Team Rocket
Final Design Report

Justin Collins

Roberto Fernandez

Alex Folz

Collin Matthews

Garrett Sauber

Contents

Introduction and Competition Parameters

For this year's rocket competition, the design goal was to achieve an altitude as near as possible to 3,000 feet given the following design parameters:

I. A motor to be selected by the team; a Cesaroni J-357 will be used.
II. The rocket can be no longer than 7'.
III. The rocket can be no more than 6" in diameter and must be less than 4"
IV. The rocket must reach an altitude of 2,500 ft. and not surpass 3,500 ft.

In addition, teams will also be judged on the amount of time required to recover the rocket as well as the engineering of an alternative means of determining rocket velocity from takeoff to landing. These goals will be met with a sophisticated electrical system which will be described later in this report.

"Theoretical" Rocket Analysis

Development of the rocket design was completed via Open Rocket, an open source rocketry program. Open Rocket incorporates a large array of common model rocket components but also allows for custom part generation. Utilization of these features allows for increased accuracy in flight simulation and as such was used extensively. This analytical portion was considered theoretical as each component's mass was treated as equal to the manufacturer specified value. Once epoxy was applied to the necessary components and massed for discrepancies, the weight values in some regions of the rocket will likely differ from the theoretical estimation. Therefore, this analysis was a general representation of how the rocket would perform after fabrication.

With these parameters in place, the Open Rocket simulation provided a stability coefficient of 1.23 at launch, increasing to 1.90 after motor exhaustion, and a maximum altitude of 2,857 feet. The plot of this simulation in addition to the flight parameters can be viewed in Figure 1.

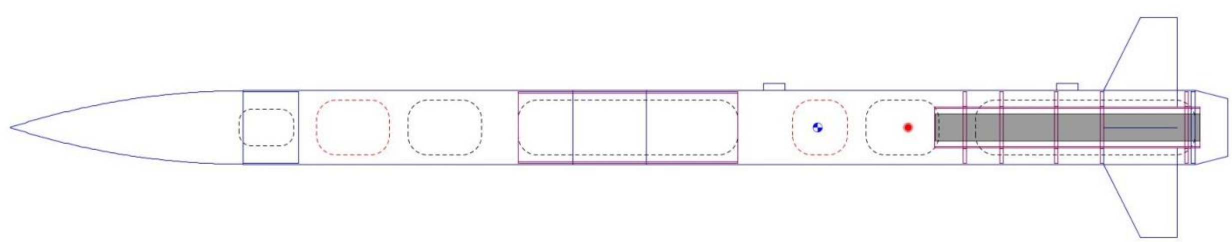

Photo 1. Theoretical positions of the center of gravity (blue) and pressure (red) before motor exhaustion, these positions provide a stability coefficient of 1.23.

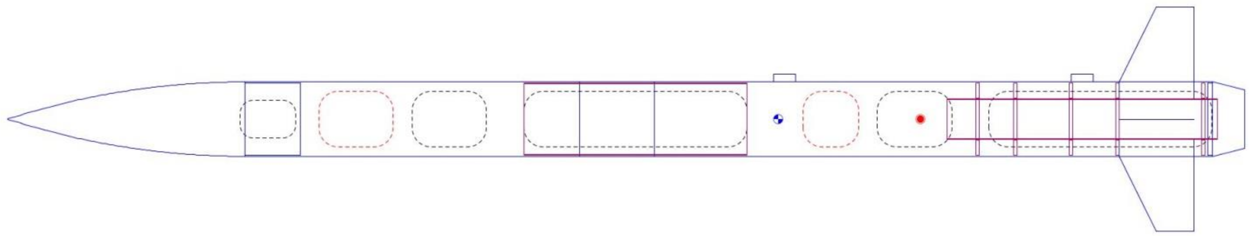

Photo 2. Theoretical positions of the center of gravity (blue) and pressure (red) after motor exhaustion, these positions yield a stability coefficient of 1.90.

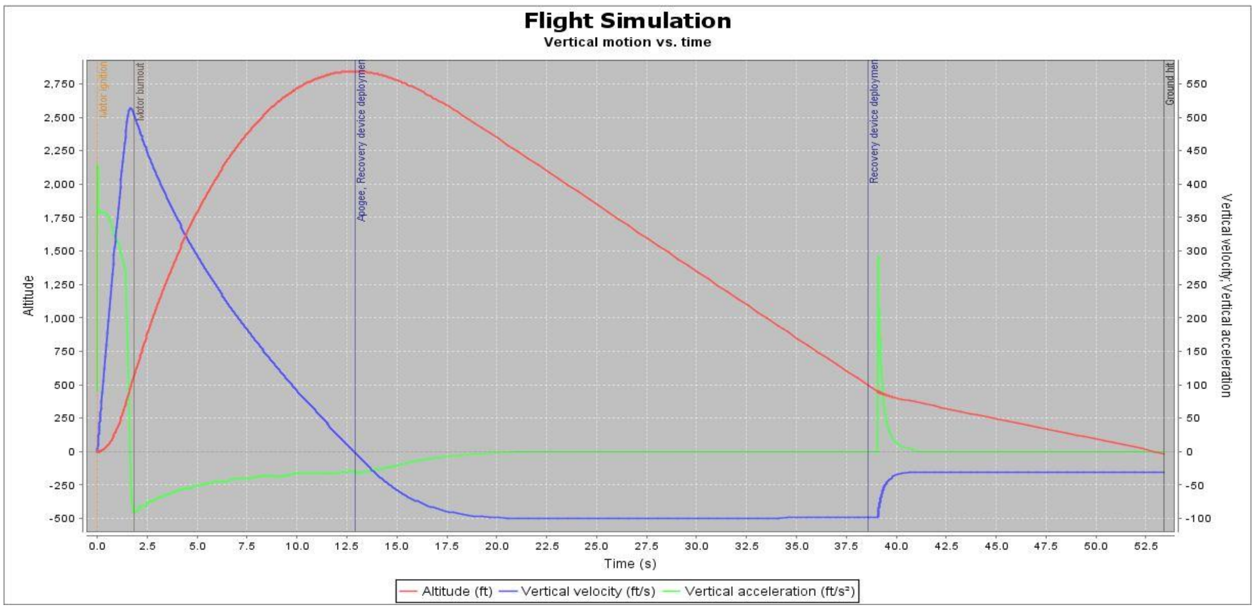

Figure 1. Plot of the theoretical rocket's simulated flight at maximum weight with launch conditions of winds averaging 10 mph, wind standard deviation of 2.0 mph, temperature of 45 degrees Fahrenheit, pressure of 1 atmosphere, and launch site altitude of 800 feet.

Engineering Component Analysis

With the initial design work done, it was time to order parts. Most parts used were ordered through Public Missiles, a small rocket company. Some important aspects of the parts ordered include the following:

I. Body tube is 4" in diameter and made of a fiberglass wrapped phenolic material.
II. The nose cone is 16.75" in long and the tailcone is 1.75" long.
III. The rocket contains a 30" drogue chute and a 36" main chute.
IV. Main payload will be housed in an interior coupler section on the rocket; it will contain two altimeters, the competition altimeter and a GPS and data collection system.

Moving forward, the build phase of the rocket can now begin over the next several weeks. Based on this timeline, the build phase can be complete several weeks before the competition itself and will be largely done in the time preceding the preliminary safety meeting.

Body Tubing

There were three major options in consideration for the body tubing of the rocket: phenolic, fiberglass wrapped phenolic, and quantum. The basic phenolic tubing was able to withstand velocities of nearly 951 feet per second and can endure sufficient impact in the event of main chute failure. Wrapping the phenolic in fiberglass increased its durability, weight and price. Quantum tubing was lightweight, more durable and easier to finish than traditional phenolic tubing. However, the material becomes brittle in cold weather conditions and risks fracturing upon impact. Considering the limited budget, phenolic was heavily considered but the fiberglass wrapped phenolic was eventually chosen. This was chosen as it did fit within the given budget and to guarantee that the rocket would not endure a body fracture such as the one that occurred during the previous year's launch.

Photo 3. Fiberglass wrapped phenolic airframes.

Booster Section/Motor Mount

The booster section is capped with a tailcone, decreasing aerodynamic drag and reducing the stability coefficient to the appropriate range. All propulsive forces of the rocket motor are transferred to the center of gravity through the booster section. Therefore, this section requires the greatest structural integrity. To ensure this is the case, the motor mount was secured to both the booster section and tailcone via five fiberglass centering rings. These rings were adhered via thirty minute slow-cure epoxy. Finally, a retainer ring was incorporated for ease of attaching and detaching the motor on launch day.

Photo 4 & 4. Motor mount before insertion into the booster section and the fully completed booster sections.

Payload Bay & Altimeters

The rocket design utilizes two extra altimeters in addition to the competition altimeter. The two selected altimeters are the Perfectflite by Stratologger and the Alts25 Dual-Deployment by

Adept. Each of these two altimeters provides an electrical current that ignite ejection charges at apogee and a user specified point following apogee. Traditionally, only one extra altimeter would be included to ignite the ejection charges. However, redundancy is gained by incorporating two altimeters. This will pay dividends in the event one altimeter fails. If this is the case and a second altimeter is not employed, the rocket will more than likely complete its descent without a parachute. The extra altimeter will not be used solely to detonate the ejection charges but also for data comparison.

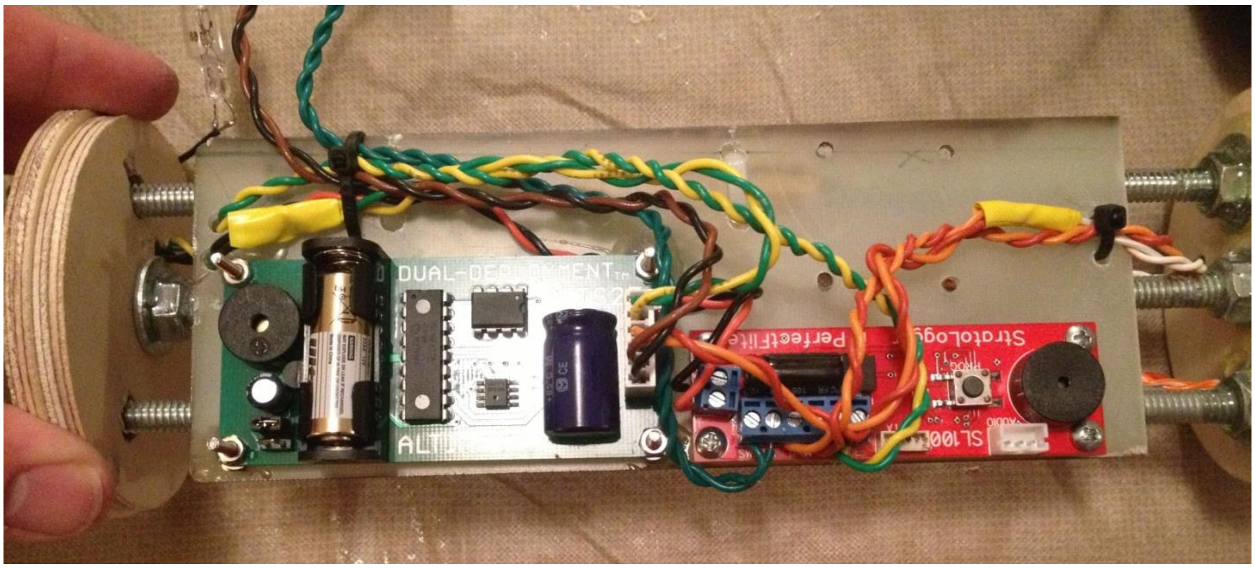

Photo 5. Perfectflite Stratologger (right) and Alts25 (Left) wired in the payload bay

GPS and Data Acquisition System

To locate our rocket in a fast and efficient manner we again decided to use a cellular GPS system. Store bought GPS systems were also found to be quite costly and as a result, a system that interfaced a prepaid cellular phone to a micro controller with an attached GPS module was developed for tracking the rocket. Last year we had great success with a custom designed gps system using a prepaid cellphone as a cellular modem.

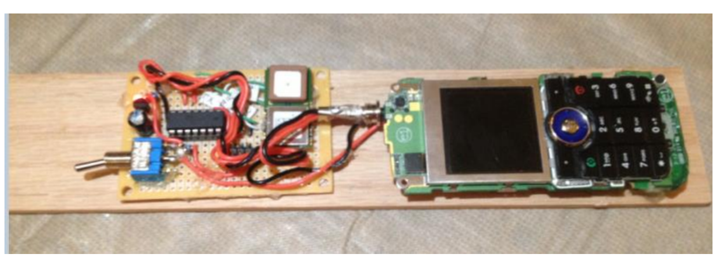

Photo 7. The makeshift GPS system from a prepaid cellular phone used previously.

This year the design was improved by creating a custom PCB and adding data logging for acceleration and altitude, temperature and pressure. The data is saved to a micro SD card and could be useful in examining performance of the rocket during flight, and for our post launch report. To locate the rocket or receive information such as its previous course trajectory and altitude, specific commands are sent to the phone via text message and the data is sent back via an SMS message.

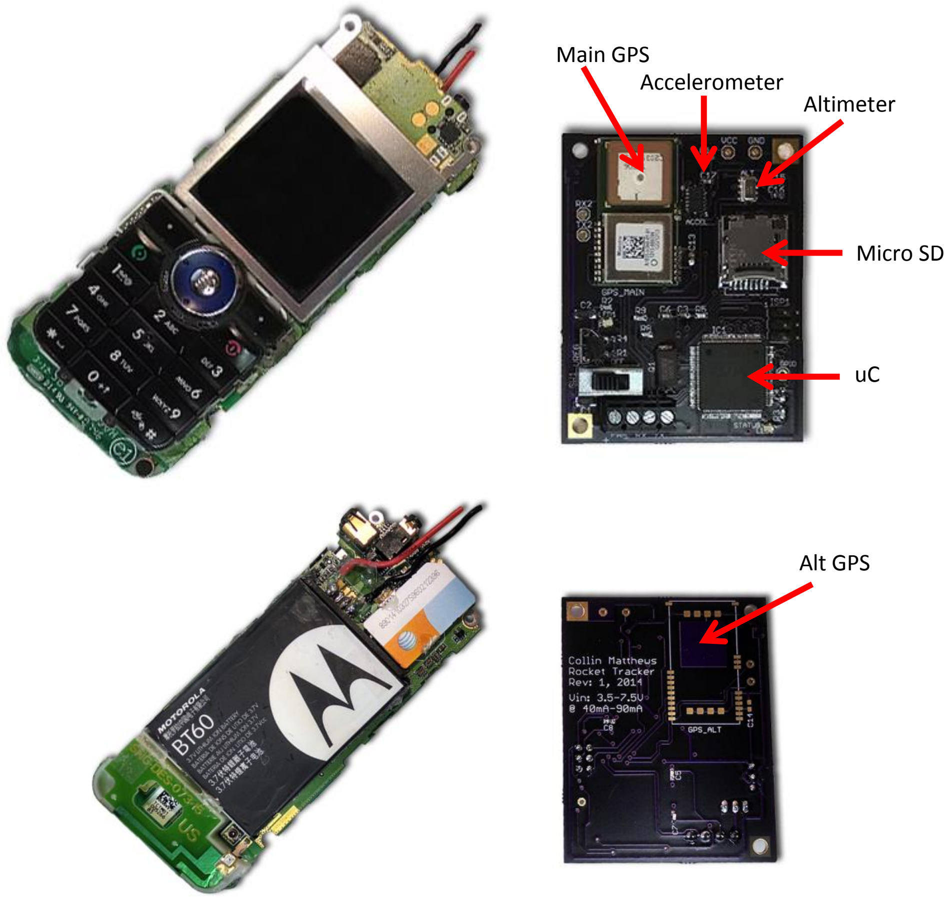

Photo 8. Rocket Tracking and Altitude Measurement Recording System

The microcontroller communicates with the phone via a serial interface built into the headphone jack of the phone. This setup allows industry standard AT-commands to be issued to the phone. These commands are designed to interface serial peripherals to cellular modems and make calls or transfer data, which is exactly what is desired.

The controller is constantly gathering GPS data via a NEMA standard GPS data-stream and storing the last known data in the event a signal is lost. When the controller receives a get location command it puts the last known good GPS data into a convenient to read format that contains the following information: location, heading, speed, UTC time, and the number of satellites currently providing position data. In the event live data is not available, it responds with the appropriate message why and the last known good coordinates.

Recovery System – Shock Chord and Parachutes

The chosen drogue chute is a 30” military surplus x-form by Public Missiles. The drogue chute, deployed at apogee, will successfully slow the rocket’s descent to approximately 100 feet per second. The altimeters were then set to deploy the main chute once reaching an altitude of 900 feet on its return. The main chute will further decrease the rocket’s speed to about 31 feet per second, slow enough for a safe landing. The large gap between deploying the drogue chute and the main chute serves to limit the lateral drift of the rocket by expediting the vertical descent. Both chutes are attached to the rocket via ½” nylon shock chords, which are present on both sides of the rocket and essentially connect the two major sections of the rocket. In the booster section, the shock chord connects the motor mount to the payload bay with the drogue chute attached intermediately. On the opposite side of the payload bay, another shock chord connects the payload bay to the nosecone with the main chute attached intermediately.

Photo 6. X-form drogue chute (left) and main chute (right).

Photo 7. Shock chord incorporated into the two major sections of the rocket.

Surface Finish

The rocket was painted using high quality polymer spray paint. The rocket was suspended vertically for painting so that it could be rotated easily by the operator. This insured even, no drip, coatings of paint. First, a white primer coat was laid on; this was done so that all the other paint would apply easily on the rocket and provided a deep, consistent color throughout the rocket. The primer was followed by a white coating of paint. After the entire rocket was painted white, blue painter's tape as well as professional pin striping tape was used to embellish the paint scheme. Essentially, this layer of tape would allow certain areas to stay white. Next a layer of blue was applied to the rocket. Once dried, all the tape on the rocket was removed which allowed the display of the desired paint scheme. After sufficient curing time for the paint, approximately three hours, multiple layers of clear coat were used to lock in and protect the paint.

Fins

On a rocket, fins are in place to provide stability. Many differing fin sizes and shapes are available based on the stability requirements of a given rocket. To provide the stability characteristics desired, A-01 shaped fins from Public Missiles were purchased. These fins have a 4" span, 2" sweep distance and are 0.062" thick. In addition, they are made up of a G-10 fiberglass material and are "Prism Plate" coated to provide additional shine. Four of these fins will be placed 90^{o} apart and approximately 1" above the base of the rocket's tailcone. As the fins are the most exposed piece of the rocket, each fin is mounted and epoxied to the motor mount and also epoxied at their entrance to the body tube with several fillets. Using this process, the fins stand the best probability of remaining intact upon landing no matter the conditions of the landing site.

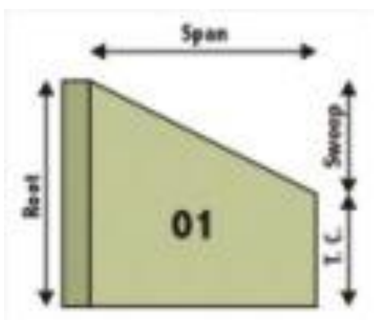

Photo 8. Shape of Fins Used; Image Courtesy of publicmissiles.com

Rocket Construction

Over the course of several months, a simple box of parts was turned into a high powered rocket. Teamwork was used to overcome many of the difficult obstacles that arose along the way. To start, the motor mount was constructed first. Images of this component under construction can be seen on the next page

Photo 4. The motor mount before insertion into the booster section.

The motor mount was created using a motor mount tube, centering rings, and a liberal application of epoxy. As all the thrust from the motor will be transferred through the motor mount, strength in the motor mount is paramount to a successful flight.

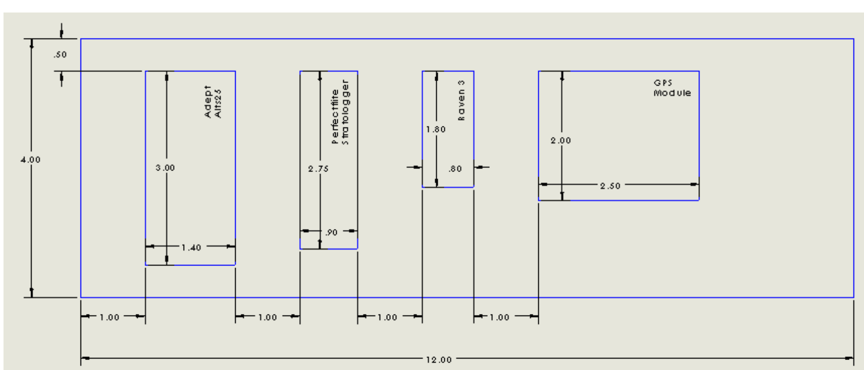

Photo 9. Payload Bay Layout, Designed in SolidWorks

Next, the payload bay was constructed. All altimeters and other hardware were mounted to the board with both epoxy and screws or zip ties. Attaching each component with two different mounting techniques provides redundancy inside of the payload bay. This is critical as the rocket's chutes will not deploy correctly if the rocket's altimeters are not functioning properly.

Photo 10. Rocket assembly before completion.

At this point, the bulk of the primary construction on the rocket was complete, as shown above. With that, the main two facets of construction to be completed are installing miscellaneous hardware to the rocket and giving it a fresh coat of paint. The results of these two steps can be seen in the conclusion section.

Budgetary Information

For the competition, a budget of $1,000 was allotted to each team to purchase high powered rocketry components. Initially, a preliminary budget was devised to estimate what the cost of the rocket components desired would be. This is as shown below:

Table 1. Preliminary Budget.

Part	Part #	Quantity	PPU	Total Price
36" Fiberglass Phenolic Airframe	FGPT-3.9	2	99.95	199.90
Plastic Nosecone	PNC-3.9	1	19.95	19.95
G-10 Prism Fins	FIN-A-08	6	6.69	40.14
Centering Rings	CR-3.9-2.1	5	3.26	16.30
Kwik Switch 2000 Motor Mount	KS-KIT-2K	1	28.95	28.95
1 Yd. 1/2" Nylon Shock Chord	TN-0.5625	15	1.99	29.85
Drogue Chute	PAR-X-FORM	2	7.99	15.98
54" Main Chute	PAR-54	1	37.95	37.95
Epoxy	Misc.	6	11.99	71.94

PML Shipping	N/A	1	16.50	16.50
Quantum Payload Bay	PSK-3.9x12-QT	1	16.02	16.02
Urethane Tailcone	TC-3.9-2.1	1	18.95	18.95
Large Airfoiled Rail Buttons	N/A	1	10.00	10.00
Misc. Hardware	N/A	1	40.00	40.00
Misc. Electronics	N/A	1	50.00	50.00
Model Rocket Misc.	N/A	1	42.00	42.00
Paint/Clear Coat/Painting Supplies	N/A	1	80.00	80.00
Airframe Custom Work	N/A	1	15.00	15.00
Extra Motor for Test Launch	N/A	1	80.00	80.00
			Total	829.43

Over the course of the build, few design alterations were made. However, the final component costs were significantly more than anticipated, resulting in the final costs exceeding the $1000 budget by roughly fifty dollars.

Table 2. Purchases upon completion of competition.

Rocketry Budget				
Part	Part #	Quantity	PPU	Total Price
36" Fiberglass Phenolic Airframe	FGPT-3.9	2	99.95	199.90
Plastic Nosecone	PNC-3.9	1	21.95	21.95
A-01 Prism Fins	FIN-A-01	6	6.69	40.17
Centering Rings	CR-3.9-2.1	6	7.13	42.78
G-10 Bulkplate	CP-3.9	2	8.51	17.02
G-10 Bulkplate Coupler	CBP-3.9	2	8.46	16.92
Kwik Switch 2000 Motor Mount	KS-KIT-2K	1	28.95	28.95
Kwik-link Fastener	HDWE-KL-2.0	2	1.45	2.91
1 Yd. 3/4" Nylon Shock Chord	TN-0.5625	14	1.63	22.82
Quantum Tube Payload	PSK-3.9x12-QT	1	16.02	16.02
Phenolic Couple	CTF-3.9-36	1	18.50	18.50
60" Main Chute	PAR-60	1	73.95	73.95
Epoxy	Misc.	2	15.99	31.98
PML Shipping	N/A	1	16.50	16.50
Quantum Payload Bay	PSK-3.9x12-QT	1	16.02	16.02
Urethane Tailcone	TC-3.9-2.1	1	18.95	18.95
Standard Airfoiled Rail Buttons	N/A	1	7.00	7.00
38mm AeroPack Retainer - P	N/A	1	31.03	31.03
Quest Recovery Wadding	N/A	1	6.41	6.41
Terminal Block	N/A	1	3.25	3.25
Altimeter Mounting Posts	N/A	2	7.00	14.00

Nylon Shear Pins	N/A	1	2.95	2.95
Misc. Hardware	N/A	1	40.00	40.00
Misc. Electronics	N/A	1	70.00	70.00
Model Rocket Misc.	N/A	1	42.00	42.00
Paint/Clear Coat/Painting Supplies	N/A	1	80.00	80.00
Custom Airframe Slotting	N/A	4	6.00	24.00
Custom Airframe Cutting	N/A	1	2.00	6.00
Custom Airframe Cutting	N/A	1	2.50	2.50
UPS Shipping	N/A	1	18.95	18.95
UPS Shipping	N/A	2	13.95	27.80
UPS Priority Mail Shipping	N/A	1	8.16	8.16
Extra Motor for Launch Day	N/A	1	80.00	80.00
			Total	1049.39

Conclusion

In conclusion, the greatest aspect of this competition was the knowledge gained. Over the course of the year, a vast deal of knowledge not only about rocketry but the general engineering professions was gained. From the initial analysis, to the choice of materials, to the build itself, this project truly was a microcosm of a large scale project that could be seen in engineering industry.

In addition to the knowledge gained, knowledge from previous was liberally used to assist in the successful flight of the rocket. Using analysis of the rocket itself, there is no reason to believe that the rocket designed and built will not apogee at approximately 3,000 ft., successfully record velocity via an alternative means and have a safe landing. This will be a great culmination of all the time, effort and money put into this rocket over the past several months.

Photo 11. The completed rocket, SkyScream, on display.