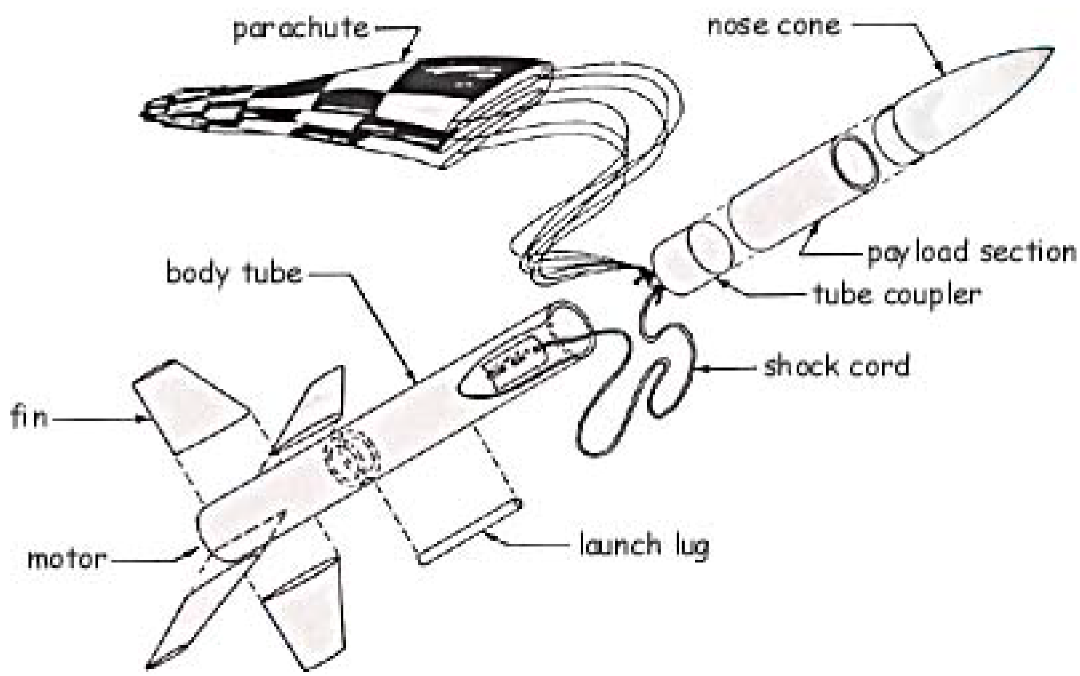
Introduction to model rocketry

Model rocketry was developed during the "space race" era as an alternative to the amateur rocket activity. Model rockets are constructed of materials such as cardboard, plastic, fiberglass and balsa wood -- and are fueled by single-use rocket motors manufactured by professional concerns. These rockets may be flown over and over simply by replacing the used motor with a fresh one. They typically contain a parachute, streamer, or other recovery device that allows them to land gently for later reflight. A model rocket will also have a nosecone and some type of motor retention devise. Model rockets can be as large as the motors that can lift them, with the largest commercial motor having a total thrust of 19525 Newtons. The two rocket motors that were used in this engineering design had a total thrust of 120 Newtons in the booster and 55 Newtons in the sustainer.



A simple diagram of a typical model rocket.

The following sections will detail how each piece of the rocket was designed and constructed and why it was constructed in that manner. Diagrams of the construction will appear in with the text to make the descriptions more understandable.

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Fin Can

The fin can of the rocket had to do a number of things. First it had to support the thrust of the rocket motor. Second it had to have fins designed to keep the rocket stable, had to be strong enough to stay attached to the rocket during flight approaching Mach 1, and had to have a low drag profile. The fin can would also require a ducting system, that has never been used before, to duct the ejection charge of the rocket out of the rocket body so not to blow the rocket apart while still in flight. All of this had to be achieved while keeping strict height and mass requirements.

The fins themselves were constructed from 1/16th inch fiberglass. Balsa wood was not an option because this was a high-speed flight. The fin shape was a clip delta fin planform. These fins are large enough to stabilize all rockets adequately if certain design formulas are adhered to. The clipped delta fin design also has little drag. ”The two best low-drag fin planforms for model rockets are the clipped delta and the elliptical. I’m personally partial to the clipped delta and have designed many high performance, record setting model rockets using this planform.”(G.Harry Stine.)

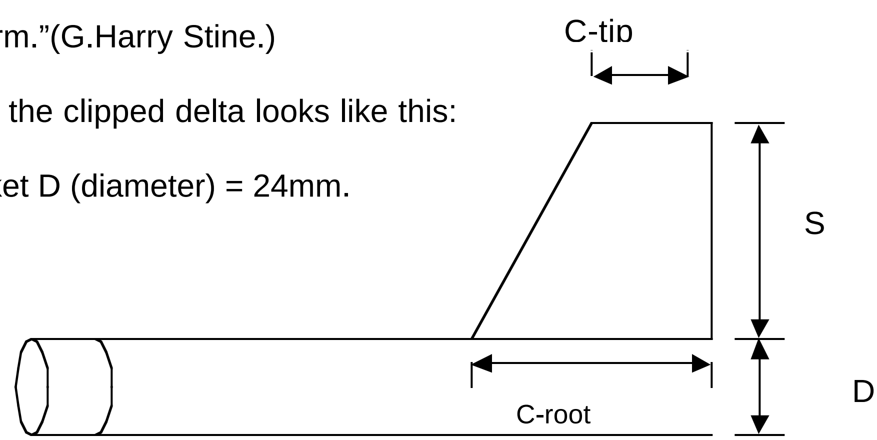
The basic plan for the clipped delta looks like this:

Note: For this rocket D (diameter) = 24mm.

C-root = 2D

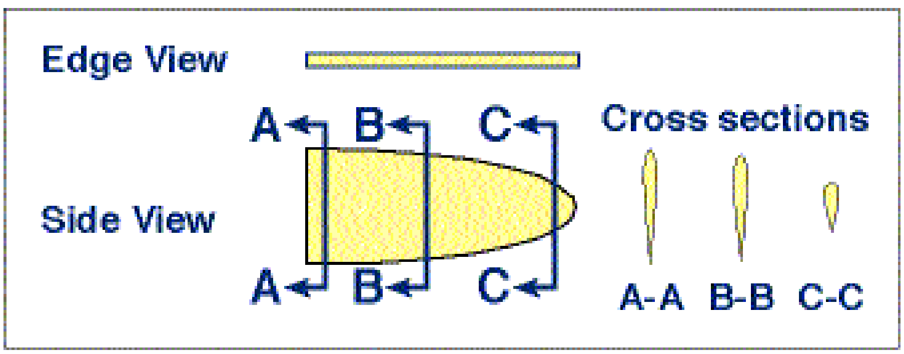
C-tip = D

S = D

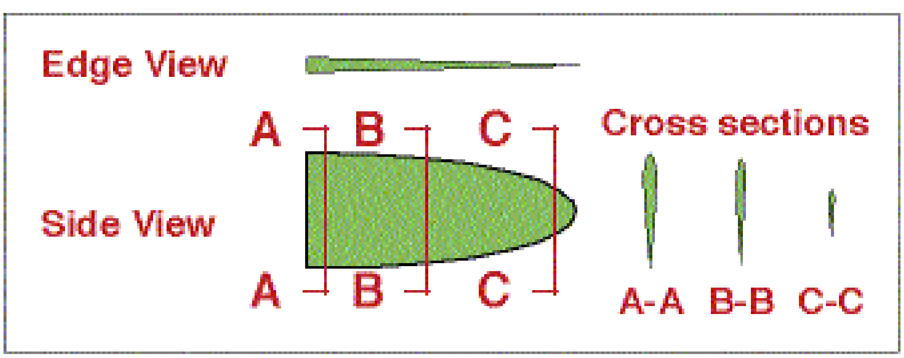


Now that the basic shape of the fin was designed, the fin shape would have to be modified to reduce drag further. To reduce drag the fins would be sanded to have a symmetrical airfoil. Then the fines would be sanded width wise to reduce drag further by making the c-tip much thinner than the c-root. This reduces drag because the most efficient part of the fin is at the tips; where the airflow is nice and smooth because it is outside the turbulence caused by air flowing over the nose of the rocket. The thinner tips reduce the profile drag and increases the efficacy of the fins(see diagram).

A cross section of properly sanded fins:



Typical Modeler's Fin

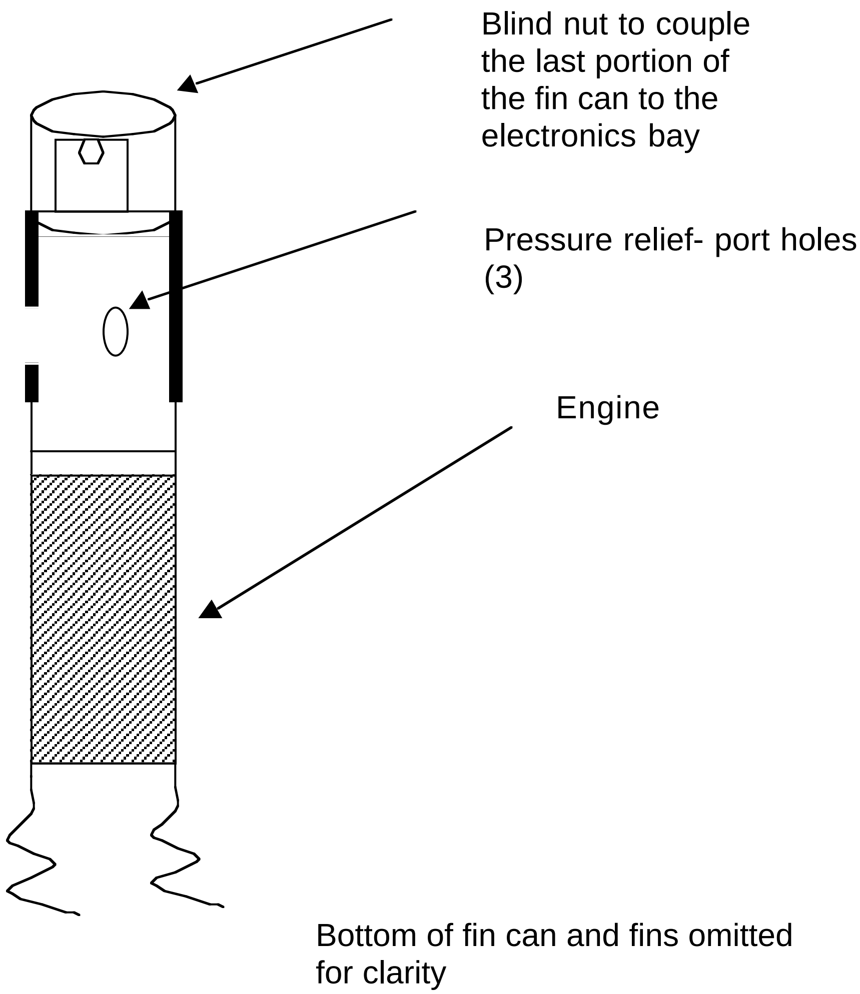


Expert Modeler's Fin

The body tube of the fin can was constructed the same way as all other tubes. That was a standard cardboard 24mm motor tube and a layer of .7 oz fiber glass around the tube for extra strength. This strength was needed because the original tubes were not designed to have as much stress as the flight would put on it. The fiberglass added much more strength will little additional weight.

The ducting system in the rocket would serve to purposes. First it would duct the rocket motor ejection gasses out side of the tube, and second it would serve as a bulkhead for the motor to put its thrust on. The ducting system was needed because all commercial motors have an “ejection charge” that will expel hot gasses through the forward end of the motor. The ejection charge would usually pressurize the body tube to deploy the parachute, but since the longest available delay for the F-32 rocket motor was a few seconds shorter than the expected apogee of the rocket, the ejection charge would hinder the rockets performance by deploying the parachute while the rocket was still going up. For this reason the ducting system would have to release the pressure of the ejection charge so the rocket can keep going up past the ejection charge. The real ejection charge will be provided by the altimeter, that will ignite an ejection charge that I designed at the top of the rocket to deploy the parachute at apogee. The ducting system consists of a heavily reinforced bulkhead with three, evenly spaced holes that give the ejection charge’s hot gasses somewhere to go. The bulkhead must be heavily reinforced because it will have to stay intact despite the large pressure that the engine ejection charge will create and send thru the ducting holes.

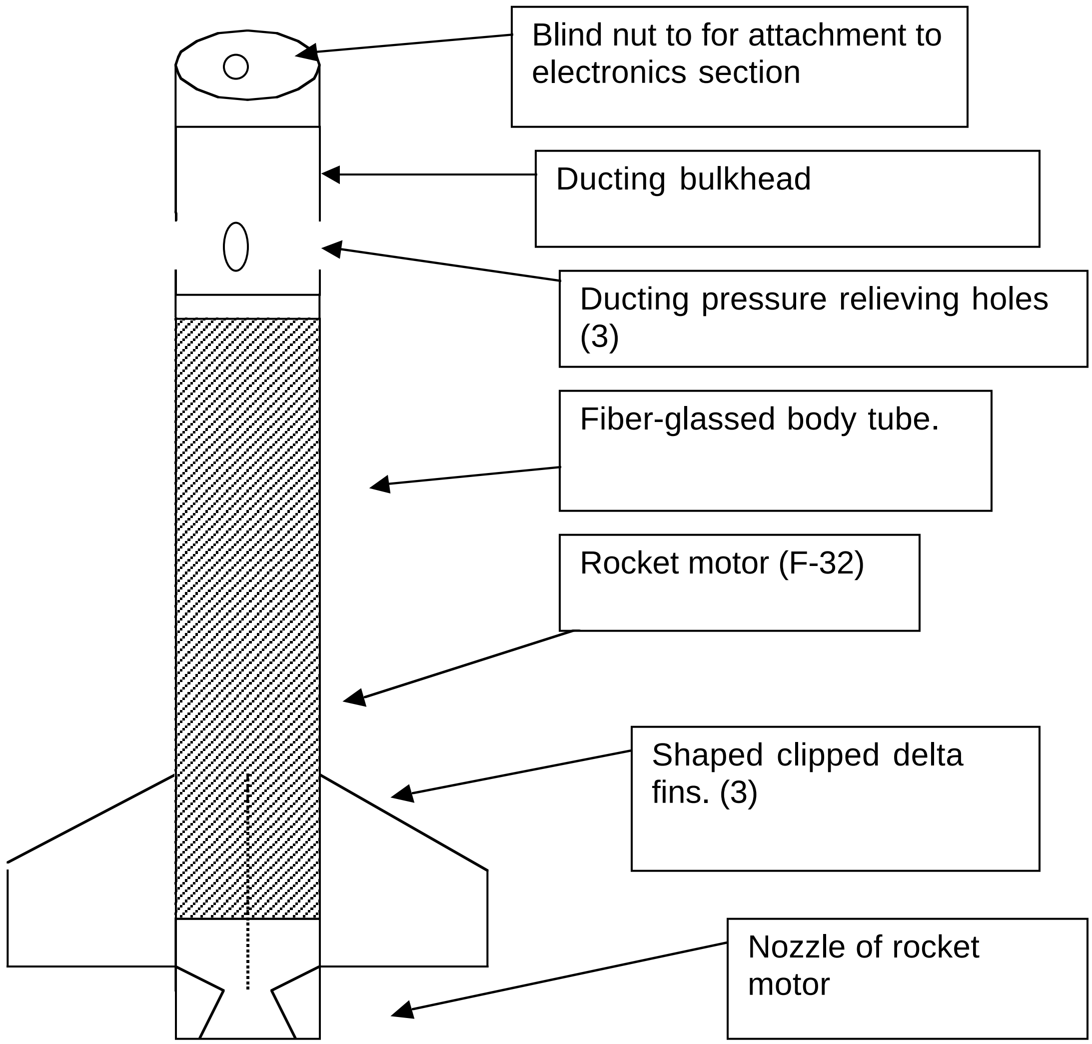
A cut away diagram of the ducting system:



The top end of the fin can needs to mechanically connect the fin can with the second section of the rocket, the electronics section. This connection point was a threaded blind nut that was mounted right after the ducting system. A screw from the electronics section would connect the two pieces. The connection point was built strong because it would take the load from all other sections of the rocket.

The fins on the fin can had to be mounted securely so that they would not rip off when approaching speeds of Mach 1. For this, thin slots in the body tube were cut so that the slots did not go through the tube, but were deep enough to give the fins more surface area to adhere to. The fins were secured using a heat resistant epoxy, since the motor, which was just millimeters away from the fins, created significant heat.

The completed fin can- Cross section view:



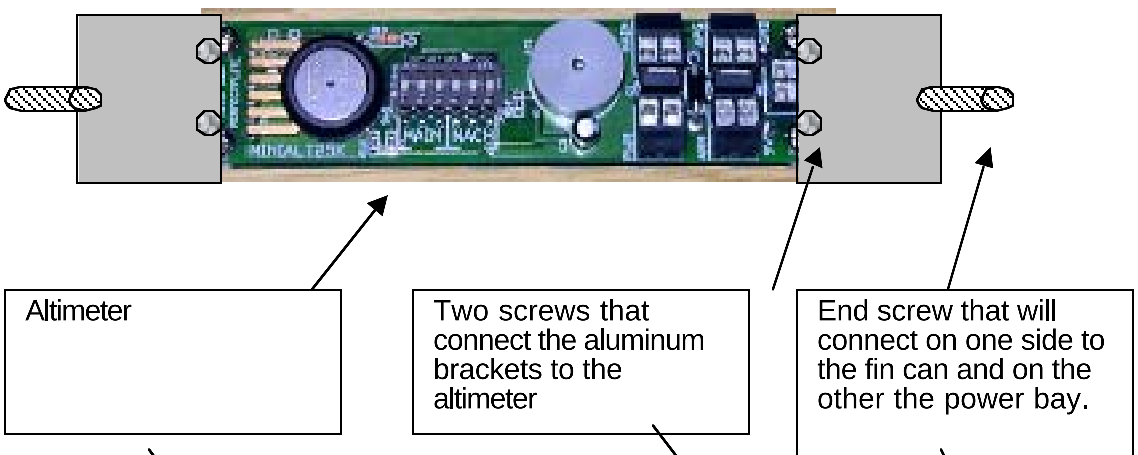
Electronics Bay

The electronics bay housed the most important and delicate part of the rocket. This was the barometric altimeter. The altimeter is a commercially available altimeter and was selected primarily because it was the only altimeter that was small enough to fit into the 24mm body tube. The altimeter will measure the barometric pressure changes during the flight of the rocket. By the pressure increase and decrease, the altimeter can determine the maximum height of the rocket. It can also tell if the rocket is still ascending or descending and will record the maximum altitude. It is programmed so that when it senses apogee-, when the rocket is no longer ascending, to switch relatively high amperage current from the battery. This current will ignite an electric match that will in turn ignite a small ejection charge of black powder. The black powder will pressurize the rocket's recovery section so that the nosecone comes off and the parachute along with the tracking powder is deployed.

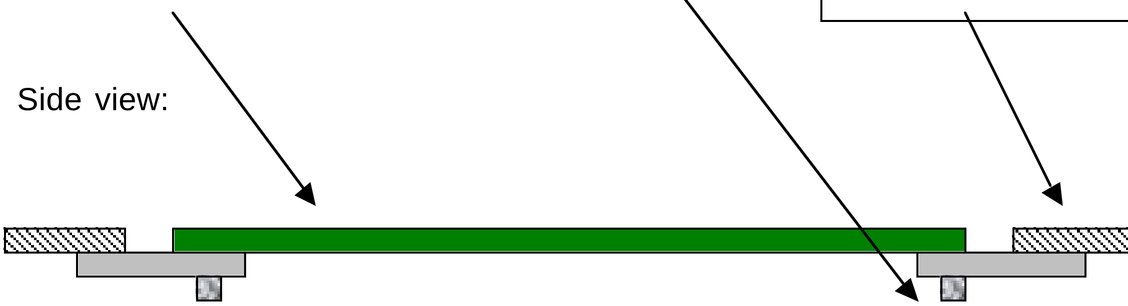
The altimeter bay itself was fairly simple, it used the altimeter's relatively strong fiberglass circuit board as the main structural component. This method is the simplest and weighs the least. The cardboard and fiberglass tube around the altimeter is not structural during flight, and is only there to protect the altimeter on landing and to maintain an aerodynamic shape. The altimeter on either side has two mounting plates that have 6/32" screw affixed to each side. These screws would attach to the fin can blind nut at one end and the power bays at the other end. The brackets themselves are constructed of aluminum.

The tube surrounding the altimeter is a plain fiberglass tube, with nothing attached to it. The only modification to the tube it that there is a 1/16" hole drilled though it for the altimeter to get proper barometric readings during flight.

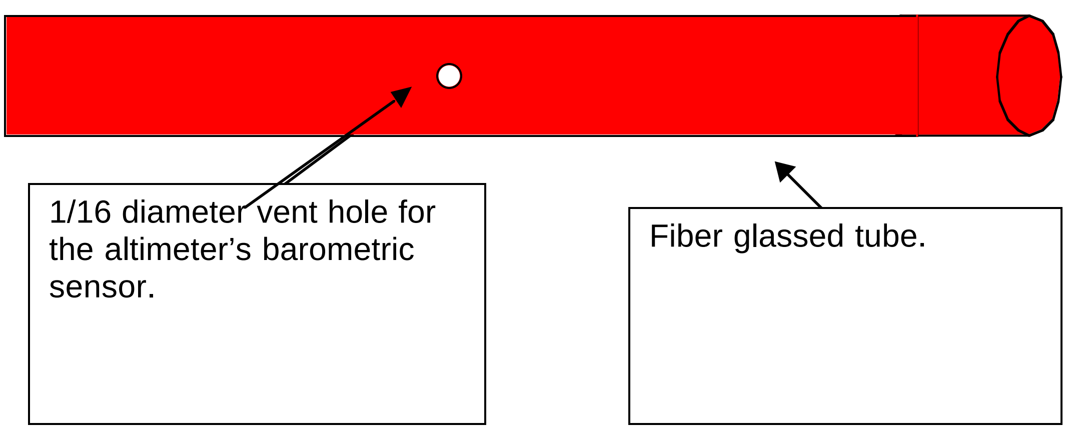
The altimeter with the mounted connecting brackets:



Side view:



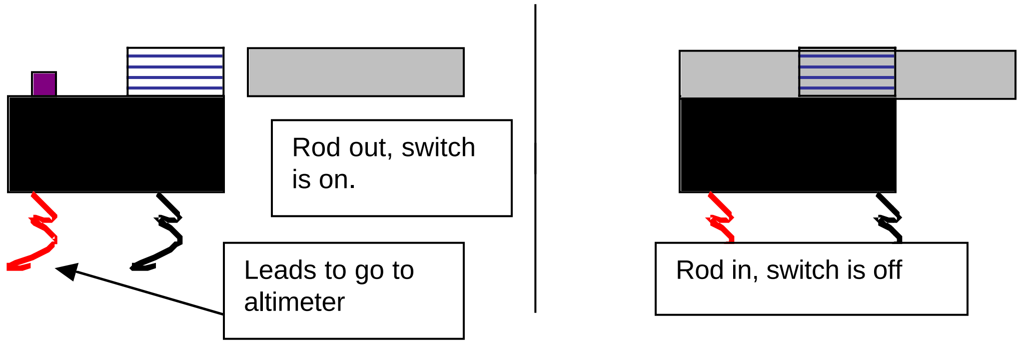
Electronics bay cover:



Power Bay

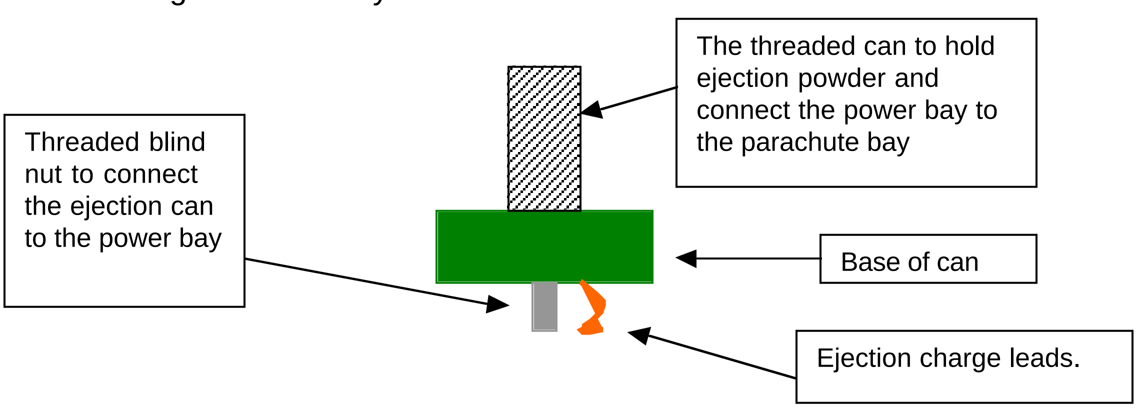
The Power Bay houses the battery for the altimeter and both arming and power switches for the altimeter. The Bay also contained a reload able ejection canister for the ejection charge. The ejection canister also served as a connection point to the parachute bay. The Battery is a heavy-duty 9v battery with a capacity of 250 mAh. A typical commercial battery could not be used because it was too large to fit inside the rocket's body tube! The leads for the battery were spot welded to the battery by a commercial battery store. During our first launch attempt , one of the leads came off and the launch had to be scrubbed. The leads were reinforced with non-conductive tape to make sure the leads would not detach. The battery had its leads pass through the bay to the threaded bulkhead that connects to the altimeter's connection brackets.

Two switches are needed to operate the altimeter. One is used to turn the altimeter on, and the other is used to arm the altimeter. The switches are lever switches that are modified so have no external parts outside of the rocket body. It was designed this way to reduce drag on the rocket. The lever switch has a small button on it that depresses, when the button is up, the switch is on. A 1/8" diameter tube was epoxied to the switch so that a 1/8" rod could pass though the switch. So when the rod is through the tube, the switch is off, and when the rod is taken out of the tube, the switch is on.



The two switches are mounted horizontally(on its side) to prevent the buttons on the switches from pressing in during the high g-forces on the rocket during flight and recovery. Like the battery, the switches leads will run though the power bay, and through the threaded bulkhead so that it can be connected to the altimeter's ports.

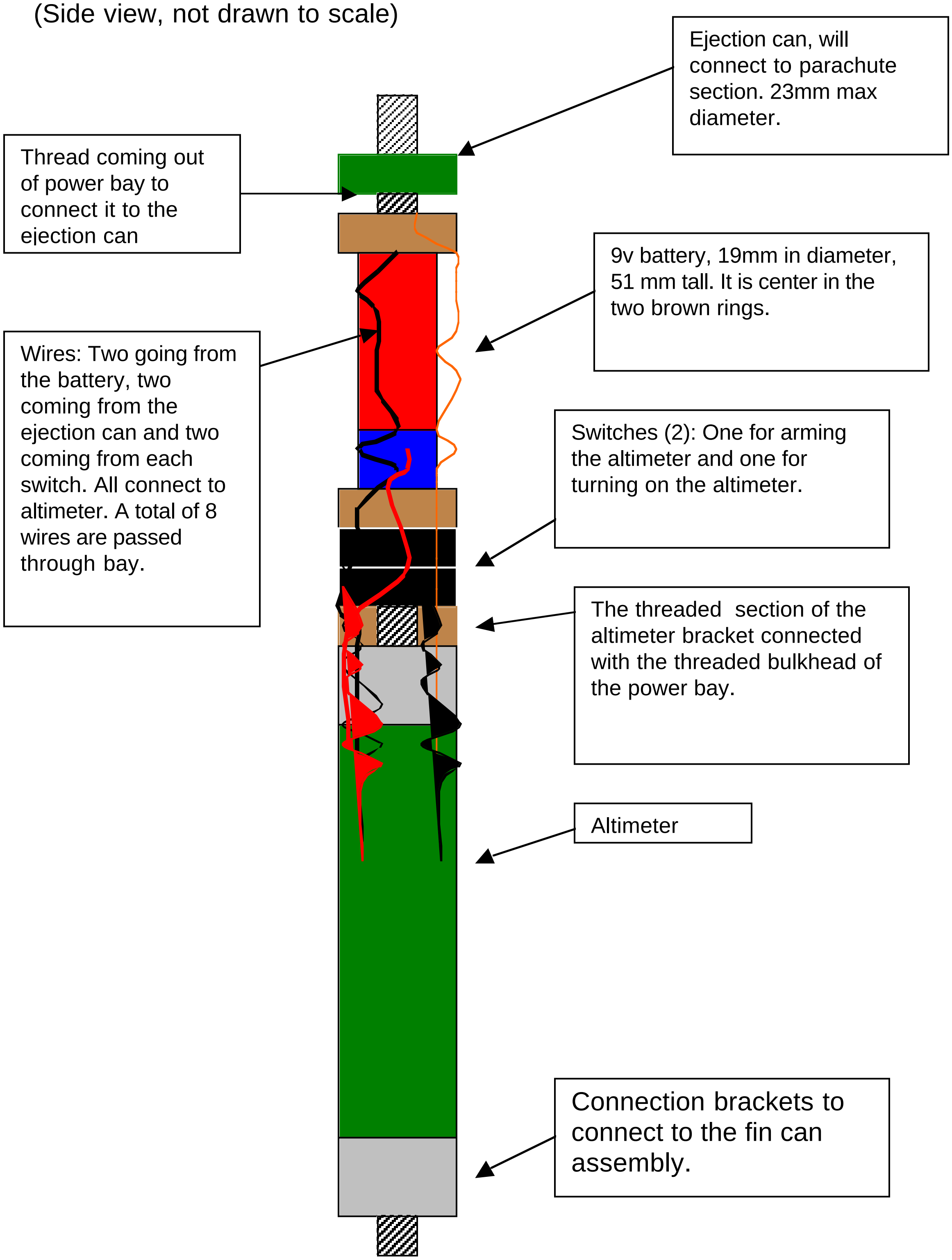
The ejection can is threaded on both ends, on end to attach to the 8/32" rod at the top of the power bay and the can itself is threaded. This will attach to the threaded bulkhead in the parachute bay. The ejection con is threaded on both sides so it can be removed after flight for cleaning, or if the igniter does not have good continuity.



The igniter leads will also pass through the entire power bay and through the threaded coupler.

The completed power bay, coupled with the electronics bay will look like this:

(Side view, not drawn to scale)



Parachute/Recovery Bay

The Recovery Bay houses the shock cord, parachute, and tracking powder. Its body is constructed from fiber glassed 24mm cardboard tubes, as the rest of the rocket. The noses cone is hollow, to allow for some of the parachute to be packed inside the nosecone. This is the last section of rocket, so it only has one connection point which connects to the power bay by the ejection canister and a threaded bulkhead inside the recovery bay.

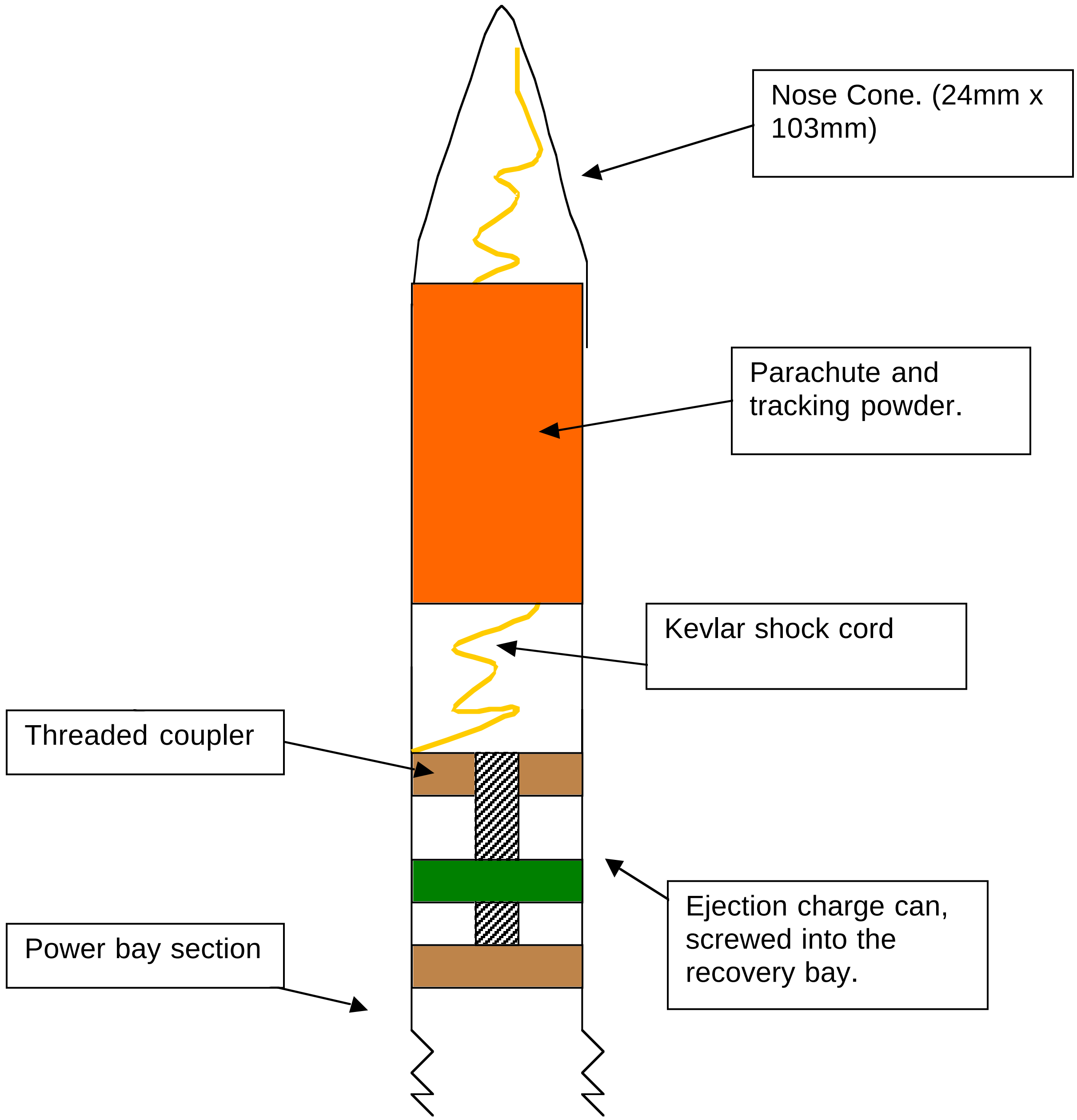
The parachute for this project does not look like a conventional parachute. The type of parachute that is used is call an “x-form” parachute. The x-form parachute looks exactly as it sounds, with equal crossing panels that forms and x. This type of parachute was picked because is will make the rocket drift less compared to a typical round parachute. The parachute is 9” in length which will provide the nearly 9 oz rocket a quick, but safe descent. The rocket will descend at approximately 35 feet per second. The descent rate should be fairly high because the faster the rocket descends, the less it will drift on its parachute. Even with the high descent rate, the drift in 15 mile per hour winds is 4000 feet. When the rocket launched the wind varied from approximately 9 miles per hour to 20 miles per hour, using the Beaufort wind strength scale. That means that the rocket drifted anywhere from 2,500 feet to 5,200 feet.

The tracking powder was florescent red, orange and white chalk. While only 2 tablespoons of chalk were used, the chalk when ejected from the rocket at a high velocity will produce a large cloud. This cloud will aide tracking of the rocket.

The nose cone's shape was picked based on the rule of nose cone size stated in G. Harry Stine's *Hand Book of Model Rocketry*. The book states the optimum length to width ratio of a parabolic nosecone was 4:1. Since the rocket was 24mm in diameter, the optimum length would be 96mm. The nose con that was used was 103 mm, just 7mm larger. The increase in drag because of the extra 7mm is minimal, but if the nosecone was 7mm too short, it would be much larger. The noses cone was a point for the shock cord attachment, The1/8" Kevlar cord was about 4 feet long and would cushion the rockets recoil after the rocket came out. The Kevlar shock cord was attached with epoxy in the top of the hollow nose cone.

The threaded bulkhead is a simple bulkhead that has a hole for the threaded ejection can to screw into. The threaded bulkhead also is used for an attachment point for the rockets Kevlar shock cord.

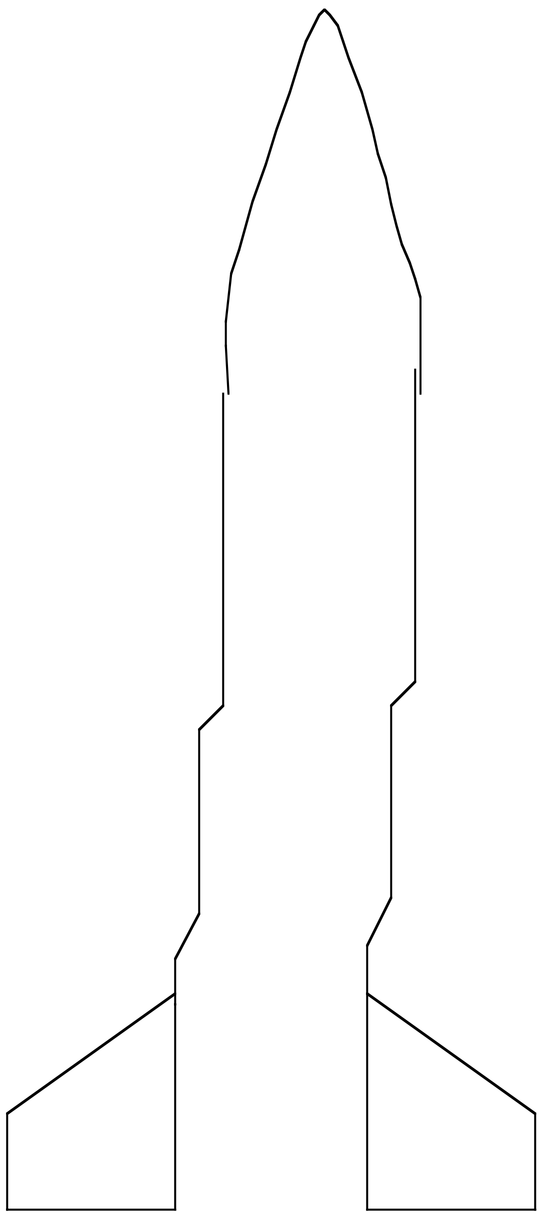
Recovery bay (Not drawn to scale)



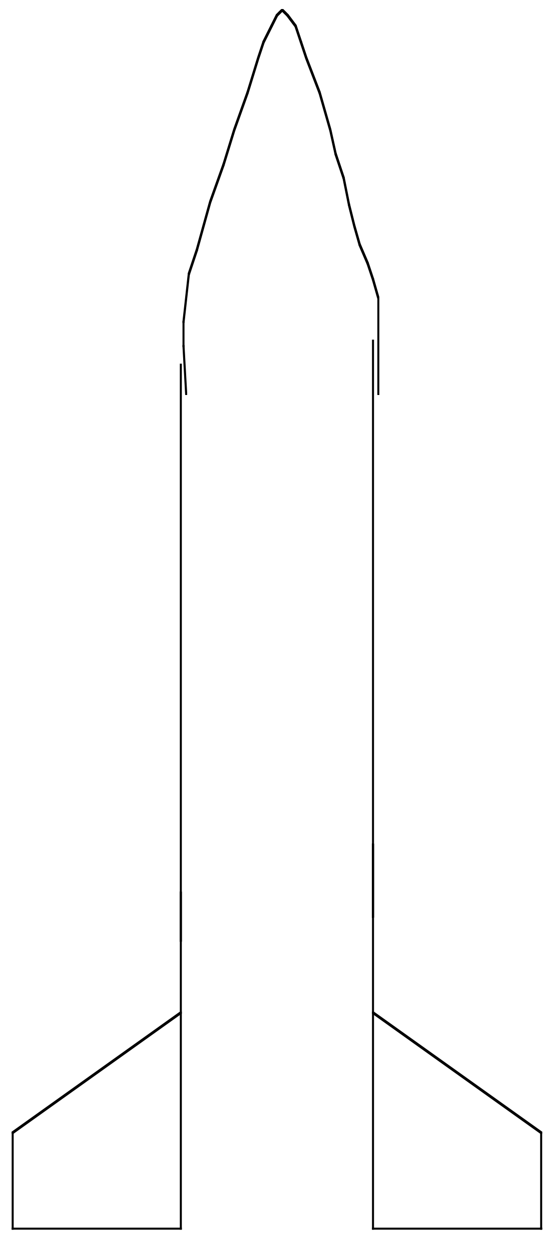
Body shroud

Since all of the pieces of the rocket were screwed together, and the couplers were not very large on the rocket, the assembled rocket has a slight canting from each rocket section. Even thought it is barely noticeable to the eye, this canting could create quite a lot of drag. The solution to this was to create a shroud the slipped over the entire rocket, from the fins to the top of the recovery bay. The shroud was made from a single wrap of .07 oz fiberglass. The mandrel that the shroud was built on was a standard 24mm tube, but with several layers of wax paper rapped around the shroud to make its diameter the correct size. The finial shroud was paper-thin and weighed only 20 grams.

Without the body shroud:
(degree of canting
highly exaggerated)



With the body shroud:



The Flight

The closest range to launch to rocket was in Whitakers, North Carolina. Given that the rocket was simulated to fly above 5000 feet it required a launch site with an FAA clearance to at least 6000 feet. Our local Pittsburgh Tripoli Rocket Club site near Charleroi, PA only has a clearance to 5000 feet but only has about 200 acres of recovery area. The nearest sites with standing FAA waivers are at the Maryland Eastern Shore and at Whitakers. Since the recovery field at Whitakers is over 2000 acres, of relatively flat cotton fields with cow pastures and few trees, we decided to attempt our launch there.

After assembling the rocket, connecting all of the electronics, and installing the body shroud, the rocket was taken out to the pad. The igniter was put in the motor and that igniter was armed. The altimeter was armed by turning on both switches in the power bay. The audio beeping pattern from the altimeter showed that it was functioning perfectly and that the igniter in the ejection charge from the power bay was armed.

After a traditional countdown the range control officer armed and switched on the launch pad power. The rocket took off quite quickly and headed on a thin trail of smoke from the rocket exhaust. The motor burned for approximately 2.5 seconds with an average of 32 Newtons/second of thrust. Approximately 17 seconds after ignition and verified by the video tape, several experienced high-power NC Tripoli members said that they saw a the tracking cloud, which meant the altimeter had detected apogee close to the simulation prediction and had fired the ejection charge in the recovery bay to deploy the parachute.

After observing the cloud of chalk, no one was able to see the rocket descent. Unfortunately while the weather was quite good, the launch conditions for a high altitude rocket with parachute deployment at 5000 feet were less than ideal. Measured on the ground, the wind varied from approximately 9 miles per hour to 20 miles per hour, using the Beaufort wind strength scale. As a result of this the rocket may have drifted anywhere from 2500 to 5200 feet in the wind maintaining an altitude that made it difficult to visually track once the initial sighting of the chalk cloud was lost. An aerial photograph from the Internet of launch site and landing zone show the launch site (RED dot) and the general wind direction, blue line. The scale on the aerial photographic is One Inch = 1000 feet. The bright orange parachute and red rocket body should have been quite visible in the cotton fields, but even with nearly 4 hours of searching with help from the North Carolina Tripoli members, I was unable to recover the rocket.

The rocket on its way to a projected 5000’ apogee.

Conclusion

In spite of this not recovering the project, I am confident that my rocket worked as designed. It is clear that there was no structural failure within visual range and that the altimeter was working at apogee to fire the ejection charge. I learned a lot about design and construction based upon aerodynamic principles and I'm sure that I'll make another attempt in the near future under better wind conditions. I consider this project a successes as I successfully built a prototype of a highly efficient design that never has been made before. The flight of the prototype was successful in all parts but the recovery once it landed, which really wasn't and objective of the rocket's design.

Acknowledgements

I would like to thank many people, without their help this project could not have been accomplished. I would like to thank Allen Whitmore, the prefect of the Tripoli rocket club in Whitakers, NC for having such a spectacular launch facility. Everyone who searched for the rocket after the flight also deserves thanks. I would lastly like to thank my parents who financially and emotionally helped me though the project.

Resources

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