WSGC Competition 2013 Design Report

University of Illinois at Urbana-Champaign

Team Soaring Squirrels

This document describes in detail the design, construction, and analysis of a high-powered model rocket designed to meet the altitude and endurance requirements of the Wisconsin Space Grant Consortium Regional Rocket Competition.

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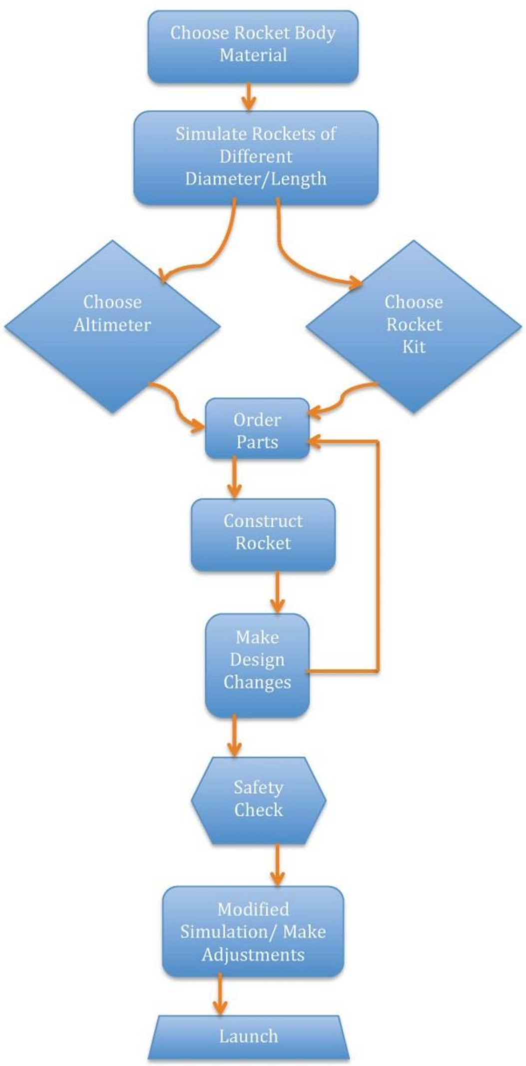
Table of Contents

1. Introduction

The 2013 annual WSGC Regional Rocket Design Competition required participants to design a one-stage, high-powered rocket. The mission goals were to reach apogee at 3000 feet and to recover the rocket in a flyable condition. The team's approach was simple and every step was taken to ensure the safe recovery of the rocket. The rocket was also designed to fit a budget and specific design requirements given by the competition's rules.

1.1 Plan of Action

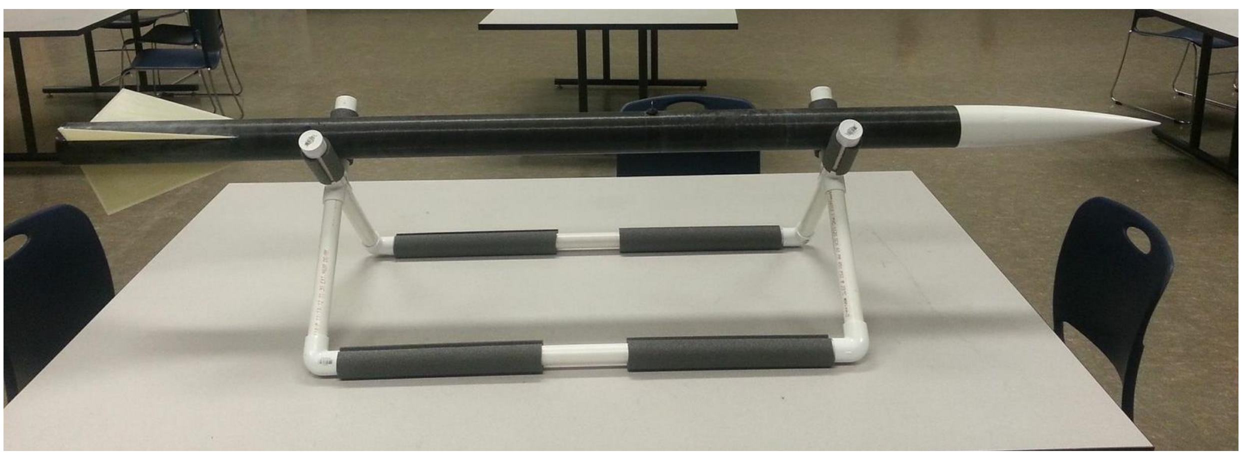


The team created a flow chart with its plan of action to ensure that the competition guidelines were met in time. After making the initial decision of what material to use, the next step was to run simulations with different length and diameters to determine which would best meet the competition goals. Then, a rocket kit was chosen that met these parameters, along with an altimeter that would work for the competition. After initial construction was begun, some small changes were made, and a few additional parts had to be ordered. Then, the rocket will be inspected for safety, and the simulation and weight of the rocket will be adjusted to ensure an apogee of 3000ft before the launch.

2. Design Requirements and Decisions

2.1 Rocket Body

Given the requirement of the competition that the constructed rocket be reusable, the initial decision was made to build a fiberglass rocket. While heavier and harder to work with, fiberglass offers durability not found in a cardboard or plastic design. Additionally, two group members had built a cardboard rocket for last year's competition and sought more of a challenge. After deciding on fiberglass, the maximum weight limit dictated that a 3 inch diameter body was to be used; a 4 inch diameter fiberglass rocket would be too heavy. Once the decision was made to look for a kit rather than build a rocket from scratch, a Wildman Rocketry Competitor 3 was selected as a workable fit, despite knowing beforehand that the maximum length requirement would require either a shorter nosecone than the one provided or trimming of the body (addressed in **Construction**.)



2.2 Avionics Bay

The avionics bay required basically no major decisions; as the requirement for electronic deployment dictated the sled have two altimeters: one for deployment and one provided by the competition. For simplicity, the same altimeter provided at the competition, a Raven3, was selected to control the deployment.

2.3 Motor

As dictated by the competition's rules, a Cesarroni I540 will be used. The motor mount provided in the kit was accommodates a 54mm motor, so an adapter was purchased to accommodate the smaller, 38mm, I540. Initial simulations placed apogee around 5000 feet, so it was realized that either weight, if possible, or a drag component were to be added.

2.4 Recovery System

The biggest decision with regards to the parachute deployment mechanism was first deciding whether to use a single parachute, or a dual-deployment system consisting of a drogue parachute that deploys at apogee, and a main, larger parachute that deploys at a lower altitude. While more complicated, a dual-deployment system was decided on because the drogue parachute's increased descent rate also meant less drifting. The drogue parachute selected is a SkyAngle24. The initial main parachute was a SkyAngle54. However, after construction began, the decision was made to use a slightly smaller, 52" parachute. This nylon parachute could fit in either portion of the body selected to house a parachute, and it also weighs less. The parachutes will be deployed by black powder ejections charges. The standard formula will be used to determine how much black powder is necessary, and then the recovery system will be ground tested to determine if the amount of black powder dictated by the equation is sufficient for parachute deployment.

3. Construction

Despite being a commercially available rocket kit, it was known that modifications would be made to the kit received. On top of this, no directions were provided. While a challenge, this allowed for discretion, something that was fully taken advantage of. Concurrent construction of the payload bay and the attachment of the motor mount were the first tasks to be taken on.

3.1 Avionics Bay

It was quickly realized that either the payload sled or eye-bolts required to attach our parachutes to the avionics bay needed trimming. Given the requirement that the sled only hold two altimeters and two batteries, two inches were cut off of the sled. On top of this, the eye-bolts were also trimmed after being attached to the end caps, so as to not run into issues with the threads. The next step was to construct the mechanism that would allow the sled to sit in the avionics bay. This was accomplished by setting up a rail system. First, the “rails”, which are two threaded rods, were cut to the length of the avionics bay. These run through the bay and attach by wing-nut to each end-cap. Next, the guides made of metal tubing attached to the sled and through which run the rails, were trimmed to

match the length of the sled. The sled was sanded, and with the system roughly assembled, the two guides were epoxied to one side of the sled. The final step in preparing the sled for the altimeters was drilling of the holes for the screws that would mount the altimeters to the sled. To retain balance, one altimeter and one battery were mounted on the same side of the sled, while the other altimeter and battery that will be given at the competition are set to be attached to the other side. Three one-eighth inch holes were drilled through the switch-band of the avionics bay. These are required by the Raven3's pressure sensor which the parachutes rely on for deployment.

3.2 Motor Mount

While the payload bay was being constructed, work was also being done on the motor mount. The motor mount also acted as an additional contact point for the rocket's three fins, which will be discussed later. To begin construction, two centering rings were epoxied to the rocket. These were attached towards the top, far enough towards the end to allow for the fins' epoxying to the mount. Through these two uppermost rings two holes were drilled. A Kevlar shock cord was placed through these holes and epoxied to the motor mount. Once this set, epoxy was put on the inside of the body tube, in the area where the centering rings would sit. The motor mount was then slid in and let to set. The third centering ring was placed at the bottom of the motor mount to ensure its centering, but the epoxying of that would come later.

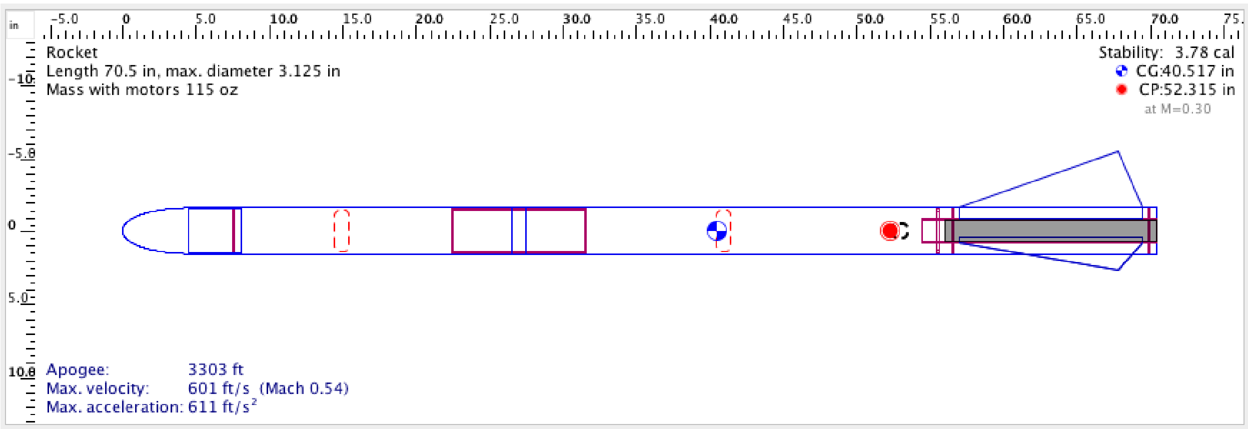
3.3 Fins

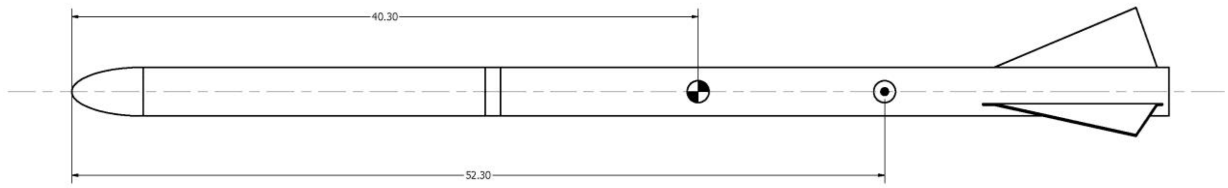
After the motor mount was in place, the fins were ready to be attached. Separated by 120 degrees, the slots for the fins were an extremely snug fit. After some sanding, the fins were put in place, butted against the motor mount, and ready for epoxy. With the 2 centering rings towards the top of the motor mount protecting against any epoxy dripping down the main

body tube, epoxy was poured down the 3 gaps formed by the outer surface of the motor mount and the fins, spread with a dowel rod, and left to sit. Each round of epoxy took care of 2 *internal sides* of fins, so this process was repeated 3 times to take care of the 6 total sides. This step created a fillet between the fins and the interior of the body tube. This process was then repeated, with the body rotated 60 degrees, to allow for a fillet to form between the 6 sides of the fins and the motor mount (as pictured).

4. Analysis of Predicted Performance

For the simulation of the rocket's performance, the program Open Rocket was utilized over Rocksim based on the group's past experience with it. The Competitor 3 rocket kit that was chosen did not have a completed file with it, so one was created based on the dimensions of the parts. In order to stay in the length requirements, 14'' was originally shaved off the lower body section for a total length of 67'' expecting to have plenty of room for the parachute. This put the max altitude at approximately 3200 feet. This is roughly 10% over the competition requirement to allow for any error in the simulation or the drag coefficient. The model also demonstrated a good stability of the center of gravity being about 7 inches or 2 body diameter length in front of the center of pressure. After the construction and design changes, the model was updated to reflect the current rocket. The new nosecone was inputted and the body tube lengths were changed to the correct value. The masses of specific components such as the payload section, parachutes, and retainer were overridden in the program to more accurately model the center of gravity. With the changes made and no additional weight, the new max altitude was approximately 3300 feet, again with the 10% error. The calculated center of gravity was roughly 12'' in front of the center of pressure meaning it was over stable and more likely to weather cock. Extra simulations were run at different wind speeds of 5, 10, and 15 mph to try and predict the effect on altitude. It was found that this only caused about 40 feet of variation of the max altitude. A screen shot of the Open Rocket model as well as a CAD model is shown below. Once the rocket is completely finished and painted, the total weight will be used to further improve the simulation by overriding its mass and also experimentally determining its center of gravity. This will allow for additional weight to be added near the center of gravity if necessary to improve performance.





6. Budget

An itemized budget to date is outlined in the table below.

Description	Price
Competitor 3 Kit	$150.00
4.5'' Elliptical Nose Cone	$25.00
Fiberglass Payload Sled	$6.00
38mm Motor Adapter	$30.00
38mm 5 Grain Engine Casing	$54.00
I540 Engine	$51.00
54mm Motor Retainer	$37.00
Kevlar Shock Cord	$37.00
Ejection Lighters/ E-Matches	$44.00
Parachutes- Main, Drogue and Protectors	$122.00
Raven3 Altimeter and Key Switches	$167.00
Miscellaneous Building Supplies	$155.00
Safety Equipment	$12.00
Rocket Stand	$20.00
Outreach Supplies	$20.00
Total Cost	**$930.00**