Level 3 Certification Project
Dave Lang – NAR 90891

Project Name: "SLUGGO"

Advisors: Howie Druckerman L3
Robert DeHate (L3CC)

Last Modified 11/14/12

I) <u>Introduction</u>

For my level 3 project, I chose to construct a modified version of Performance Rocketry's Gizmo XL kit. This is an 8" diameter, 3-fin all fiberglass rocket measuring 54.4" in length. Estimated empty weight will be 23 lbs with estimated launch weight of 33 lbs.

Planned certification motor: 75mm CTI M2250 C-star.
Projected Max. Alt: 7060 ft AGL
Drogue deployment: At apogee
Main deployment: 700 ft. AGL
Backup main deployment 500 ft. AGL

The plan is to launch the rocket to apogee at which time the nosecone will separate from the sustainer deploying a drogue chute. The purpose of using a drogue is to orient the nosecone higher than the sustainer during freefall to prevent the two from colliding and to set up for a tangle-free main chute deployment. The main chute will be deployed at a lower, predetermined altitude above ground to minimize drift and a long trek to the recovery area. Redundant altimeters and ejection charges will be utilized for both apogee and main events. A GPS tracking system will be installed which continuously transmits the lat-long co-ordinates to a handheld receiver allowing the rocket to be recovered should it land out of visual range. Two onboard, rearward facing high definition video cameras will record the flight.

I painted the rocket using DuPont Nason 2-stage catalyzed polyurethane paint. This began with 2 coats of Nason Selectprime 421-19 gray urethane primer. The Green metallic pearl color consisted of 3 coats of DuPont Nason Ful-Base polyurethane followed by 2 coats of 496-SelectClear 2K polyurethane.

Rocksim 9 is the chosen software used in determining flight parameters such as C/P, C/G, weights and performance. Most every component was weighed before being entered into Rocksim 9 (except for adhesives, fasteners, electrical wiring and paint). Below is the Rocksim 9 simulation summary.

The planned altitude is 7500 feet AGL. Since flying the rocket on a test flight with an L motor in July 2012, the CD was adjusted in Rocksim to match the actual achieved altitude, so the 7500' figure should be pretty accurate for the M2250 motor. Below is figure 1 showing a scale drawing of the project without the motor installed.

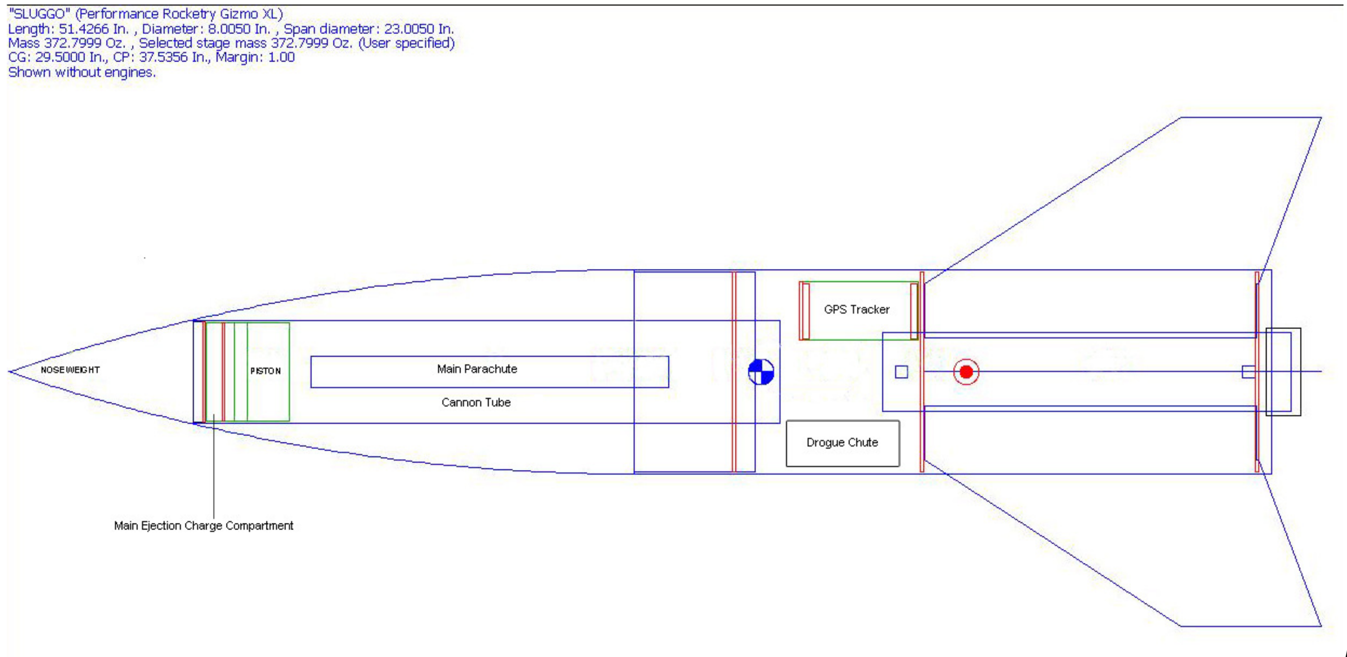


Fig. 1 – Scale drawing unloaded

Preliminary flight simulation data with CTI M2250 loaded:

Center of pressure: 37.535 inches from nose (Rocksim V9)
Center of gravity: 32.16 inches from nose (Rocksim V9)
Mass at liftoff: 33.03 lbs. (Rocksim V9)
Total impulse: 5472 N-Sec.
Burn Time: 2.4 Sec.

Below is figure 2 showing flight simulation data, followed by a printout of the data.

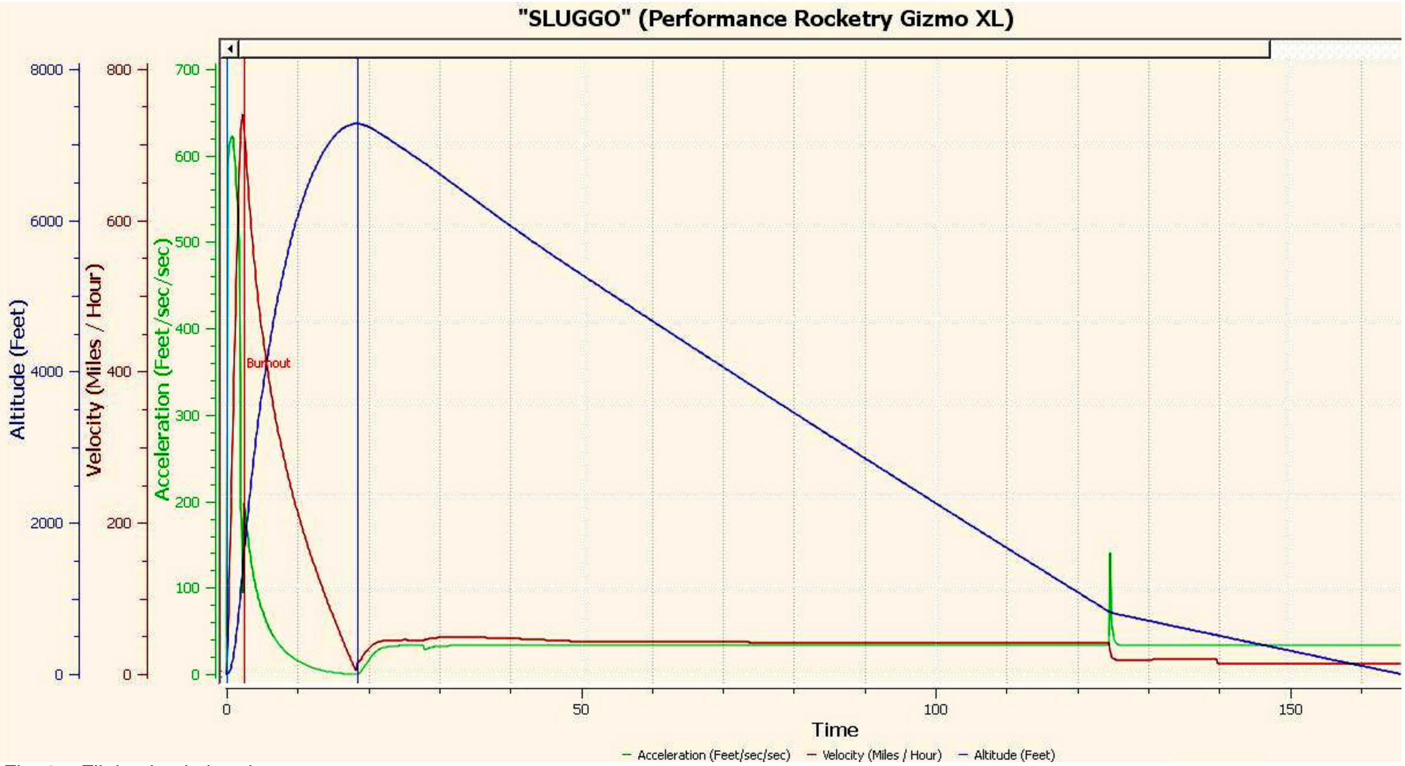


Fig. 2 – Flight simulation data

"SLUGGO" (Performance Rocketry Gizmo XL) - Simulation results

Engine selection - M2250-CS

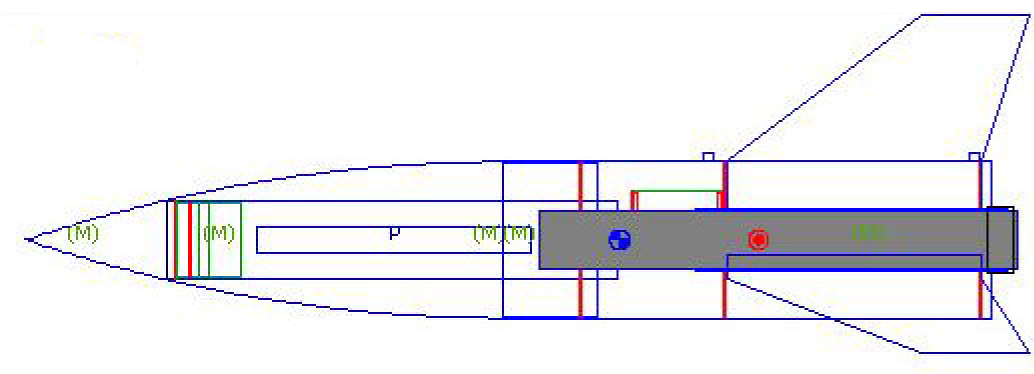
Simulation control parameters:

Flight resolution: 800.000000 samples/second
Descent resolution: 1.000000 samples/second
Method: Explicit Euler
End the simulation when the rocket reaches the ground.
Launch conditions
Altitude: 125.0 Ft.
Relative humidity: 50.000 %
Temperature: 75.0 Deg. F
Pressure: 29.9139 In.
Wind speed model: Slightly breezy (8-14 MPH)
Low wind speed: 8.0 MPH
High wind speed: 14.9 MPH
Wind turbulence: Some variability (0.04)
Frequency: 0.04 rad/second
Wind starts at altitude: 500 Ft.
Launch guide angle: 0.0 Deg.
Latitude: 0.0 Degrees
Launch guide data:
Launch guide length: 96.0 In.
Velocity at launch guide departure: 63.3835 MPH
The launch guide was cleared at: 0.183 Seconds
User specified minimum velocity for stable flight: 29.9996 MPH
Minimum velocity for stable flight reached at: 23.4907 In.
Max data values:
Maximum acceleration: Vertical (y): 571.317 Ft. /s/s Horizontal (x): 2.651 Ft. /s/s Magnitude: 571.317 Ft. /s/s
Maximum velocity: Vertical (y): 719.8382 MPH, Horizontal (x): 14.8004 MPH, Magnitude: 719.8986 MPH
Maximum range from launch site: 1703.70 Ft.
Maximum altitude: 7060.8 Ft.

Recovery system data:
P: Drogue Parachute Deployed at: 18.334 Seconds
Velocity at deployment: 3.7111 MPH
Altitude at deployment: 7060.84413 Ft.
Range at deployment: -2.22886 Ft.
P: Main Parachute Deployed at: 129.242 Seconds
Velocity at deployment: 42.7494 MPH
Altitude at deployment: 499.97417 Ft.
Range at deployment: 1703.70908 Ft.
Time data
Time to burnout: 2.498 Sec.
Time to apogee: 18.334 Sec.
Optimal ejection delay: 15.836 Sec.
Time to wind shear: 1.350 Sec.
Landing data
Successful landing
Time to landing: 151.514 Sec.
Range at landing: 1703.70908
Velocity at landing: Vertical: -12.8024 MPH (18.7769 FPS)
Competition conditions are not in use for this simulation.

II) <u>Scale drawing</u>

Below is a scale drawing showing the CTI M 2250 motor installed:



The calculated Center of Pressure is 37.535 inches aft of the nosecone tip and is shown in the drawing as a red C/P symbol just aft of the leading edge of the fins. Using Rocksim 9 the Aft C/G limit using the M2250 motor was calculated at 37.1” employing Rocksim’s stability equations. Actual measurement of the fully loaded flight-prepped rocket confirmed the aft C/G at 32.0”. This gives an acceptable stability margin of .67 calibers. This rocket has been proven to fly very stable with margins below .50 calibers due to its stubby stature.

III) <u>Description of construction materials and techniques (Construction Package)</u>

This project was constructed primarily from epoxy impregnated fiberglass components. The large nosecone on this rocket affords the ability to house both electronics and main recovery equipment giving the bonus of moving the C/G forward on this short, stubby rocket. This reduces the amount of ballast weight necessary in the tip of the nosecone. The supplied 8” diameter nosecone bulk plate was drilled out to convert it into a centering ring to accommodate a 4” diameter fiberglass “cannon” tube which runs the interior length of the nosecone. The aft end of this tube was epoxied into this centering ring and the forward end closed off with a reinforced bulk plate, the whole being epoxied to the interior of the nosecone near the tip. 4.2 lbs of steel BB shot was glued into the tip of the nosecone to bring the stability into acceptable limits. The aforementioned cannon tube contains a fiberglass piston to eject the main parachute which will be housed inside the tube with a Kevlar recovery harness. The open end of this tube will have a tethered, tight fitting foam plug installed to prevent the main chute and recovery harness from falling out during the drogue deployment event that separates the nosecone from the airframe. During the main deployment event the foam plug will easily be displaced by the piston and parachute. Two vials of black powder will be placed between the cannon tube's forward bulk plate and the piston, each hooked up to a separate altimeter. The backup altimeter timing will be offset by 1.5 seconds to prevent the possibility of both charges going off simultaneously causing over-pressurization of the tube.

Redundant Altimeters, power supplies and ejection charges will be utilized for maximum reliability. They will be housed between the nosecone wall and cannon tube. A GPS tracking device will also be used to aid recovery.

It should be noted that both altimeters and the GPS unit have flown successfully in other rockets that I have built and all 3 items have flown successfully during the maiden flight of this rocket in July 2012.

Three 2-56 Nylon shear pins attach the nosecone to the airframe. The 32" drogue chute and its Kevlar recovery harness will be housed conventionally in the fuselage protected from ejection charges by a large Kevlar blanket.

This project has been successfully flown with a CTI L820 motor with the rocket setup in the identical configuration as for the L3 attempt. The same 4 grain motor casing that will be used for the L3 attempt was used with a single spacer to accommodate the shorter L820 Motor. It should be noted that this casing protrudes approximately 3 inches into the cannon tube where it butts up against the foam plug that retains the main recovery gear.

Construction materials

Airframe: The fuselage consists of a single 25" long, 8" diameter thick-wall, filament wound G12 fiberglass tube. It arrived pre-slotted for 3 fins and is extremely robust. The motor mount tube is a 16" length of 75mm ID filament wound G12 fiberglass tube. A 22" long, 4" diameter G12 filament wound "cannon" tube was installed inside the nosecone to house the main recovery components. All tubes are manufactured by Performance Rocketry.

Fins: The three fins are precision CNC cut from 3/16" thick G10 fiberglass. The leading edges are tapered on a 12 degree angle to reduce drag. They were installed using standard through-the-wall techniques with internal and external fillets using a combination of Proline 4500 high temperature epoxy and West Systems 105/205 epoxy with colloidal silica filler where needed. Fins are manufactured by Performance Rocketry.

Centering rings: The two motor tube centering rings are precision CNC cut from 1/8" thick G10 fiberglass and are manufactured by Performance Rocketry. The Nosecone centering ring is precision CNC cut on its OD by Performance rocketry with the 4" interior hole cut by jigsaw and brought to final size with a large drum sander.

Launch rail buttons: Two 1515 Delrin rail buttons from 3 Dogs Rocketry will be utilized. They are secured to the airframe with Philips head, countersunk, ¼-20 screws running into lock nuts epoxied to the inside of the airframe just forward of each of the motor tube centering rings.

Reinforcement materials: In addition to through-the-wall fin can construction, 1” wide carbon fiber biaxial reinforcing tape soaked in Proline 4500 high temperature epoxy was used to reinforce each internal fin-to-motor mount joint. Fillets were then made with the same epoxy.

Adhesives: West Systems 105 epoxy and 205 fast hardener was the primary adhesive being used for all joints except for the fin can where heat is a consideration. West Systems colloidal silica was used as a thickener/filler where needed. Proline 4500 high temperature epoxy was used to tack the fins to the motor tube and for both the fin to motor tube fillets and fin to airframe fillets.
JB Weld was used to secure the Aeropack motor retainer to the motor tube. CA adhesive was used to seal any ragged edges produced by drilling into the G12 airframe tubing and nosecone.

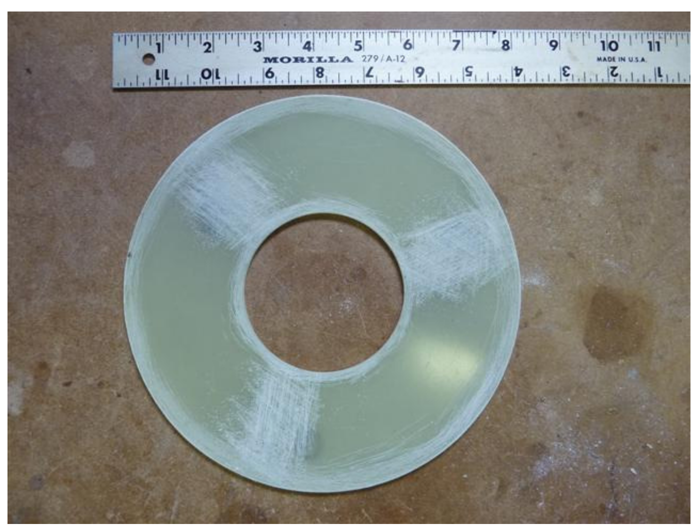
Nosecone: The 8” diameter 24” long nosecone is constructed of bias layered G-10 fiberglass cloth with a gel coat finish. It is manufactured by Performance Rocketry.

Construction techniques

Fin mounting method: The three 1/8” thick G10 fins were mounted using common through-the-wall techniques where the fins pass through slots in the airframe to butt up against the motor tube. The fin tabs were roughened with 36 grit abrasive paper to provide a good key for the epoxy. West Systems epoxy was applied to the inside edges of the slots prior to fin insertion. This causes the epoxy to be drawn into the joint through capillary action resulting in better fin to airframe adhesion. It also seals the fin joint so epoxy does not drip through when the internal fillets are made.

Fin reinforcement areas: 1” wide carbon fiber biaxial reinforcing tape from Soller Composites was soaked in Proline 4500 high temperature epoxy and a 3/8” wide epoxy fillet poured into the crease of each fin joint while the biaxial tape epoxy was still tacky to ensure good adhesion. Fillets were applied to both the internal fin-to-motor tube and fin-to-airframe joints. All fillets were made using Proline 4500 high temperature epoxy. Additionally, 2 large nylon tie wraps were installed through slots close to the fin roots and drawn up under tension to pull the fins towards each other and the motor tube. This has the effect of providing additional reinforcement should a hard landing on one or more fins take place. This should help prevent the shock from propagating a crack or adhesive joint failure. Where the Nylon tie wraps intersect the motor tube, Birch strips were coated with epoxy and jammed into place to further increase tie wrap tension and also prevent direct contact between the nylon and hot motor mount.

Below are fin can construction photos.






No frangible or breakaway components were used in this rocket’s design.

IV) <u>Description of recovery system components and operation (Recovery Systems Package)</u>

This project will use a “dual deploy” recovery system. Redundant altimeters and black powder ejection charges will be employed in case one or the other fails to function correctly. The primary altimeter is a Perfectflite MiniAlt/wd and the secondary is a Raven II. Powder charge containers consist of plastic centrifuge tubes containing an electrical igniter and 1.5 grams of Goex 4F black powder. Power sources and wiring will be unique to each altimeter for maximum reliability. The altimeters are supplied by two different manufacturers and use differing methods of altitude detection (barometric and accelerometer based) which should eliminate potential failure modes associated with either design.

The pair of altimeters will be programmed to separate the nosecone from the sustainer at apogee releasing a 32” Skyangle Classic II drogue chute constructed of Ripstop Nylon. The nosecone and sustainer will remain tethered for the complete flight. At 700’ AGL the main 84” Rocketry Warehouse Starchute parachute constructed of ripstop Nylon by will be ejected by a second 4F black powder charge. The second altimeter will be programmed to fire the backup charge at 600’ AGL.

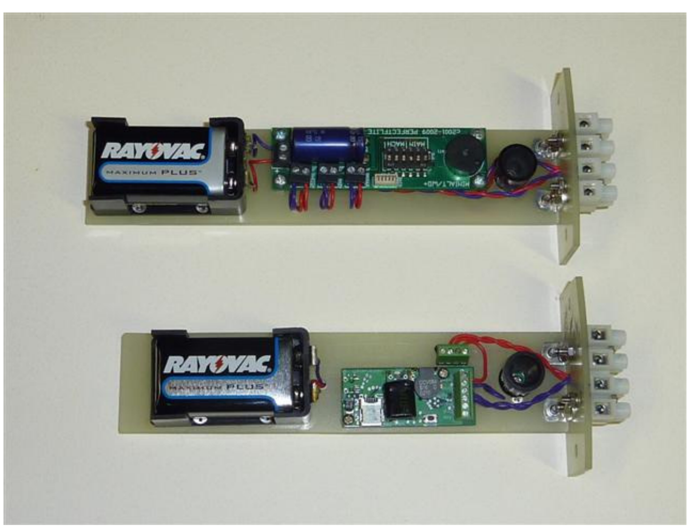
Due to lack of space for a conventional avionics bay in this very short rocket, the dual altimeters will reside in the nosecone. A tubular GPS avionics bay will reside in the airframe just above the fin can.

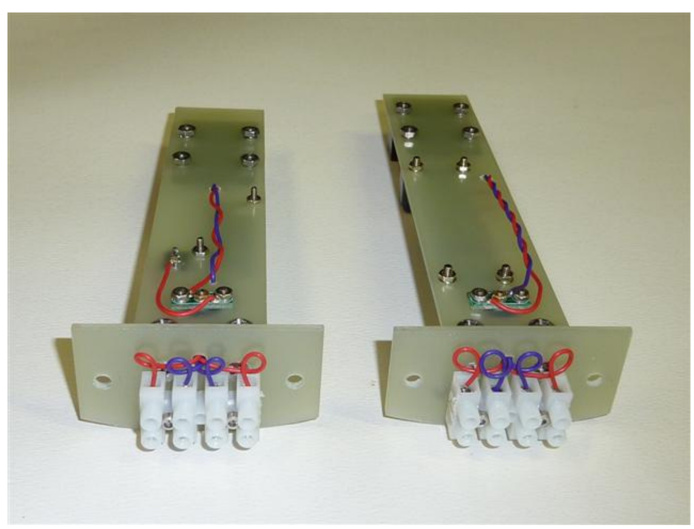
The periphery of the nosecone centering ring is divided into three imaginary segments. Two segments have cutouts to accept the altimeters. The third segment has a U-bolt for attachment of the Kevlar shock cords that will tether the nosecone to the parachutes and airframe as well as securing the short tether for the foam cannon tube plug. The two altimeters reside on G-10 fiberglass sleds that slip through the cutouts in the cannon tube's centering ring and into the nosecone cavity. The sleds are attached at right angles to G10 fiberglass bulkheads that are secured to the nosecone centering ring with knurled thumb nuts. Each sled has an altimeter, battery and a Featherweight screw type disarming switch installed. I made two captive funnels and epoxied them to the altimeter sleds to guide a screwdriver blade directly to the screw heads of these switches with no effort. These switches are accessible by poking a #1 Philips screwdriver through 2 of the 3 static ports, and will be activated after the rocket is installed on the launch rail. Below are photos of the completed sleds and their installation in the nosecone centering ring as seen from both sides. Note: the batteries will be secured to the sled with a wrapping of electrical tape to prevent accidental dislodgement.

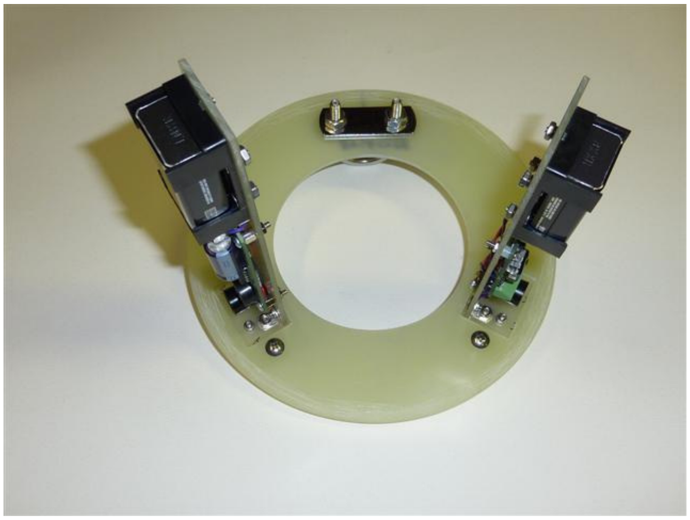
The main parachute riser consists of a 1500 Lb tensile strength, Giant Leap 20 feet long 3/8" tubular Kevlar shock cord with sewn loops at both ends. It will be attached to the nosecone's stainless steel U-bolt via a ¼" quick link with the other end similarly secured to the swivel on the main chute's shroud lines.

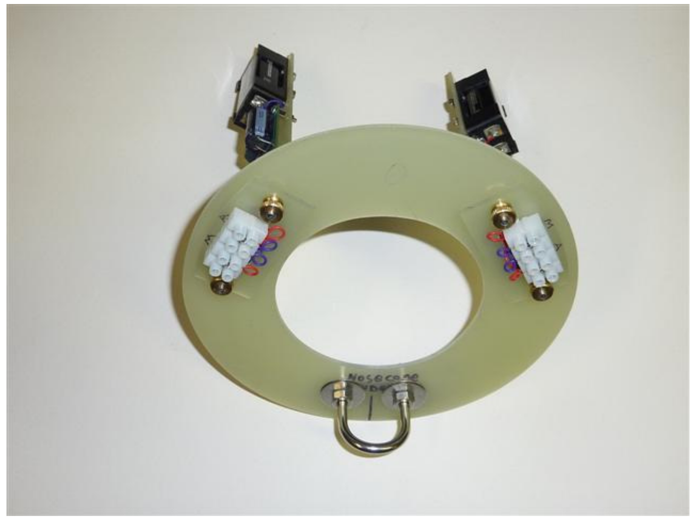
The apogee-deployed recovery riser will consist of a 1500 Lb tensile strength, Giant Leap 20 feet long 3/8" tubular Kevlar shock cord with sewn loops at both ends. It will be attached via a ¼" quick link to the aforementioned nosecone U-bolt on one end and to the U-bolt secured to the forward centering ring of the airframe on the other end.

The drogue chute will be attached via a ¼" quick link to a knotted loop in the shock cord 3 feet from the nosecone. This setup ensures that when the apogee charge separates the nosecone from the airframe that the nosecone will be held at the top of the riser stack by the drogue chute with the airframe dangling harmlessly below. Without a drogue set up in this manner there would be a good possibility that the nosecone could strike the airframe and vice versa if allowed to freefall. The drogue parachute will reside conventionally in the airframe beside the motor casing protected from ejection charges by a large Kevlar blanket from Giant Leap rocketry.



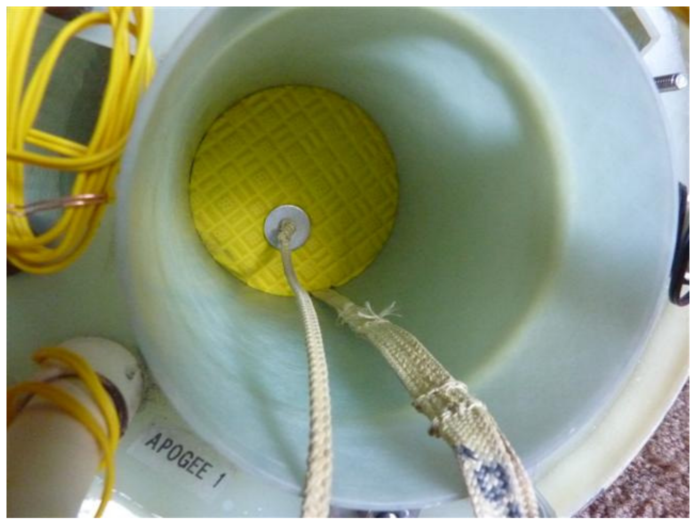


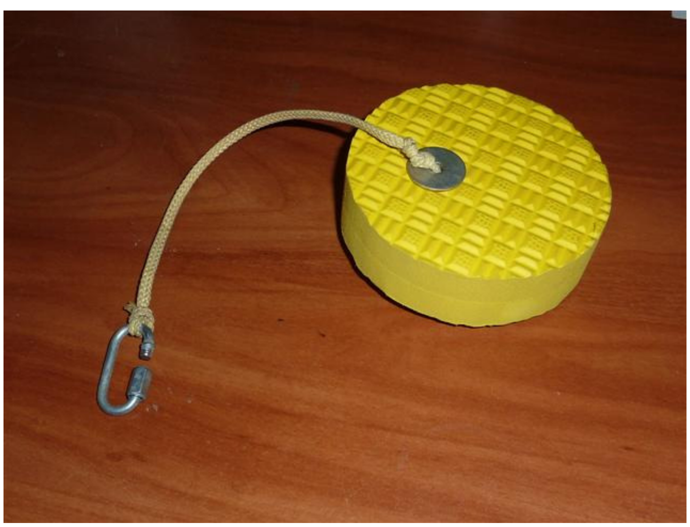




As mentioned in the preamble, the main parachute will reside in a cannon tube inside the nosecone. A fiberglass piston will be propelled rearward by redundant ejection charges to deploy the chute. The aft end of the tube will be fitted with a tethered, snug fitting foam plug to protect the chute from the apogee ejection charges and prevent its accidental exit during apogee separation and freefall.

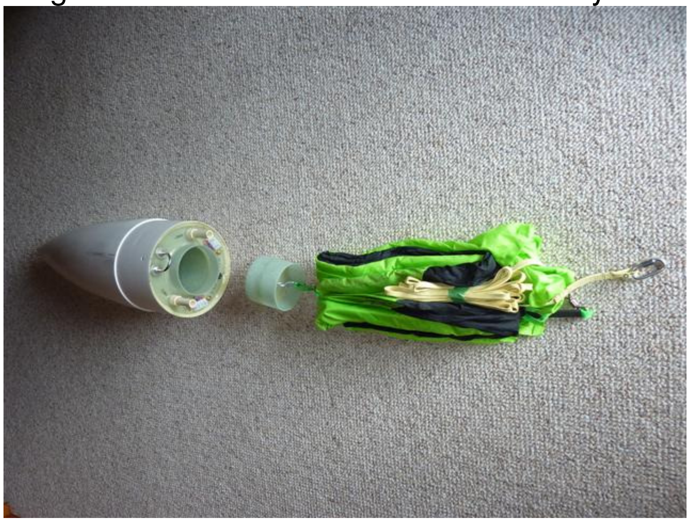
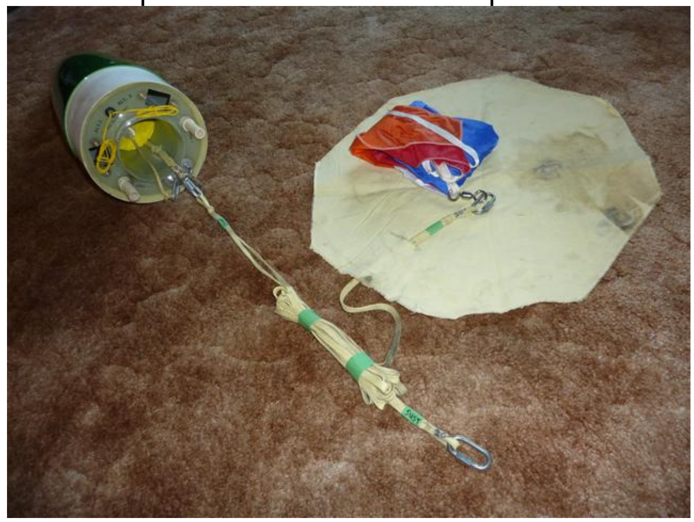
Below are photos of the aft end of the nosecone showing main chute inside the cannon tube with and without the tethered foam retaining block.





Below on the left is a photo of the main chute and shock cord attached to the piston and ready to be inserted into the cannon tube. (Foam block not shown here.)

Below on the right is a photo showing the main chute and foam retaining block installed and the drogue chute and riser attached and ready to be hooked up to the airframe anchor point.

The 32” drogue parachute will be protected by a captive Kevlar blanket supplied by Giant Leap Rocketry. The Main parachute is protected by the ejection piston the forward end and the foam sealing block at the aft end.

The nosecone which contains the barometric sensing altimeters is statically vented via three ¼” diameter ports drilled around the circumference of the airframe. These ports line up with similar holes drilled through the nosecone’s shoulder at a point 3.75” aft of the nosecone to airframe joint; far enough away from the nosecone’s curve ensuring non turbulent airflow. The static port size was originally calculated using a typical volume vs. hole size calculator which showed that three 1/2” holes were required. The size of these holes seemed excessive and I was assured by Gary Tortora the rocket’s designer that ¼” holes are sufficient. Three 2-56 Nylon shear pins secure the nosecone to the airframe via tapped holes.

The nosecone is indexed to the airframe by lining up two red pips as the two are joined. This accomplishes a number of things.

a) It holds the nosecone in a fixed position allowing the 3 static ports and threaded shear pin holes to line up perfectly.

b) It lines up the U-bolt of the nosecone directly over the U-bolt in the airframe.

c) It prevents the nosecone's ejection canisters from fouling the GPS avbay and directs heat blast away from the avbay's wooden cap.

A single 1/4" diameter vent hole was drilled through the airframe to prevent pressurization during ascent.

The estimated decent rate under drogue will be 54.7 FPS and under main at 18.8 FPS as calculated by Rocksim 9.

Description of components

Each of the two altimeters resides on its own G10 fiberglass sled containing a battery and arming switch. Each altimeter will operate black powder charges for both apogee deployment of the drogue chute and preset altitude deployment of the main chute.

The primary altimeter will be a Perfectflite MiniAlt/WD altimeter. It uses barometric sensing to determine altitude.

The backup altimeter is a Featherweight Raven II. It uses X and Y accelerometers as well as a barometric sensor to determine altitude and spatial orientation. A timer function built into the Raven II will also be incorporated to delay the firing of both the main and apogee backup charges by 1.5 seconds so as to avoid the possibility of over pressurizing the airframe.

Both altimeters will use fresh 9 Volt alkaline batteries. The battery holders are mounted such that G-loading can not separate the battery from battery holder contacts. The batteries will be further secured by a wrapping of electrical tape around the altimeter sleds as an added precaution. Additionally the altimeter bulkheads are sealed to the nosecone's centering ring with Blu-Tack mastic to prevent the apogee ejection charges from pressurizing the avbay thereby affecting the barometric readings.

Each altimeter will be armed on the pad via positive screw switches on each altimeter sled. Both altimeters have quick discharge backup capacitors so no safe switch is necessary.

A Garmin DC40 GPS tracking device is housed in a separate 54mm diameter G10 fiberglass avionics compartment which is secured to the inside surface of the airframe and the forward centering ring between the outside wall of the booster and the motor tube. The GPS unit will be inserted into its compartment antenna first and locked in place by a plywood cap secured by two thumb screws. The GPS antenna trails rearward through the forward centering ring of the fin can and protrudes into the empty cavity between the forward and aft centering rings of the fin can. This puts the antenna as far away as possible from the altimeters in the nosecone to eliminate any RF interference. The GPS unit is cushioned by soft materials to protect it from high G-forces. A handheld Garmin Astro 320 handheld receiver will be used to receive location information from the DC 40 tracker.

To be added - Wiring schematic showing connections of the control devices to power sources, arm controls, and pyrotechnic devices

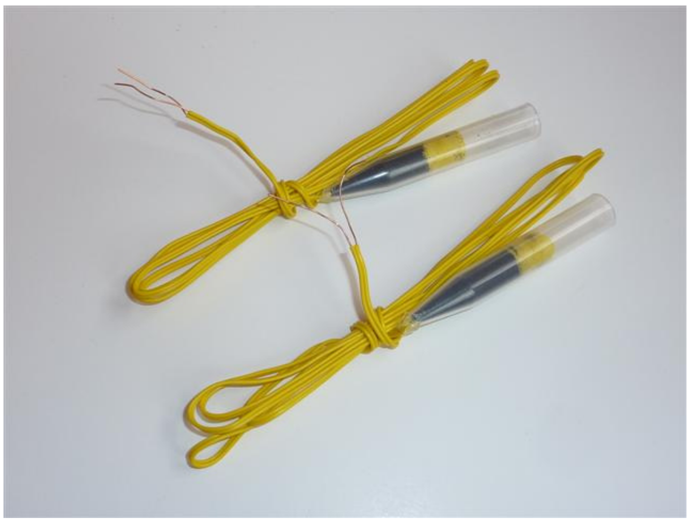
Mounting hardware
Where possible most every fastener used on this project is of quality stainless steel.

Mounting points
Two ¼" stainless steel U-bolts are used as anchor points for recovery components and risers. One is attached to the forward centering ring of the fin can, the other to the centering ring of the nosecone. Their mounting is reinforced on both sides of the fiberglass centering rings with oversize diameter, stainless steel washers and stainless steel straps. The threads were epoxied to the nuts to prevent loosening. The outside joints of the centering rings were built up with a strong epoxy fillet to prevent the joint from shearing under G loading during parachute deployment.

Five stainless steel ¼" quick disconnect links (Quick Links) are used in the recovery system as well as one 1/8" quick Link for attaching the foam piston tether to the nosecone.

Pyrotechnic devices

a) Two pairs of 1.5 gram black powder charges will be utilized, two for the apogee event and two for the main parachute event.



Each pair will be operated by the two totally independent altimeters. If the first charge misfires from the primary altimeter, a second charge will go off 1.5 seconds later from the backup altimeter. The charges will be initiated by J-Tek electric matches both being contained in plastic centrifuge tubes with the black powder being sealed in by a foam earplug. The two apogee charges will reside in protective CPVC ejection canisters located on the aft end of the nosecone and will fire into the airframe to separate the nosecone.

The two main charges will reside in a small cavity in the nosecone's cannon tube just forward of the cannon tube piston. The lead wires for these charges are fished through a ¼" ID aluminum conduit tube that runs from the nosecone's centering ring to a radially drilled hole at the forward end of the cannon tube. The conduit tube is epoxied at both ends to seal ejection gasses from the altimeters. Once the wires exit the plastic ferrule at the aft end of the conduit, the ferrule is sealed with mastic to prevent the apogee ejection gasses from entering the cannon tube through the conduit even though it is highly unlikely that any negative results would ensue.

It should be noted that extensive ground testing of the deployment system was used to determine that 1.5 grams of Goex 4F black powder was just the right amount to fully deploy both main and apogee systems without stressing any components. Videos of the finals tests can be seen on Youtube here:
Apogee charge test: http://www.youtube.com/watch?v=D66t7yfLC_g
Main charge test: http://www.youtube.com/watch?v=fUag4HUHpgA

The recovery system worked flawlessly during the test launch in July 2012.

V) Stability evaluation

A) This rocket required a 1515 High power rail of 8 feet in length
B) Center of pressure calculations: 37.535 inches from nose (Rocksim V9)
C) Aft CG limit as calculated by Rocksim 9 is 30.8521 giving a 0.82 stability margin
   Actual C/G on the flight prepped rocket was measured as 32.0” giving a 0.85 stability margin
D) This rocket has been shown to fly stable with even lower margins in the 0.50 range

VI) Expected performance/flight profile (Rocksim 9)

1) Launch weight 33 lbs
2) Motor type CTI M2250 C Star
3) Estimated drag coefficient of .40 was determined by adjusting Rocksim’s calculated figure with real life performance of the test flight that used an L820 motor
4) Velocity as the rocket leaves the launch system 63.3835 MPH
5) Maximum expected vertical velocity: 719.8382 MPH
6) Maximum expected altitude: 7060 Feet AGL
7) Maximum expected acceleration: 571 Ft. /s/s Vertical

VII) Pre-launch checklist

- Verify presence of all components and necessary tools.
- Assemble motor per manufacturer’s instructions.
- Prepare 4 ejection charges by Installing 4 igniters into plastic centrifuge tubes and seal the wires at the exit point with hot melt glue.
- Using an ohmmeter, verify continuity in each igniter.
- Twist each stripped pair of wires together to ensure that igniters are shorted for safety
- Fill each centrifuge tube with 1.5 grams of Goex 4F black powder

- Insert foam rubber bungs into each tube and compress against the black powder with the eraser end of a pencil.
- Using a fish wire, pull the two main ejection charge leads from inside the forward end of the cannon tube through the charge lead conduit, exiting the plastic ferrule on the nosecone's centering ring
- Lay the charges flat against the cannon tube's bulkhead angled away from each other and take up any wire slack.
- Use a ball of mastic sealant (Radio Shack # 278-1645, or Blu-Tack) to seal the wires where they exit the ferrule on the nosecone's centering ring.
- Fold the main recovery riser and secure it in the center with masking tape
- Fold the main parachute
- Fold the apogee recovery riser and secure it in the center with masking tape
- Attach the main chute to the main recovery riser using a ¼" Quick Link
- Attach main chute piston's eye bolt to the top loop of the main chute with a ¼" Quick Link
- Insert piston, main chute and main recovery riser into the cannon tube of the nosecone as far forward as it can go.
- Insert the foam retention plug into the cannon tube as far forward as it can go.
- Attach the loose end of the main recovery riser to the nosecone's U-bolt anchor point with a ¼" Quick Link
- Attach the foam retention plug's Kevlar tether to the nosecone's U-bolt anchor point with a 1/8" Quick Link
- Check 2 fresh 9 Volt batteries for a terminal voltage of at least 9.35 volts
- Insert batteries into battery holders on both altimeters and secure each with a nylon tie wrap or 3 turns of electrical tape
- Cycle both altimeters to verify correct function
- Run a bead of Blu-Tack mastic around the periphery of each altimeter sled's opening in the nosecone's centering ring
- Insert both altimeter sleds into the appropriate opening in the nosecone's centering ring and secure with the four thumb screws ensuring the sealing mastic gets compressed
- Insert two apogee ejection charges into the two CPVC ejection charge canisters with their leads exiting the holes at the base of each canister
- Wrap the leads once around each canister to secure the charges in place.

CAUTION – Verify both altimeters are safe (OFF) before proceeding further

- Shorten all 4 ejection charge leads, strip the ends and insert into the appropriate terminal on the terminal blocks on each altimeter sled.
- Tighten all terminal screws and tug on each lead to make sure they are secure.

CAUTION – The flowing test will be done with LIVE charges. Wear protective eye and ear protection.

- With the nosecone securely held under arm with cannon tube opening pointed in a safe direction, insert a Philips screwdriver through the two appropriate static ports and cycle each of the altimeters to verify continuity to all 4 ejection charges. When complete disarm the altimeters and wait 30 seconds before putting the nosecone down.

CAUTION – The charges are still LIVE.

- Prepare a 20 foot Kevlar shock cord for the apogee riser by making a knotted loop 3 feet from one end. This loop will attach the drogue parachute.
- Using masking tape, mark the 3 attachment points as NOSE, AIRFRAME, and Drogue

- Fold up the apogee shock cord riser leaving one foot loose at each end and secure in the center with masking tape (Ensure that the drogue chute's attachment loop is closest to the nosecone and the Kevlar blanket is closest to the airframe's attachment point).
- Slide what will be the aft end of the apogee shock cord riser through the hole in the Kevlar blanket
- Fold the drogue chute
- Attach the drogue chute's swivel to the riser using a ¼" Quick Link
- Fold the drogue chute and riser together into the Kevlar blanket and stuff them against the top of the forward centering ring of the fin can.
- Attach the apogee shock cord riser to the airframe's U-bolt anchor points using a ¼" Quick Link.
- Remove the cover of the GPS avbay located in the airframe.
- Turn on the Garmin DC-40 GPS tracker and insert it antenna first through the ¼" hole at the bottom of the GPS avbay.
- Re-install the cover
- Turn on the Garmin Astro receiver and verify the tracker's signal is present. Turn off receiver
- Attach the apogee shock cord riser to the nosecone's U-bolt anchor point using a ¼" Quick Link.
- Lower the nosecone onto the airframe ensuring that the two red indexing pips line up.
- Install the 3 nylon shear pins
- Install the motor casing and secure with the threaded Aeropack retainer.
- Install the camera(s) with filament tape NOT masking tape
- Secure the motor igniter to the airframe with masking tape so as not to lose it
- Fill out Flight Card
- Get rocket inspected by RSO

AT THE PAD – Pre-flight Checklist

- Verify the altimeters are safed (no beeping)
- Install the rocket on the launch rail.
- Verify intended launch angle is set
- Install the igniter
- Verify the launch pad wires are disarmed
- Connect igniter to launch system
- Arm primary altimeter and verify correct beep pattern
- Arm secondary altimeter and verify correct beep pattern
- Turn on camera(s)
- Verify GPS tracker signal is being received
- Verify all removable items are removed
- Verify Flight Witnesses are ready
- Put Flight Card on LCO's board
- Indicate flight readiness to LCO/RSO
- Retreat to safe distance.

Post flight checklist

- Verify all pyrotechnics are discharged
- Safe the pyrotechnic systems if live devices are present
- Attempt to identify the reason for any unfired pyrotechnic device
- Record or save any flight data that might be lost after power removal
- Switch off power to altimeters, GPS tracker and camera(s)

Contingency checklist - For misfires, launch aborts, or crashes

- Safe pyrotechnic systems to allow safe handling and/or disassembly

- Disconnect and remove motor igniter
- Note operating time to determine if flight batteries need charging or replacement
- Check time critical items, e.g. memory storage capacity
- For re-launch, follow the pre-flight checklist again