

Make checklists and "application" notes for your team. Update the checklists before each launch (by the FRR) and keep them concise and clear. At your early meetings, teach everyone present how to perform each task. I feel the following tasks should get the greatest emphasis.

- Making flight predictions
- Filling and tying off the balloon

Other tasks like assembling the stack and using lanyards historically have been less critical for TVNSP.

Everyone forgets. So every year, before the beginning of the year's near space campaign, TVNSP crews meet to review procedures. We get out the filling equipment and run through the procedure. TVNSP also reviews making predictions.

You will notice there is a lot involved with setting up APRS on a laptop. TVNSP has documented their recommended APRS +SA settings. When a member wishes to set up an APRS tracker, they bring their equipment to a meeting and get the help they need. By the end of the meeting, they should have a functional APRS tracker. During the morning of a launch is a very bad time to help someone set up his or her tracker. During a chase is equally a bad time for someone to be using APRS for the first time.

2.3. Support

Even though a near space program is less expensive than a space program, it can be difficult to support out of pocket. However, I have found that being single does improve my ability to run a near space program off of my paycheck. To do so means you have to commit to it like it is your only hobby.

2.3.1. Monetary Support

Being a part of amateur radio club allows the near space program to be a part of their annual budget. While it probably won't pay for every flight, the club may be able to pay for one or two flights each year. Be professional and responsible so the near space program is a feather in the cap of the club. In public venues, be sure to mention that the program is a part of the local amateur radio club. Even try to increase membership in the club with the near space program.

Consider flying experiments for other groups and organizations. In some cases, they can be asked to help offset the cost of the launch by perhaps providing the balloon or a tank of helium. Since the program uses amateur radio equipment for telemetry, no profits can be made from launching amateur near space missions.

Ask for donations. Local civic clubs or your helium supplier may be able to sponsor a flight once a year. A thank you to the sponsor can be attached to the outside of a module and photographed before launch. Another way to thank a sponsor is to fly a memento into near space and present it to the sponsor after recovery. Good mementos include a patch or bumper stick from the sponsor. After the flight, return the memento mounted to a frame along with photographs from the flight. Be sure, however, that the cost of making the presentation doesn't end up costing more than the donation.

2.3.2. Volunteer Support

Not just money is needed to operate a near space program. Each program seems to have its core of dedicated individuals. However, there may be times when that isn't enough people to successfully launch a near spacecraft. KNSP made use of volunteers who would lend a hand to launch a near spacecraft but not to chase or recover it. Other times KNSP made use of volunteers who couldn't help launch, but who would lend a hand if the landing zone was in their neck of the woods.

The only way to get this kind of support is to talk it up. Get around to all the local clubs, be they radio, astronomy, civic, or other. Get people excited about what your program is accomplishing. After a couple of flights you will have some of the neatest photographs and videos to show. Displaying a photograph taken from 85,000 feet makes people think you're an astronaut (just ask Bill

Brown). Images like these attract attention and interest. Also, think long term, and give presentations annually. Each year there's always someone new to the club.

2.4. Get Involved In Special Events

Spread the word about what the program is doing and get some public attention. When possible, launch in support of special events that commemorate the sciences and technology. Good examples include the following.

- Astronomy Day
- Space Day
- Star Parties
- Museum Open Houses
- Field Day

If your program cannot launch at times like those, then set up a static display or launch a dummy payload. In either display type, show how tracking is done and examples of the telemetry and results from flights. You may want to hand out diskettes with actual flight data in a spreadsheet format. Include directions with the diskette explaining how to process the data and generate interesting result. Also try to get some public exposure for your crews.

2.5. Visit Classrooms

If you know a teacher then talk to him or her about your program. If your program fits in with what his or her class is doing, you can be given permission to present to the class. It can be tough to present if the teacher doesn't know you. So be ready to explain what your presentation can do to excite children. Don't be disappointed if you can't present any time soon. Teachers have their own lesson plans and you may not fit in those plans. It can also help if you know the spouse of a teacher.

Before presenting to a classroom, ask the teacher about special interests of the class. Have lots of visual displays that are appropriate for the age of the class. I found elementary students like to see and touch the parachute. If you're presenting to a science class, recommend flying an experiment for the class. Share possible experiments with the teacher. It's best if the teacher works with the class on setting up the experiment, but be ready to offer help if asked. You may have to provide parts for the experiment. Classrooms have limited resources and it can take some time to receive equipment that they order. Be ready to provide equipment so the teacher doesn't have to purchase items out of pocket. Be ready to have an experiment ready to go, in case the class has trouble deciding on an experiment or can't build it in time. Sweat the details. If your first classroom presentation and experiment fails, you may not have a second chance. After arranging for students to design an experiment, have them also create a name for the experiment and a mission patch to accompany it. See to it that the patch printed and attached to the experiment. Additional copies of the patch can be laminated and placed onboard the near spacecraft. After recovery, give the flown patches to the students.

Be careful about inviting students out to the launch. Any student attending a near space launch needs to be accompanied by their parents or guardians. Under no circumstance allow unsupervised students to attend launches and/or go on chases by themselves.

Possible classroom experiments include the following.

2.5.1. Seeds In Near Space

Small children like planting seeds. Seeds also make a great way for children to practice applying the scientific method to an experiment they helped design. Consult Chapter Eight, Section 7.3 for directions on flying seeds into near space. To encourage future experiments, offer to fly seeds from the surviving seeds next semester or next year. You could offer to fly later generation seeds every year.

2.5.2. Balloons Filled With Various Gasses

Consult Chapter Eight, Section Ten for ideas on flying balloons into near space. Aside from balloons filled with gasses, also consider flying marshmallows into near space and photographing the results. Students should design and construct the lightweight sample holder. Remember to place the sample holder arm far enough from the camera to keep the samples in focus. This may require a ground test before the flight. Returned images of the samples will be far more interesting when you have the edge of the Earth in the background of the samples. If balloons contain various gasses, make sure to label the balloons with a felt-tipped marker. Don't rely on people remembering which balloon carried which gas.

2.5.3. Measuring The Temperature Of Samples

A temperature sensor array is needed to perform this experiment. Consult Chapter Eight, Section Nine on constructing temperature arrays. Have students collect or make sample materials to send into near space. The color or method of construction influences how they retain or lose heat. The vacuum of near space and ultraviolet radiation of the Sun also has an impact on samples that's not easy for students to recreate on the ground. Double-check any code the students write before launch as a part of a ground test. As a part of the ground test, have the students process the generated data log. After the flight, give students a copy of the data log.

2.5.4. Flight Logs

Generic flight logs make a good math exercise. Students get to practice what they have learned by using real data collected in near space. Give the classroom copies of cleaned up flight log so they can make graphs. Example graphs include, ascent rate, latitude and longitude of the balloon, air temperature at altitude, and cosmic ray counts. Be sure the teacher is comfortable with the format of your data, or else the teacher cannot help out students with questions. Along with the data, include a copy of a video taken in near space that the teacher can play, photographs taken at altitude to pass around or give out, or even stickers of photographs taken of the near spacecraft or images from near space (younger children like stickers).

2.5.5. Analyze Ground Photographs

Give the class a set of ground photographs taken from near space along with the latitude and longitude of the photographs. Have the students find the location of photographs on a map. Before a flight, demonstrate how the capsule will take photographs during the flight. Also give the students a graphic of the expected flight path. After the flight, present the students with a set of 4 by 6 inch prints with the altitudes of the photographs. Also give them a copy of the flight log. Students can relate the time of the photograph with the GPGGA sentence in the log. They can use this data to determine the latitude and location of each photograph.

Photographs indicate geomorphic features of the ground. Find and read an introductory text on Geomorphology for more information. A flight six months later shows how foliage changes over the course of a year. It also shows how rivers and creeks can also change.

2.6. Develop And Fly Experiments For Other Groups

Remember there are more than just school students out there. The scouts, 4H, Boys and Girls Clubs may want to participate in a near space mission. Heck, there's even civic clubs out there. Why shouldn't adults be doing their own amateur science experiments?

2.7. The Media

Invite the local news media to cover one of your missions. Be sure to ask them to cover any experiments you are flying for schools and clubs. The news media may not be able to go on the chase for liability reasons, so work with them and give them materials from past flights.

3.0 National Organization

There is no national organization for near space at this time. One reason is that the numbers of groups and their members remains low. With more exposure, this may change in the near future. Currently, these are the parts of a national organization, virtual national organization, so to speak.

3.1. Ralph Wallio's Records Website

Ralph Wallio (W0RPK) maintains a website with a focus on many aspects of amateur near space. One of the most popular is his list of amateur near space records, where he keeps track of the state-of-the-art. Ralph keeps track of the following amateur near space records.

- Highest GPS Reported Altitude (ASL)
- Lowest Reported Maximum Altitude (AGL)
- Highest Continuous Ascent Rate (averaged over >10,000ft)
- Lowest Continuous Ascent Rate (averaged over >10,000ft)
- Longest Great Circle Distance, Release to Touchdown
- Shortest Great Circle Distance, Release to Touchdown (at least 50kft maximum altitude ASL)
- Longest Mission In Time, Release to Touchdown[E]
- Heaviest Payload
- Lightest payload
- Largest Balloon Envelope(s) (Fully Expanded Volume)
- Smallest Balloon Envelope (Fully Expanded Volume)
- Greatest Telemetry Downlink Reception Range (Two Categories)
    - VHF/UHF near line-of-sight
    - HF via any mode of propagation
- Greatest Two-Way QSO Repeating/Transponding Great Circle Distance
- Total Missions Flown
- Longest Recovery Time (any method)
- Touchdown Prediction Closest to Actual Coordinates

Ralph's website is located at http://showcase.netins.net/web/wallio/ARHABrecords.htm

3.2. Balloon Announcement Email Lists

There are several active email lists in the amateur near space community. When forming your own group, consider establishing an email list for it. You should also consider subscribing to the current email lists to keep up to date with what's happening across the US. By doing so, you will be kept informed on upcoming Super Launches (covered in the next subsection).

All the currently active near space related email lists are hosted on Yahoo.Groups. When at their website, try subscribing to some (all?) of the following email lists.

- ANSR: Based in Tucson, AZ
- EOSS: Based in Denver, CO
- HABITAT: Based in the Kansas City, KS metro
- HamBONE: Based in New York
- KNSP: Based in the Midwest
- NAHBG: Based in Seattle, WA
- Project Traveler: Based in Hutchinson, KS
- TVNSP: Bases in Boise, ID

3.3. Super Launches

The first Super Launch was the Great Plains Super Launch (GPSL) and occurred Manhattan, KS in July of 2001. The name, Great Plains Super Launch, was the idea of Bill All (N3KKM) when we were looking for a name to call our attempt to simultaneously launch balloons from four near space programs. Three balloons were launched at the first Great Plains Super Launch. At the second, a total of eight balloons were launched in support of six near space missions. A second Super Launch has been formed in Idaho. This Super Launch is called, the Northwest Super Launch (NWSL) and is scheduled as to not to conflict with GPSL. The author hopes to begin the Strato-Bowl Super Launch (SBSL) in a few years. With the creation of more near space programs, these additional Super Launches can take place. Think of them as a Field Day specifically for amateur near space.

Super Launches are more than just launching a bunch of balloons at the same time. It's a chance to meet other programs and share knowledge and history. The GPSL includes a more formal symposium element the day before the mass launch. Social events are also planned. As currently planned, the GPSL is sponsored by different near space programs each year. Once your program is established, consider sponsoring a Super Launch.

3.4. Benefits Of A National Organization

If sufficient numbers of people get involved with amateur near space, a national amateur near space organization can be started. There are several benefits to be gained, once there are enough people or programs are involved.

3.4.1. Liability Insurance

Like any hobby, liability insurance has become necessary in this world. No accidents have occurred with any amateur near space program to date. The NWS launches over 75,000 radiosondes a year with very few incidents over their 65-year history. That being said, it is still a good idea to look into liability insurance through a club or through your homeowner's insurance.

One benefit of a national near space organization is that group insurance can be purchased, saving every group money. Such insurance would be tailored to the needs of the amateur near space community.

3.4.2. Publications

With enough launches each year, an annual report of sorts could be published. A year in review becomes affordable when sufficient copies are printed.

3.4.3. Awards Programs

Currently the only planed sponsorship of a near space award is by TVNSP. The near space program with the currently highest flight, as documented by Ralph Wallio's Records List, receives a plaque. As new altitude records are set, the award is updated and sent to the new winner. With more groups involved in a national organization, more awards can be sponsored.

4.0 The International Geophysical Year Plus Fifty

The author proposes the following amateur science event to coincide with the fiftieth anniversary of International Geophysical Year. A part of this celebration will focus on amateur near space programs.

4.1. A proposal to create and manage a coordinated amateur science program in celebration of the fiftieth anniversary of the International Geophysical Year (IGY)

4.1.1. Name of Program

IGY + 50

4.1.2. Dates

1 July 2007 to 31 December 2008 (corresponding to the fiftieth anniversary of IGY)

4.1.3. Purpose

To encourage the exploration of the Earth, from pole to pole, and from the oceans to the top of the atmosphere, by amateur scientists from around the world in the spirit of IGY

4.1.4. Overall Goals

A. To create as many amateur science programs as possible
B. To encourage amateur science activities
C. To give guidance to these groups

D. To collect as much data and stories as possible in an organized fashion
E. To host a symposium at the conclusion of the program
F. To publish a book of the results at the conclusion of the program

4.1.5. Specific Near Space Objectives

A. To create as many amateur near space programs as possible
B. To coordinate a large number of balloon launches with each mission carrying at least one experiment
C. Develop a suite of suitable near space experiments
D. Coordinate mass-purchases to lower costs
E. Launch, chase, and recover several long duration (cross-country) balloon flights

4.1.6. Governance

I believe at least five committees are needed
A. Directors to oversee all other committees
B. Membership to register and track all participating groups or individuals
C. Public Relations to spread the word and line up supporting organizations or donors
D. Standards to develop a standard for terminology and a format for experimental results
E. Publications to see to the publication of a final book, symposium, and webpage

4.1.7. Background

Beginning in the spring of 1950, James Van Allen (University of Iowa) began leading discussions with American researchers, and eventually European researchers, to create a coordinated, worldwide research program in order to better understand the Earth's upper atmosphere and outer space. Together they declared the 18 months between July 1957 and December 1958 to be the International Geophysical Year (IGY).

As a part of IGY, the Eisenhower administration declared America's intention to launch an earth-orbiting satellite. Later the Soviet Union also announced their intention to do the same. The opening of the Space Age is due in part to IGY.

IGY was the last time a peaceful and professional worldwide effort was made to scientifically explore the regions above the surface of the Earth (the two prior times were International Polar Years in 1883 and 1933). I'd like to commemorate the fiftieth anniversary of IGY with what will essentially be an amateur reenactment. But this time it will be an effort of amateurs exploring and experimenting.

4.1.8. Starting IGY + 50

A. Get sufficient agreement to begin the program
B. Develop an organizational chart for the committees and define their responsibilities
C. Develop a website for the program
This website should have at least three sections.

The first section is the Groups Section and is a list of links to those groups that have been formed and are planning to take measurements.

The second section is the Help Section. This section is for those giving or needing help. If a group needs help, they list their requirements there. If you have help to give, you list your specific help there. Any donors or mass-purchases are listed in this section.

The third section is the Events Section. This section lists individual, regional, and global events of interest. The list encompasses scheduled events, tours, or nice to know events.

D. Develop an email list for the program
The email list doesn't replace those email lists now in, or planned to be in, existence. Just include the email list in your program's emails, so we can all share information.

4.1.9. Conclusion

Please share this idea with anyone who may be interested in being a part or supporting those getting involved. We have a few years to get new groups up to speed in designing their programs. I believe we need to develop a recruitment video and a series of posters to help spread the word. I'd like to see some early media coverage of the program. Opportunities to have amateur experiments be a part or performed in conjunction with professional experiments should be explored.

IGY + 50 won't work unless many people make an effort to get involved. Please discuss this issue with me so that I can gauge the level of support and further refine the concept.

L. Paul Verhage
Program Manager, TVNSP
paul.verhage@boiseschools.org

4.2. The Near Space Part Of IGY + 50

If sufficient interest is generated, the author will set up a website for the International Near Space Year (INSY), the near space part of IGY + 50. Currently the planned URL for INSY is at: http://www.insy.org

The website will have three sections. The first section is the Groups Section. It is for those groups that have been formed and are launching, or planning to launch near spacecraft to announce their participation in INSY. There will be links to their official websites. The second section is the Help Section. This section is for those looking or needing help. If you can help financially or with equipment, please let us know. If your group needs help, again, let us know. The third section is the Events Section. It will contain information on special offers or INSY meetings. It will also have the link to HABET, Hank Riley's website, which provides announcements of launches and Ralph Wallio's Records website.

The author also plans to sponsor an email list for INSY. The INSY email list is not to replace those email lists now in, or planned to be in, existence. The INSY email list is in addition to those in existence. Once (if?) INSY is setup, please include the INSY list in your emails, so we can all share information.

In conjunction with the Super Launches, there will also be a conference or symposium during this period so all groups can meet in person and share the results of their flights.

Finally, I'd like to publish a journal at the close of INSY. It would include articles from all groups participating in INSY. In each section, groups will be asked to write about their experiences and show pictures.

Please share this idea with any group who may be interested in launching or supporting those who launch. We have a few years to get groups up to speed in designing their own near spacecraft. If you can help out, please contact me at the email address given in the help section. I'd like to see many science fair entries using data from near space flights. The only way this can happen is if you create a near space group and get the local community involved.

I'd design a recruitment video that will be available at cost to those groups making their participation in INSY official. I'll also try to arrange news coverage.

INSY won't work unless you make an effort to get involved. Please do so. With this book and information available over the Internet from the other near space groups, you can design and launch your own near spacecraft.

Good To Know - Notable Firsts Of Amateur Near Space Exploration

Jeff Melanson, KD7INN, of the TVNSP, suggested this section. Good idea, Jeff! Many people have documented the history of professional near space exploration, but up to this point of time, no one has written any kind of history about amateur near space. So here's my small attempt to record some of the important firsts of amateur near space. Perhaps someone, maybe every a reader of this book, will write a more complete history.

The first amateur near space launches took place in Finland in 1967. Amateur near space began in the United States on 15 August 1987, when Bill Brown launched his first balloon carrying amateur radio. The payload consisted of 2m CW IDer and ATV IDer. No live ATV from near space or GPS receiver was carried. Over fifteen years later, look at the difference!

1967 May 28	Ilamari program launches first amateur balloon in Finland. Payload consists of 2m and 70 cm beacons and a 2m to 70 transponder (OSCAR-like two band repeater). Ilamari flew a total of 18 missions through 1980.
1987 Aug 15	Bill Brown launches the USA's first amateur near space capsule, The Birthday Balloon - it was Bill's birthday (Findlay, OH). Payload consists of two IDers, one on ATV and the other on 2m (CW beacon). Capsule is recovered by DFing.
1988 Jun 4	Indiana launches its first near space flight, The W9PRD Balloon Launch (Greensburg, IN). In 1990, this group became Windtrax and eventually launched balloons for 22 Indiana high schools, involving over 2000 students.
1988 Oct 23	Bill Brown launches a 2m digi-peater.
1988	Bill Brown launches first ATV black & white camera into near space. (Mojave Desert)
1988	Bill Brown launches first film camera into near space.
1990 Feb 10	BYBG launches their first flight. (location, Argentina).
1990 Nov 18	EOSS launches its first near space capsule, WVN-1 (later called EOSS-1) (Denver, CO). Payload consisted of an ATV system and camera, a 10m beacon, and temperature and pressure sensor.
1991 Jan	SSOK launches its first near space capsule, SSOK-1 (Salina, KS).

1991 Aug	Bill Brown writes first article on amateur near space flights for 73 Magazine
1992 Jan 2	First amateur launch of a zero pressure balloon, EOSS-4 (Denver, CO)
1993 Feb 6	First near space capsule carrying Loran-C, EOSS-10 (Denver, CO)
1993 May 2	First near space capsule to carry a GPS receiver, EOSS-12 (Denver, CO)
1993 Aug 20-22	First balloon symposium. Hosted by EOSS, (Denver, CO)
1993 Dec 4	HABET launches its first near space capsule, HABET-1 (Des Moines, IA). Payload consists of SAREX Robot QSO software
1993	Dave Mullinex writes first FAQ on amateur near space
1994 Feb 27	First 9600 baud packet sent from near space, HABET-2 (Des Moines, IA)
1994 Nov 12	First GPS documented flight into high near space (above 100,000 feet), SSOK-9 (Salina, KS). Altitude reached is 111,557 feet
1996 Nov 2	KNSP launches its first near space capsule, KNSP Flight 96A (Manhattan, KS). Payload consists of dust sampler, two 35mm cameras, and Geiger counter
1997 May 11	First rocket launch from a near space platform, Space Launch-1, (Hampstead, NC). Rocket reaches an altitude of 36 miles.
1997 Oct 4	HABITAT launches its first near space capsule, 98A (Kansas City, KS). Payload consists of APRS tracker and a camcorder
1997 Dec 9	The launch of PCIS-1 (later to become SkyQuest-1), (Plymouth, MA). Payload consists of a expendable 2m CW transmitter because of the mission’s proximity to the Atlantic Ocean.
1997 Dec 13	First camcorder carried into near space, KNSP Flight 97D (Manhattan, KS)
1998 Oct 10	First live SSTV images of near space, KNSP Flight 98D. Uses Kenwood Visual Communicator, VC-H1
1998 Oct 10	First capture of a landing near space capsule, KNSP Flight 98D (Manhattan, KS), Payload caught by Dan Miller (KE4SLC)
1998 Oct 24	University of South Dakota launches its first near space capsule, Margaret-Myrtle, payload consists of APRS tracker, 35mm camera, and dust collector
1999 Oct 9	TVNSP launches its first near space capsule, TV99A (Boise, ID). Payload consists of Geiger counter, camera, and weather station
2000 Feb 8	Into The Air launches its first near space capsule, ITA-1, payload consists of fireball CW beacon
2000 March 25	NSBG launches their first flight from Kansas City.
2000 Oct 7	NSTAR launches its first near space capsule, 00-A (University of Nebraska, Lincoln, NE). Payload consists of flight computer and 2m simplex repeater
2001 Apr 22	Project Traveler launches its first near space capsule, 2001a (Hutchinson, KS). Payload consists of a PIC-based Flight Computer and a 35mm camera
2001 July 1	First Super Launch, GPSL 2001
2001 July 27	Ham-Bone launches its first near space capsule, HamBONE-LD1. Payload consists of flight computer with pressure and humidity sensors, 10m and 30m beacons
2001 Sept 15	ES-OS (Experimental Sub-Orbital Society) launches its first near space capsule, ES-OS ONE (Denver, CO). Balloon consists of envelope built by Mark Caviezel (KC0JHQ)
2001 Nov 17	First video tape of an entire flight, from launch to landing, TV01H (Boise, ID)
1991	Bill Brown launches first cross band repeater (440 in and 10m and 2m out) into near space (Peterborough, NH)
	Joe Mayenschein (WB9SBD) launches first near space capsule, Repeat-1. Payload consists of air pressure sensor, 28 MHz beacon, and dual band

	repeater (10m and 2m).

Near Space Humor - Comix

Crater - *At the recovery site of a near spacecraft that broke free of its parachute.*

So Close… *yet so far*

[A] KimWipes™ are an excellent product. They are made by Kimberly-Clark, makers of Kleenex.™

[B] Many robotics websites explain how to modify a standard servo for continuous rotation, so it is not covered in this book. Optionally, Parallax, Inc. sells inexpensive continuous rotations servos (Part number 900-00008).
[C] Powerpole® is a registered trademark of Anderson Power Products.
[D] Your editor pictures a near space capsule wearing a bright yellow ducky pool float.
[E] You really don't want this record. Groups get it when their near spacecraft are lost for several months and later found (usually by a stranger).

CHAPTER FOURTEEN

Federal Aviation Regulation FAR 101

"Good amateur practice is never having to say you're sorry."
--The American Radio Relay League
Brought to my attention by Mike Manes (W5VSI)

Chapter Objectives

1.0 Understanding FAR 101

To promote the safe use of airspace, the FAA wrote Federal Aviation Regulation 101 (FAR 101). FAR 101 is the near space bible. Violating FAR 101 is a serious mistake, but I'm not saying this to scare you. Meeting the requirements of FAR 101 is easy, but you need to follow the requirements consistently. So be familiar with FAR 101 before launching a near space capsule. When everyone follows FAR 101 it maximizes the use of US airspace while limiting the risks their risks. While a federal agency wrote FAR 101, it is not difficult to understand with a little help. I devote the rest of this chapter to explaining the portions of FAR 101 applying to the amateur near space program. There is a current copy of FAR 101 at the end of this chapter. I recommend you tackle it once you are ready to launch your first mission.

Preliminaries
Early in the development of your near space program, you need to accomplish these tasks.

- Find acceptable launch sites
- Become familiar with FAR 101
- Locate a Flight Service Station (FSS)

Launch Sites
Identify launch sites as early as possible. Do not wait until a week before launch to find your near space port or potential launch sites. A good launch site is one located away from airports and other restricted airspaces. It's also clear of trees, power lines, and other tall obstacles.

Plan your launches so the balloon does not ascend or descend through class B, C, and D airspaces. Consult the sectional chart to determine the tops of these airspaces. As long as the balloon is above them, you can travel over these air spaces. Restricted air spaces are another type of air space to avoid, unless you receive permission from the air space owner. Consult the FSS and sectional chart for more information.

Purchase a sectional chart to locate restricted air spaces. Visit your local airport for the chart. You want an airport that caters to private aircraft so don't bother major airports that service airliner companies. Now that you have found the launch perfect site(s), locate them in relation to the nearest airport. Use the aeronautical map to determine your sites' ranges and azimuths from airports or VORs. Write this information down once you have it. You need to share this information with your FSS contact, as they like to locate sites in relationship to airports and VORs.

FAR 101

Now it is time for you to get familiar with FAR 101. Balloon launches are not a frequent occurrence, so there is a chance that the local FSS will not be familiar with FAR 101. Demonstrating a thorough understanding of FAR 101 makes the FSS feel more comfortable about your balloon launches. Section 1.1 explains the requirements of FAR 101.

The FSS and NOTAMs

To reduce the risks of launching a near space mission, file a Notice To Airman (NOTAM) before each launch. The local Flight Service Station is the organization to call to file the NOTAM; small airports can give you their phone number. A few days before launch, call and explain to the FSS that you're planning to launch a HIBAL (high altitude balloon) and would like to file a NOTAM. Pilots read NOTAMs before they fly, so they will become aware of the time and location of your launch. Here are two ways to locate a FSS near you.

Call the phone number (800) 992-7433. This should route you to the local weather briefing office, which can give you the phone number to the nearest FSS. Note that this phone number does not work with a cell phone, as you could go through any cell phone tower.

Stop at your local airport that caters to private pilots. They will most likely have the phone number listed, and if not, someone there can give you the phone number.

1.1. The Gory Details of FAR 101

FAR 101 governs the operation of kites, rockets, and balloons. It is the regulation you need to be familiar with if you are to operate a near space program. Be familiar with the balloon portion of FAR 101 before you file a NOTAM and launch your first near space mission. Focus on the fact that you are launching a weather balloon, just like the National Weather Service does every twelve hours. If asked, be sure to state that you do not need a wavier, as you meet the requirements of subpart A.

Unfortunately, since a bureaucratic organization developed FAR 101, it can be difficult to understand initially. In this chapter I explain FAR 101, and as best as I know, my interpretation is accurate. This chapter is not an excuse for not reading FAR 101 for your self. Reading it will not take much of your time. If you have earned a radio license, then you can read and understand FAR 101. When it comes to a near space exploration project, subpart A is the portion of this regulation that concerns us most. As long as you do not exceed the applicability (limitations) covered in subpart A, then subpart D does not apply to your near space exploration program.

1.1.1. Subpart A

Subpart A begins the regulation and is general in nature. It begins by stating the regulation's applicability, that is, what conditions it does and does not govern. Then FAR 101 states that these rules apply unless you get a wavier. It goes on to say that you cannot operate kites, balloons, or rockets in a restricted or prohibited area unless you get permission from the using or controlling agency. Finally, subpart A closes by saying that you cannot operate in a way that presents a hazard to others.

1.1.2. Subpart B

Subpart B covers moored balloons (balloons tied down to the ground) and kites. Therefore this subpart does not apply to us.

1.1.3. Subpart C

Subpart C applies to unmanned rockets, so it does not apply to us.

1.1.4. Subpart D

Subpart D ends the FAR by covering unmanned free balloons that exceed the limitations laid out in subpart A. In other words, it will not apply to your program if you keep the payload weight light. Subpart D begins by saying FAR 101 applies to unmanned free balloons. The second section lists limitations to the launching of unmanned free balloons. The third section of subpart D states the required equipment and markings on the balloon. Finally it finishes by stating the requirements for reporting balloon positions.

1.1.5. Meeting Subpart A

To meet this requirement your capsules must meet one of the following requirements when it comes to capsule weight.

a. The balloon payload cannot exceed more then four pounds in weight IF it has a surface density greater than three ounces per square inch. To calculate surface density, calculate the area of the smallest face of the module and divide by the capsule's weight.

b. If the surface density is less than 3 ounces per square inch AND the balloon payload consists of one package, then it cannot weigh more than six pounds.

c. If the balloon payload consists of more than one package, then the total weight of the packages cannot exceed 12 pounds AND the heaviest package cannot exceed six pounds in weight.

After meeting one of these weight requirements, your load line must allow the balloon to separate from its payload with an impact force of no more than 50 pounds.

As long as your near space stack meets one of the above weight requirements, and the balloon can separate from the rest of the stack with a less than 50 pounds of force, then you only need to meet requirements under 101. 3 (Waivers), 101.5 (Operations in Restricted Areas), and 101.7 (Hazardous Operations). Let us look at these three requirements in depth.

Section 101.3, says that if you want to carry more weight or use a stronger connection between payload and balloon, then you will need to get a wavier. Section 101.5 says you need permission to launch from restricted or prohibited areas (use an aeronautical chart). Finally section 101.7, says you cannot operate in such a way that the flight becomes a hazard for others.

So here's what the regulation requires, starting with the most restrictive requirement and going to the least restrictive requirement.

a. You cannot launch in such a way that it represents a hazard to people or property when they are not a part of the crew.

b. You cannot drop objects from a near space stack if they represent a hazard to uninvolved people or their property.

c. You cannot launch from restricted or prohibited areas without permission. I recommend staying away from airports, even though most are not located in restricted areas.

d. The load line and its attachment points cannot require more then fifty pounds of force to sever.

e. You cannot launch a near space capsule that has a surface density greater than three ounces per square inch unless the capsule weighs no more than four pounds.

f. If you launch a single near space capsule with a low surface density, then it cannot exceed six pounds in weight.

g. If you fly two or more modules in the stack, then their total weight cannot exceed twelve pounds. Also, no one module can exceed six pounds in weight.

The near space stack discussed in this book will meet these requirements by

a. Using a load line that breaks or separates from the balloon (or the balloon separates from itself) with a force of fifty pounds. Do not use rope or a wire.

b. The near space consists of two Styrofoam boxes. Their individual weights are no more than six pounds. This limits their total weight to twelve pounds. Each module has faces greater than 36 square inches (six inches on a side). This keeps module surface densities below three ounces per square inch when module weights are at the maximum six pounds of weight.

You do not need a wavier to launch with this design. In fact you do not need to file a NOTAM, but it is strongly encouraged. It is your responsibility not to launch from airports or other restricted or prohibited locations without permission. It is also your responsibility not to launch in a way or perform experiments that are a hazard to others.

What If You Exceed These Limitations?

DO NOT exceed the limitations as explained above for your first missions. Wait until you have a couple years of experience before expanding your program into this territory.

If you are operating a flight that exceeds the limitations explained above, then meet the following additional requirements.

First, you cannot launch in the following conditions

You cannot launch:
A. Within 2000 feet of the ground in Class B, C, D, or E airspace

B. When the clouds cover more than 50% of the sky
C. When horizontal visibilities are less than 5 miles
D. Where the first 1000 feet of the flight takes the nearcraft over towns and cities
E. Where the flight represents a hazard to nonparticipating people

Before you can launch the near space capsule, you must notify an ATC six to twenty-four hours before launch. Give ATC the following information

A. The balloon's identification
B. The time of balloon launch (be accurate to within 30 minutes)
C. The location of the launch site
D. The expected cruising altitude of the balloon[A]
E. The expected trajectory of the balloon to 60,000 feet, including the amount of time required reaching this altitude
F. The dimensions of the near space stack
G. The duration of the flight
H. The predicted landing site

- √ If you have to abort the launch, notify ATC immediately
- √ After the balloon is launched, notify ATC immediately

- √ Record the position of the balloon every two hours during the flight,
- √ Report these positions to the ATC if they ask for them

- √ One hour before you terminate the flight, you must notify an ATC of the following,

A. The location of the balloon (bearing and range to the nearest airport should work)
B. The altitude of the balloon
C. When the balloon is expected to drop below 60,000 feet
D. The expected descent path of the balloon
E. The expected time of landing
F. Call the ATC when the balloon has landed

Your stack must be equipped with the following devices

A. At least two cutdown devices that act independently of each other
B. At least two devices for terminating the balloon envelope (so that it doesn't get stuck up in air space)
C. The near space capsule must be equipped with a radar reflector

Note, there is no reason that A and B couldn't be the same devices. However, each device must be capable of bringing both the near space capsule and the balloon back down to the ground, without losing the location of either. When you use latex balloons you do not have to worry about devices for terminating the balloon envelope, since they will burst at altitude. This envelope termination rule applies to zero pressure balloons, which do not burst.

Now here are additional requirements that may, or may not, apply to your stack, depending on its design or time of flight.

A. If your near space capsule will be operated at night, then it must have strobes attached to it that are visible for at least 5 miles

B. If it has a long, trailing antenna greater then 50 feet long, then the antenna must be able to separate from the nearcraft with less than 50 pounds of force, or be marked with colored pendants that are visible for more then a mile. The pendants cannot be spaced more than 50 feet apart from each other
C. If the load line is more than 50 feet long, it must be marked with conspicuous pennants visible for at least a mile

Wrap Up

Let me state again, the rules outlined in the last section of this chapter do not apply if you fly near spacecraft as outlined in this book. Only when you launch heavy nearcraft, launch with ZPBs, or fly at night, do these last requirements apply.

2.0 2.0 The Current FAR 101

The Current FAR 101 is printed below. This document appears as shown on The Government Printing Office Access Website, at the URL given below:

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Home Page > Executive Branch > Code of Federal Regulations > Electronic Code of Federal Regulations

2.1.1. Electronic Code of Federal Regulations (e-CFR)

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Title 14: Aeronautics and Space

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PART 101—MOORED BALLOONS, KITES, UNMANNED ROCKETS AND UNMANNED FREE BALLOONS

Section Contents

Authority: 49 U.S.C. 106(g), 40103, 40113–40114, 45302, 44502, 44514, 44701–44702, 44721, 46308.

Subpart A—General

top

§ 101.1 Applicability.

top

(a) This part prescribes rules governing the operation in the United States, of the following:

(1) Except as provided for in §101.7, any balloon that is moored to the surface of the earth or an object thereon and that has a diameter of more than 6 feet or a gas capacity of more than 115 cubic feet.

(2) Except as provided for in §101.7, any kite that weighs more than 5 pounds and is intended to be flown at the end of a rope or cable.

(3) Any unmanned rocket except:

(i) Aerial firework displays; and,

(ii) Model rockets:

(*a*) Using not more than four ounces of propellant;

(*b*) Using a slow-burning propellant;

(*c*) Made of paper, wood, or breakable plastic, containing no substantial metal parts and weighing not more than 16 ounces, including the propellant; and

(*d*) Operated in a manner that does not create a hazard to persons, property, or other aircraft.

(4) Except as provided for in §101.7, any unmanned free balloon that—

(i) Carries a payload package that weighs more than four pounds and has a weight/size ratio of more than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface;

(ii) Carries a payload package that weighs more than six pounds;

(iii) Carries a payload, of two or more packages, that weighs more than 12 pounds; or

(iv) Uses a rope or other device for suspension of the payload that requires an impact force of more than 50 pounds to separate the suspended payload from the balloon.

(b) For the purposes of this part, a *gyroglider* attached to a vehicle on the surface of the earth is considered to be a kite.

[Doc. No. 1580, 28 FR 6721, June 29, 1963, as amended by Amdt. 101–1, 29 FR 46, Jan. 3, 1964; Amdt. 101–3, 35 FR 8213, May 26, 1970]

§ 101.3 Waivers.

top

No person may conduct operations that require a deviation from this part except under a certificate of waiver issued by the Administrator.

[Doc. No. 1580, 28 FR 6721, June 29, 1963]

§ 101.5 Operations in prohibited or restricted areas.

top

No person may operate a moored balloon, kite, unmanned rocket, or unmanned free balloon in a prohibited or restricted area unless he has permission from the using or controlling agency, as appropriate.

[Doc. No. 1457, 29 FR 46, Jan. 3, 1964]

§ 101.7 Hazardous operations.

top

(a) No person may operate any moored balloon, kite, unmanned rocket, or unmanned free balloon in a manner that creates a hazard to other persons, or their property.

(b) No person operating any moored balloon, kite, unmanned rocket, or unmanned free balloon may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 12800, 39 FR 22252, June 21, 1974]

Subpart B—Moored Balloons and Kites

top

Source: Docket No. 1580, 28 FR 6722, June 29, 1963, unless otherwise noted.

§ 101.11 Applicability.

top

This subpart applies to the operation of moored balloons and kites. However, a person operating a moored balloon or kite within a restricted area must comply only with §101.19 and with additional limitations imposed by the using or controlling agency, as appropriate.

§ 101.13 Operating limitations.

top

(a) Except as provided in paragraph (b) of this section, no person may operate a moored balloon or kite—

(1) Less than 500 feet from the base of any cloud;

(2) More than 500 feet above the surface of the earth;

(3) From an area where the ground visibility is less than three miles; or

(4) Within five miles of the boundary of any airport.

(b) Paragraph (a) of this section does not apply to the operation of a balloon or kite below the top of any structure and within 250 feet of it, if that shielded operation does not obscure any lighting on the structure.

§ 101.15 Notice requirements.

top

No person may operate an unshielded moored balloon or kite more than 150 feet above the surface of the earth unless, at least 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation:

(a) The names and addresses of the owners and operators.

(b) The size of the balloon or the size and weight of the kite.

(c) The location of the operation.

(d) The height above the surface of the earth at which the balloon or kite is to be operated.

(e) The date, time, and duration of the operation.

§ 101.17 Lighting and marking requirements.

top

(a) No person may operate a moored balloon or kite, between sunset and sunrise unless the balloon or kite, and its mooring lines, are lighted so as to give a visual warning equal to that required for obstructions to air navigation in the FAA publication “Obstruction Marking and Lighting”.

(b) No person may operate a moored balloon or kite between sunrise and sunset unless its mooring lines have colored pennants or streamers attached at not more than 50 foot intervals beginning at 150 feet above the surface of the earth and visible for at least one mile.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 1580, 28 FR 6722, June 29, 1963, as amended by Amdt. 101–4, 39 FR 22252, June 21, 1974]

§ 101.19 Rapid deflation device.

top

No person may operate a moored balloon unless it has a device that will automatically and rapidly deflate the balloon if it escapes from its moorings. If the device does not function properly, the operator shall immediately notify the nearest ATC facility of the location and time of the escape and the estimated flight path of the balloon.

Subpart C—Unmanned Rockets

top

§ 101.21 Applicability.

top

This subpart applies to the operation of unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply only with §101.23(g) and with additional limitations imposed by the using or controlling agency, as appropriate.

[Doc. No. 1580, 28 FR 6722, June 29, 1963]

§ 101.22 Special provisions for large model rockets.

top

Persons operating model rockets that use not more than 125 grams of propellant; that are made of paper, wood, or breakable plastic; that contain no substantial metal parts, and that weigh not more than 1,500 grams, including the propellant, need not comply with §101.23 (b), (c), (g), and (h), provided:

(a) That person complies with all provisions of §101.25; and

(b) The operation is not conducted within 5 miles of an airport runway or other landing area unless the information required in §101.25 is also provided to the manager of that airport.

[Amdt. 101–6, 59 FR 50393, Oct. 3, 1994]

§ 101.23 Operating limitations.

top

No person may operate an unmanned rocket—

(a) In a manner that creates a collision hazard with other aircraft;

(b) In controlled airspace;

(c) Within five miles of the boundary of any airport;

(d) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;

(e) At any altitude where the horizontal visibility is less than five miles;

(f) Into any cloud;

(g) Within 1,500 feet of any person or property that is not associated with the operations; or

(h) Between sunset and sunrise.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 1580, 28 FR 6722, June 29, 1963, as amended by Amdt. 101–4, 39 FR 22252, June 21, 1974]

§ 101.25   Notice requirements.

top

No person may operate an unmanned rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours prior to and no more than 48 hours prior to beginning the operation:

(a) The names and addresses of the operators; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;

(b) The estimated number of rockets to be operated;

(c) The estimated size and the estimated weight of each rocket; and

(d) The estimated highest altitude or flight level to which each rocket will be operated.

(e) The location of the operation.

(f) The date, time, and duration of the operation.

(g) Any other pertinent information requested by the ATC facility.

[Doc. No. 1580, 28 FR 6722, June 29, 1963, as amended by Amdt. 101–6, 59 FR 50393, Oct. 3, 1994]

Subpart D—Unmanned Free Balloons

top

Source: Docket No. 1457, 29 FR 47, Jan. 3, 1964, unless otherwise noted.

§ 101.31   Applicability.

top

This subpart applies to the operation of unmanned free balloons. However, a person operating an unmanned free balloon within a restricted area must comply only with §101.33 (d) and (e) and with any additional limitations that are imposed by the using or controlling agency, as appropriate.

§ 101.33   Operating limitations.

top

No person may operate an unmanned free balloon—

(a) Unless otherwise authorized by ATC, below 2,000 feet above the surface within the lateral boundaries of the surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport;

(b) At any altitude where there are clouds or obscuring phenomena of more than five-tenths coverage;

(c) At any altitude below 60,000 feet standard pressure altitude where the horizontal visibility is less than five miles;

(d) During the first 1,000 feet of ascent, over a congested area of a city, town, or settlement or an open-air assembly of persons not associated with the operation; or

(e) In such a manner that impact of the balloon, or part thereof including its payload, with the surface creates a hazard to persons or property not associated with the operation.

[Doc. No. 1457, 29 FR 47, Jan. 3, 1964, as amended by Amdt. 101–5, 56 FR 65662, Dec. 17, 1991]

§ 101.35 Equipment and marking requirements.

top

(a) No person may operate an unmanned free balloon unless—

(1) It is equipped with at least two payload cut-down systems or devices that operate independently of each other;

(2) At least two methods, systems, devices, or combinations thereof, that function independently of each other, are employed for terminating the flight of the balloon envelope; and

(3) The balloon envelope is equipped with a radar reflective device(s) or material that will present an echo to surface radar operating in the 200 MHz to 2700 MHz frequency range.

The operator shall activate the appropriate devices required by paragraphs (a) (1) and (2) of this section when weather conditions are less than those prescribed for operation under this subpart, or if a malfunction or any other reason makes the further operation hazardous to other air traffic or to persons and property on the surface.

(b) No person may operate an unmanned free balloon below 60,000 feet standard pressure altitude between sunset and sunrise (as corrected to the altitude of operation) unless the balloon and its attachments and payload, whether or not they become separated during the operation, are equipped with lights that are visible for at least 5 miles and have a flash frequency of at least 40, and not more than 100, cycles per minute.

(c) No person may operate an unmanned free balloon that is equipped with a trailing antenna that requires an impact force of more than 50 pounds to break it at any point, unless the antenna has colored pennants or streamers that are attached at not more than 50 foot intervals and that are visible for at least one mile.

(d) No person may operate between sunrise and sunset an unmanned free balloon that is equipped with a suspension device (other than a highly conspicuously colored open parachute) more than 50 feet along, unless the suspension device is colored in alternate bands of high conspicuity colors or has colored pennants or streamers attached which are visible for at least one mile.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 1457, 29 FR 47, Jan. 3, 1964, as amended by Amdt. 101–2, 32 FR 5254, Mar. 29, 1967; Amdt. 101–4, 39 FR 22252, June 21, 1974]

§ 101.37 Notice requirements.

top

(a) *Prelaunch notice:* Except as provided in paragraph (b) of this section, no person may operate an unmanned free balloon unless, within 6 to 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation:

(1) The balloon identification.

(2) The estimated date and time of launching, amended as necessary to remain within plus or minus 30 minutes.

(3) The location of the launching site.

(4) The cruising altitude.

(5) The forecast trajectory and estimated time to cruising altitude or 60,000 feet standard pressure altitude, whichever is lower.

(6) The length and diameter of the balloon, length of the suspension device, weight of the payload, and length of the trailing antenna.

(7) The duration of flight.

(8) The forecast time and location of impact with the surface of the earth.

(b) For solar or cosmic disturbance investigations involving a critical time element, the information in paragraph (a) of this section shall be given within 30 minutes to 24 hours before beginning the operation.

(c) *Cancellation notice:* If the operation is canceled, the person who intended to conduct the operation shall immediately notify the nearest FAA ATC facility.

(d) *Launch notice:* Each person operating an unmanned free balloon shall notify the nearest FAA or military ATC facility of the launch time immediately after the balloon is launched.

§ 101.39 Balloon position reports.

top

(a) Each person operating an unmanned free balloon shall:

(1) Unless ATC requires otherwise, monitor the course of the balloon and record its position at least every two hours; and

(2) Forward any balloon position reports requested by ATC.

(b) One hour before beginning descent, each person operating an unmanned free balloon shall forward to the nearest FAA ATC facility the following information regarding the balloon:

(1) The current geographical position.

(2) The altitude.

(3) The forecast time of penetration of 60,000 feet standard pressure altitude (if applicable).

(4) The forecast trajectory for the balance of the flight.

(5) The forecast time and location of impact with the surface of the earth.

(c) If a balloon position report is not recorded for any two-hour period of flight, the person operating an unmanned free balloon shall immediately notify the nearest FAA ATC facility. The notice shall include the last recorded position and any revision of the forecast trajectory. The nearest FAA ATC facility shall be notified immediately when tracking of the balloon is re-established.

(d) Each person operating an unmanned free balloon shall notify the nearest FAA ATC facility when the operation is ended.

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Good To Know - Sky Color

Everyone knows the sky is blue, but many people don't know why it's blue. As you know, the visible spectrum, the colors of light emitted by the Sun, starts at violet at one end, goes to blue, green, yellow, orange, and finally ends at red on the other end. Each color of the spectrum consists of particles of light, or photons. Photons of light can also be thought of as waves, similar to the waves in water (except waves of light don't require a medium to carry them like waves in water need water to carry them). Waves have many characteristics, one of them being their wavelength. Wavelength is a measure of the distance between similar portions of the wave, for instance, from one peak to the next peak. The difference between the colors in the spectrum is the wavelength of the photon carrying them. Blue light consists of photons with a wavelength smaller than the wavelength of red light photons. Photons that carry blue light have a wavelength of about 450 nanometers (billionths of a meter) whereas red light photons have a wavelength of about 700 nanometers (nm). How photons react with particles of matter depends partially on the size of the particles in relationship to the wavelength of the photons. For the most part, photons of light do not interact with particles that are smaller than their wavelength. As it happens, the molecules in our atmosphere (molecules from the air and the dust and droplets of water suspended in the air) have an average size close to the wavelength of a photon of blue light. Photons of red light, with wavelengths larger than the molecules in our atmosphere, do not interact as strongly with air molecules. Because of their smaller wavelengths, photons of blue light interact about five times more strongly with atmospheric molecules than do the photons of red light. Because air molecules more greatly effects visible light closer to the blue end of the spectrum than to the red end of the spectrum, most of the red and lesser amounts of orange and yellow light travel straight from the sun to our eye. Photons of blue light are randomly scattered out of this beam of red light and eventually reach our eyes from all directions, even from the direction of the ground. If there's enough air below your eyes, then the ground takes on a blue tint. This preferential scattering of light makes the sun more yellow in color and the sky blue. When looking away from the sun in the sky, you still see sunlight, but only its bluer wavelengths. As the sun approaches the horizon sunlight travels through more atmosphere. This extra atmosphere scatters more of the longer wavelengths out of the Sun's light, eventually leaving only red light to reach our eyes, hence red sunsets. This scattering based on wavelength was first explained in 1871 by the physicist, Lord Rayleigh and is called Rayleigh Scattering.

An ascending near spacecraft experiences a reduction in the air pressure. Less air pressure means there are fewer air molecules to scatter the Sun's light. As a result, the sky begins to take on a darker, purpler color (less blue mixed in with the black of space). Once in near space, the amount of air molecules in the sky is far too low to effectively scatter the blue photons emitted from the sun. This gives the sky an inky black appearance (remember that black is not a color but is really an absence of light). Instead of being scattered out of the Sun's light, more blue light reaches us directly from the Sun. The sun appears whiter in color (white being a combination of all colors) than it does on the ground. Not only is the Sun whiter, it's also brighter because there's also less air to absorb sunlight. One consequence is that the sunlight in near space also contains more dangerous UV radiation. Once in near space, there is much more atmosphere below the near spacecraft than there is atmosphere above it. With greater amount of atmosphere below, there is more scattering of blue light below. This gives the ground a blue tint.

Photograph of Horizon in Near Space

The Ground Photographed from Near Space

Encyclopedia Of Physics, second edition, Rita G. Lerner and George L. Trigg

Blue Sky Demonstration
You may want to give this demonstration when giving near space presentations to groups. I first saw this demonstration presented at an astronomy conference in Kansas.

Materials

- An overhead projector
- A small aquarium[B]
- A large plastic stirring spoon
- A small measuring cup
- A bottle of pine oil cleaner

Preparation

√ Set up the projector where it can shine on a wall or screen that everyone can see
√ Fill the aquarium with plain water
√ Set the aquarium on the projector
√ Set aside a small amount of pine oil (do not add it to the aquarium water, yet) and the spoon

Explanation

Explain to your audience that light is made of particles and waves. But for this demonstration, the wave aspect of light is more important. One characteristic of all waves is the distance between their peaks. This characteristic is called wavelength.

√ This is basic science stuff but you may want to draw a diagram at this point.

The only difference between the waves making up blue light from say red light is the size of their wavelengths. Red light has a wavelength about twice as long as blue light. The wavelength of red light is about 700 nanometers and the wavelength of blue light is about 400 nanometers. A nanometer is one billionth of a meter, or one millionth of a millimeter. One millimeter compared to one kilometer (about 3000 feet) is the same ratio as one nanometer compared to one millimeter. It takes over 63,000 wavelengths of blue light to span one inch.

If the obstacle in the air is smaller than the wavelength of a photon of light, then the light beam does not notice it. The light continues in its original direction as if the obstacle was not there. Waves of light behave a little funny when they approach obstacles about the size of their wavelength. If an obstacle is about the same size as the wavelength of a photon of light, then the light crashes into the obstacle and bounce off in a random direction (assuming the light isn't absorbed first). It so turns out that air molecules have sizes in between the wavelengths of red and blue light. As a result, red light hardly notices molecules in the air while blue light cannot help but notice the same molecules in the air.

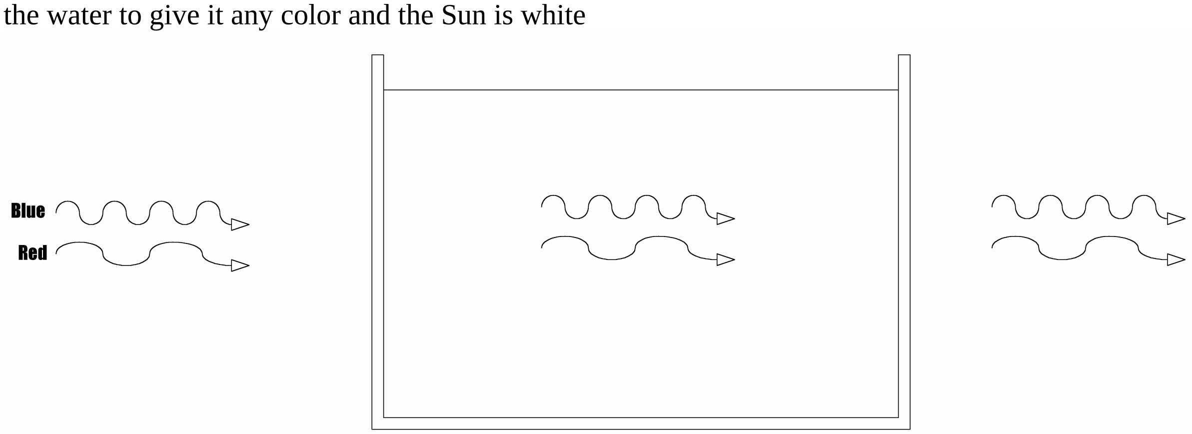
Imagine how an elephant would respond to a gnat in its way and how an elephant responds when another elephant is in its way.

Demonstration

√ Turn on the projector

Explain that the aquarium of water represents the atmosphere and the projector represents light from the Sun.

Currently this is an atmosphere with no particles of dust, droplets of water, or tiny variations in density. At this time, with nothing to scatter light in the atmosphere, no sunlight is being scattered in the water to give it any color and the Sun is white

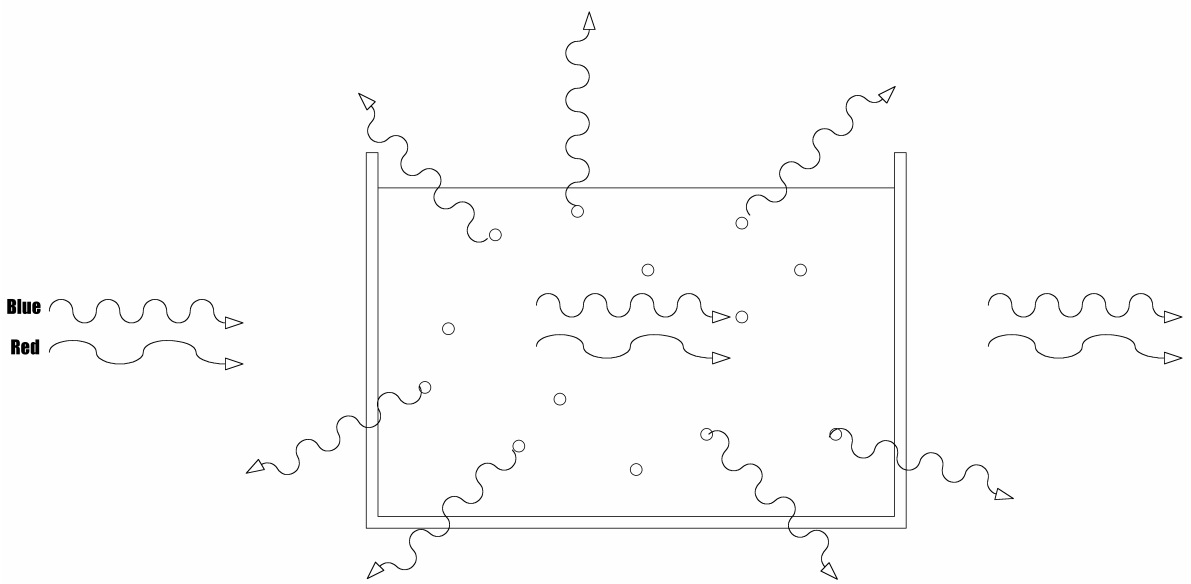


***Clear Water** – Both blue and red wavelength pass through*

When dissolved in water, pine oil forms tiny little droplets. The droplets are the proper size to strongly effect blue light, but not red light. The droplets of pine oil you are about to add represent molecules in the atmosphere.

- √ Pour a capful of pine oil into the water and stir
- √ Note: It doesn't take very much pine oil, so add too little to begin with and add more if necessary.

(The water in the aquarium takes on a blue tint while the projected light on the wall becomes reddish). 1



Water with Particles *– The blue wavelengths collide with the particles and are scattered*

- √ Point out that now with scattering molecules in the air, the Sun has taken on a redder appearance and the sky a bluer appearance.

As the Sun sets, its light passes through more molecules in the atmosphere. In doing so, the red light begins to be affected, and starts scattering out of the beam of sunlight.

- √ Add more pine oil and stir
- √ Note: The more pine oil added, the redder and dimmer the projected light on the wall.

Near Space Humor – Comix

Job Hazards – *Recovery crewmember given ample motivation to hustle; neglects site documentation in favor of saving his own skin.*

[A] This requirement indicates the FAA expects you are flying zero pressure balloons. This requirement doesn't make sense for latex balloons, and therefore may not be applicable.

[B] Get an aquarium that fits on an overhead projector. It is not important if it is a snug fit, only that you can fit the aquarium on the overhead.