Preliminary Design Report

University of Iowa

THE UNIVERSITY OF IOWA

AIAA

Prepared By:
The University of Iowa AIAA
Midwest High Power Rocketry Competition 2017-2018
Faculty Advisor: Albert Ratner
albert-ratner@uiowa.edu
319 384 0883
Student Team Lead: Thomas Niemeyer
thomas-neimeyer@uiowa.edu
630 743 1029
Student Team Members
Student Team Members: Chris Sosnowski, Zachary Luppen, Seema Suthar, Joe Jalowiec, Anthony Scola, Austin Russ, Nick Farino

Table of Contents

Executive Summary:

This report contains information about the University of Iowa's preliminary design for this competitions rocket. Detailed descriptions of all the components of the rocket, such as funs, airframe, propulsion system, and payload, are included. Each description includes any calculations and formulas used as well as the reasoning behind the chosen design. An analysis of the rocket design is included with appropriate figures and plots used to show the rocket simulation data. This analysis is used to predict the flight performance of the rocket as it is designed. There is also a safety analysis included along with all relevant safety procedures necessary. A final section of appendices is included to show a breakdown of all equations as well as any external sources utilized for the design of the rocket.

Rocket Airframe

Rocket Body Specifications

The main body tube of the rocket is approximately 61.81 in (157 cm) long and will be constructed out of G12 fiberglass tubing with a diameter of 4 in (10.2 cm). This length was decided such that the internal space was large enough to accompany all of the subsystems of the rocket that will be operating during the flight. These systems include recovery, electronics, roll control, and propulsion. G12 fiberglass was the chosen material because it has been proven as a very strong material, highly suitable for high power rocketry. In order to accomplish the assigned task of capturing visual data of successful parachute deployment, a camera will be mounted on the side of the airframe, coincident with the electronics bay. This is done in order to limit the amount of extra wiring, electronics bays, and power sources needed to fulfill this requirement. The camera will be mounted facing downwards, in such a way that is as close to flush with the body tubing as possible to minimize drag. Simulations also estimate the total mass of the launch vehicle to be 6.738kg Figure 0 below shows the general construction/design of our high-powered rocket this year.

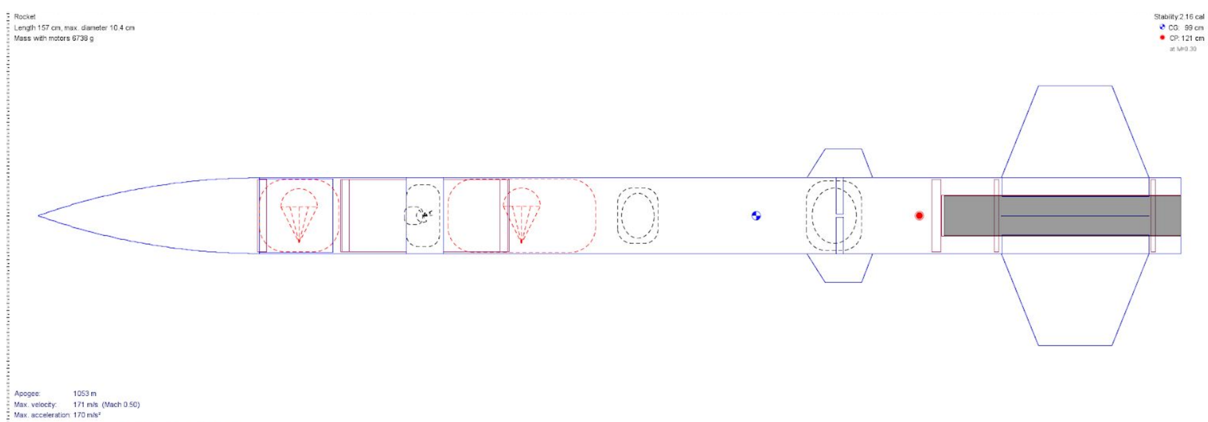


Figure 0: Rocket Design for 2018 Competition

Nose Cone Specifications

The nose cone, which is also made of fiberglass, adds an additional 12.0 in (30.5 cm) with a shoulder length of 4.7 in (11 cm). This brings the total length of the rocket to 65.1 in (165.5 cm). The nose cone can be seen below in Figure 1 and has an ogive profile. The length was extended a small amount to account for the payload bay, which is where a mass will be placed during launch with the larger motor. This concept will be further explained in the payload section.

Figure 1: Nose Cone

Fin Specifications

Four fins will be manufactured in-house, comprising of 1/16 in (1.59 mm) thick carbon fiber. This material was chosen since it was surplus from a separate competition, and thus there was no cost to purchase the material. This material has also been proven to be a strong material to use for fins, and has performed excellently in the past. Also, because the fins will be manufactured in-house, that will also not cost the team any additional funds. The fins will be tabbed such that they can be attached to the motor mount via internal filleting for extra strength. This internal filleting will be complemented by external filleting with epoxy resin composite. This will not only provide extra strength on the external airframe, but will also serve to reduce the drag from surface imperfections. Each fin is trapezoidal, with an 6 in base, 4 in free side, and a 6 in height. This shape was chosen to take advantage of the stability of wider wings, and fins will be placed 90 degrees apart from each other in order to achieve symmetry. Figure 2 below shows a model of the fins.

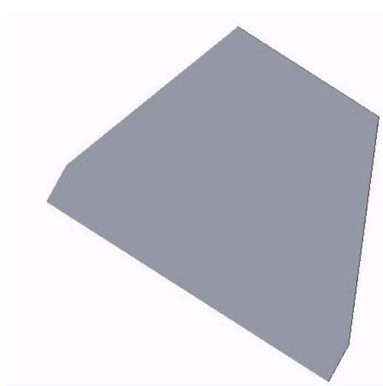


Figure 2: Fin Geometry

Rocket Recovery System

The recovery subsystem is not only comprised of the parachutes that will ensure safe descent, but also the electronics that control the blasting charges. The electronics that control the subsystem are laid out in greater detail in the electronics section. Other than electronics, the recovery subsystem is made up of the drogue parachute, main parachute and blasting caps that will deploy the aforementioned parachutes. The drogue parachute will be 15 in (38.1 cm) in diameter. It will be deployed just after apogee is reached at the start of the descent. The objective of the drogue parachute is to slow the descent of the launch vehicle so that when the main parachute is deployed, the connection points for the parachute are not fractured due to shear stress that is brought on by the immense drag forces. Further into the descent stage (roughly 800 - 1000 ft above ground), the main parachute will be deployed. This parachute will be approximately 36 in (91.45 cm) in diameter. The purpose of this parachute will be to further decrease the descent velocity of the launch vehicle, allowing it to land safely. Although the mass of the launch vehicle is currently an estimation, the estimate was given a comfortable amount of cushion in order to size the drogue and main parachute.

Rocket Propulsion System

For the propulsion subsystem, the motor chosen is the J800T-14. According to the simulations conducted using OpenRocket, this motor will be able to get the vehicle above the 3000 ft requirement by nearly 400 feet. The motor will be enclosed in an appropriate motor casing, which will then be slotted into 2 in (54 mm) fiberglass tubing. Each motor casing is made out of thin-walled 6061-T6 aluminum tubing with an anodized coating for corrosion protection and also includes a rear enclosure. On the end of the tubing towards the tail end of the rocket, the casing will be secured with a retaining ring. Two centering rings will then be adhered to the tube and slotted into the tail end of the main body tube. Slots will have been cut into the body tube to allow the tabs from the fins to fit inside. These tabs will be adhered to the 54 mm tube, lying in between the centering rings, with epoxy and will serve as the base of the internal filleting. The predicted performance of these two motors will be further detailed in the Analysis of Anticipated Performance Section.

Dual Deployment and Altimeter

Overview

The device selected for the dual deployment has a built in altimeter to measure the altitude of flight. The device, known as the stratologger, is capable of deploying two parachutes, a main and drogue. After the flight has concluded, the stratologger communicates to the user the flights apogee. The velocity of the flight is then transferred to the computer for further data evaluation.

Setup

The materials needed to assemble the dual deployment and altimeter are listed below in table 1:

Table 1: Dual Deployment and Altimeter Materials List

Description	**Quantity**
9V Battery	1
StratologgerCF Altimeter	1
Switch	1
Electrical Wire	Arranged

The DT4U Transfer Kit and Computer are not listed as materials for the actual build of the electronics recovery system. There are only needed for post flight data transfer and analysis.

The connections for Stratologger and battery can be seen in the wiring diagram below:

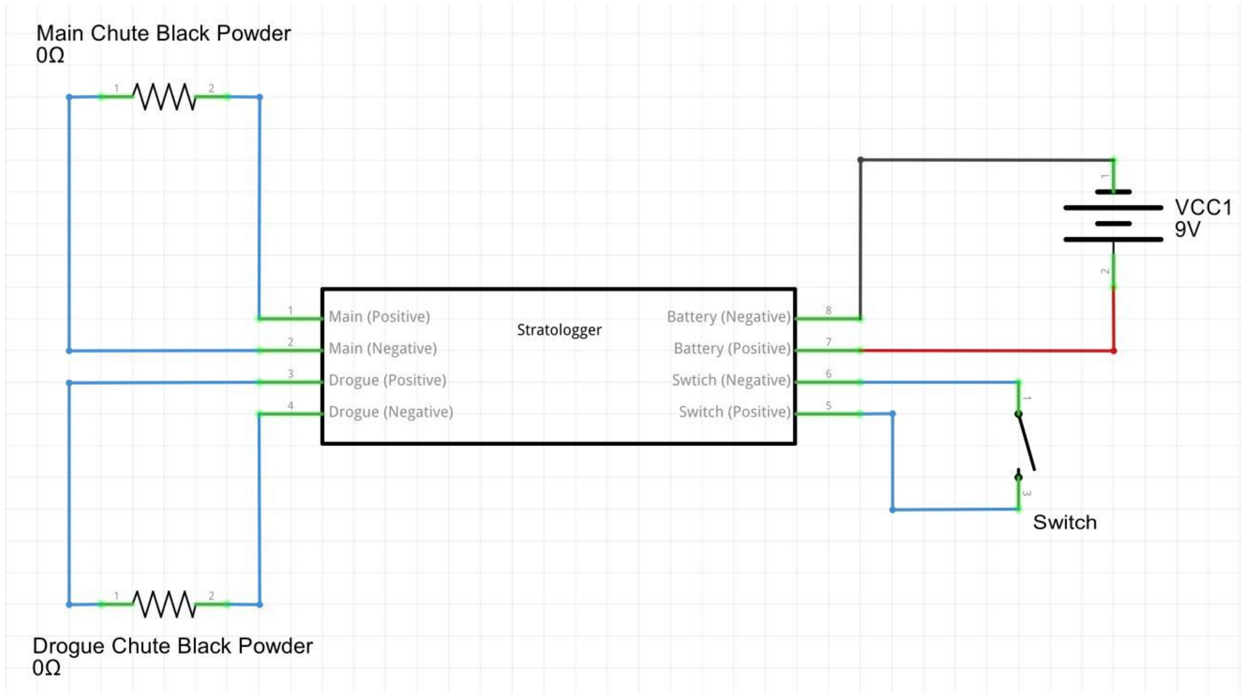


Figure 3: Recovery System Wiring Diagram

Design Features

The Stratologger various features produces a lot of adaptivity in the design of the recovery system. The Stratologger has a set of terminals designated for an external switch. The external switch allows the user to turn on the Stratologger right before launch in order to reduce any possible misfires of the black powder charges. The external switch will be in the off position during mounting on the launch rail. The switch will be activated when the rocket is ready for launch.

When the Stratologger is turned on, the Stratologger will sound a continuous series of beeps to notify the user the current settings. When a steady beeping noise is present from the Stratologger, it is in launch mode and ready to record altitude.

During the flight of the launch vehicle, the stratologger uses pressure readings to determine the altitude. Once the launch vehicles reaches apogee, a current is sent through the drogue terminals on the Stratologger to ignite the black powder that will deploy the drogue parachute. The second charge, the main terminals, will send a current when the predetermined height is reached. The main parachute ignition can be chosen from preset values on the Stratologger or programmed manually.

After the flight, the Stratologger will repeat the max altitude and max velocity using audible beeps until powered down. The Stratologger will also play a high pitched siren in order to find the launch vehicle. Using, the DT4U transfer kit, PNUT and Stratologger software, the altitude and velocity of the flight can be displayed graphically for the user.

Velocity Measurement Device

Overview

The noncommercial velocity measurement device will use software capabilities of the Arduino and Sparkfun accelerometer to determine the velocity of the launch vehicle. The accelerometer will record the acceleration of the launch vehicle and relay that information to the Arduino where it will be processed and saved. Using a USB, the data will be transferred and analyzed to determine the velocity of the launch vehicle.

Setup

The materials needed to assemble the velocity measurement device are listed below in Table 2:

Table 2: Velocity Measurement Device Materials List

Description	**Quantity**
9V Battery	1
Arduino	1
ADXL345	1
Switch	1
Electrical Wire	Arranged

The USB and and computer used to interpret and display the data are not listed as they are used post flight.

The connections for the ADXL345, Arduino, and battery can be seen below in Figure 4:

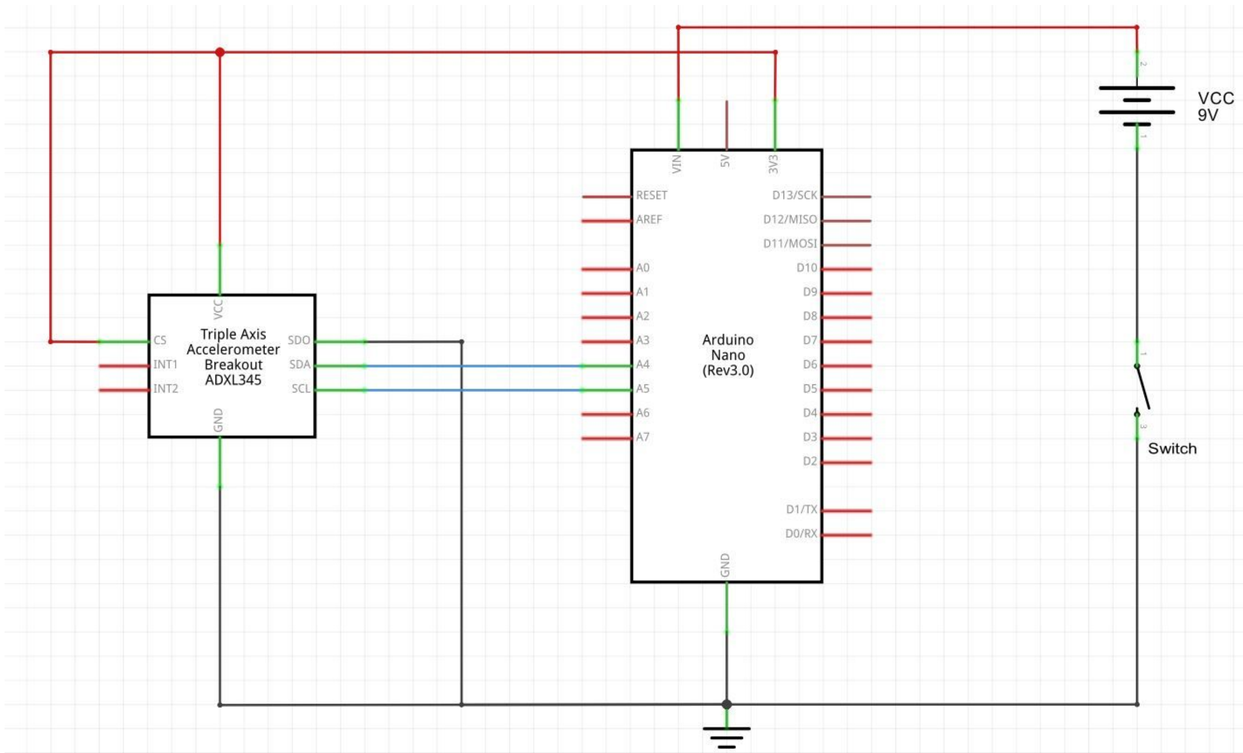


Figure 4: Velocity Measurement Device Wiring Diagram

Design Features

The Arduino is connected to the ADXL345 through serial communication either SP1 or I^{2}C. The ADXL345 stores the acceleration in registers corresponding to their axis of acceleration and sends the real time acceleration to the Arduino, where the Arduino will store the data for the entire flight. After the flight is over the data will be transmitted serially to the computer through the USB for further data calculation to determine the velocity of the launch vehicle.

The ADXL345 has an inactivity register built into the processor. The register acts as an inactivity threshold in which data will not be collected until the acceleration is higher than user defined value. This allows keeps the ADXL345 from transmitting extraneous values that are unrelated to the flight to the Arduino. A switch will separate the power supply from the two devices in order to keep the Arduino and ADXL345 from reading and recording prior to launch during the assembly of the launch vehicle on launch day.

Electronics for Mission Objective

Functionality of our electronics system is key to the competition goal this year. In order for the competition objective to be reached, the electronics system we create must be problem-free.

All of our electronics are operated by a physical switch on the side of the rocket. A portion of the electronics are dedicated to operating the altimeter and deploying our chutes. These electronics are almost identical to past years, as each Minnesota Space Grant Consortium competition has required us to have an altimeter to record flight data and have a drogue chute and main chute. Prior to launch, the switch will be turned flipped on, and the Arduino powering the altimeter will be switched on and will begin outputting data to a microSD card. Once the rocket has launched, the Arduino will reference a setpoint altitude as a minimum that we intend to reach and compare it to the value being received. Once the rocket reaches apogee, the Arduino board will create an output signal that will activate the drogue chute ejection charge. At a descending altitude of 1,000ft, also referenced by a set value in the Arduino, the main chute will be deployed.

The switch also powers the electronics necessary to accomplish the mission objective. This includes a gyroscope to measure the orientation of the rocket and a radio receiver/transmitter that can communicate with one of our members on the ground. The person on the ground will be able to receive the orientation of the rocket, as given by the gyroscope to the altimeter via an Arduino, and then transmit a signal back that will operate a motor to move the worm gear in our rocket that will alter the orientation of the rocket.

Lastly, we include a camera with its output saved to an SD card. The camera will allow us to visually monitor the rocket's journey and be used post-launch for any further analysis and at the competition banquet.

All electronics are shown in the block diagram below.

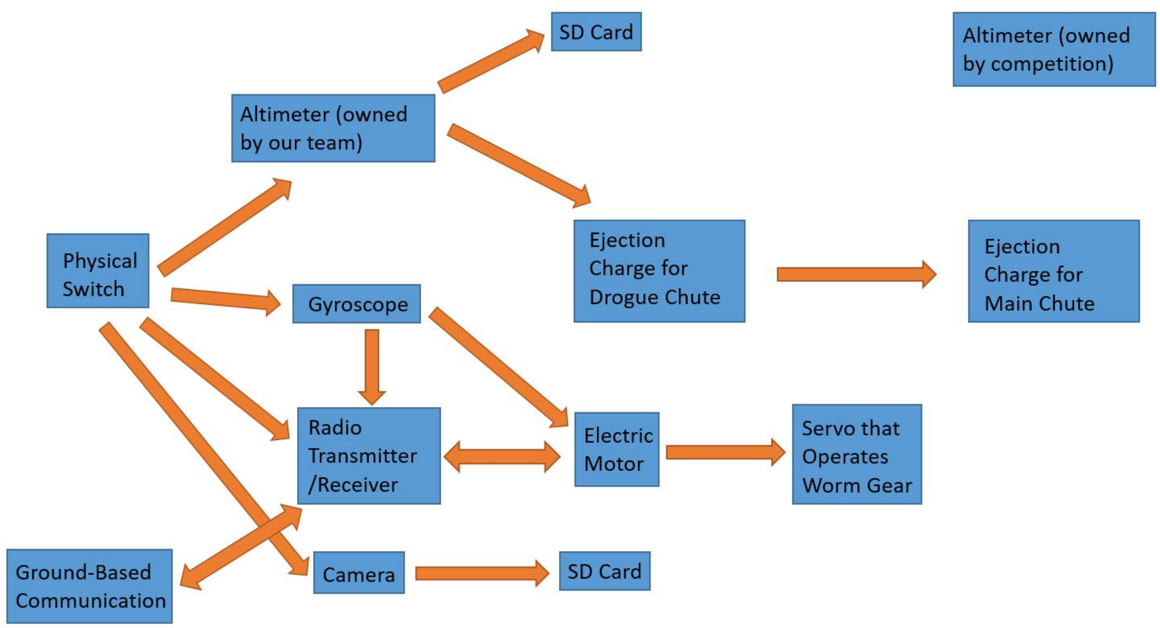


Figure 5: Block diagram of all electronics.

Design Features of Active Roll System

The roll control system will operate using two fins mounted 180 degrees apart from each other at the center of mass of the rocket. The fins will be made from the same material, 1/16th inch carbon fiber, as the fins located at the base of the airframe. The fins will be trapezoidal with a 4 inch base, and a 2 inch free edge. These fins will rotate about a horizontal axis to cause the rocket to roll without destabilizing the rocket. Both of the fins will be controlled by the same physical mechanism, powered by a servo with 180 degrees of travel. The mechanism itself will consisted of a simple gear system with a gear ratio greater than one, so that each fin will have less than 45 degrees of travel at its maximum roll. Each fin will be controlled by two radial gears constantly meshed with each other, the larger of which drives a worm gear to translate the rotation of the gears to the rotation of the fins. The radial gears will be made from aluminum so that they will be strong enough to withstand the stresses of operation, while not adding much mass to the rocket. The worm gear will also be made from aluminum so that the bending moment caused by the drag forces on the fins does cause a failure due to shear stress. The worm gear will also be rigidly mounted to the roll control fins. The entire system will be mounted inside of a payload bay, similar to Figure 6.

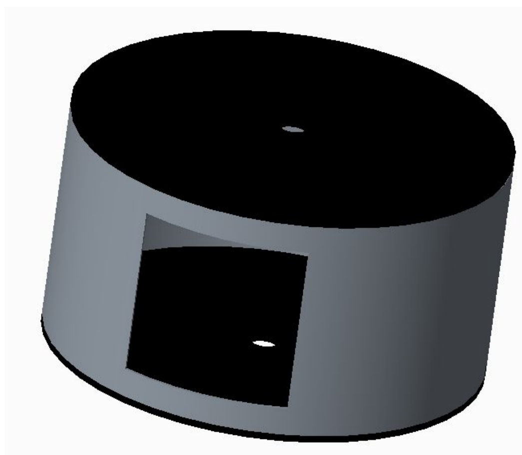


Figure 6: CAD Model of Payload Bay

The roll control system will be mounted at the center of mass of the airframe, with a fiberglass bulkhead protecting it on either side. These bulkheads will serve to protect the mechanism and electronics from the parachute ejection charges. The payload bay will be held in place with the brackets shown in Figure 7.

Figure 7: CAD Model of Elbow Bracket

These brackets will be fastened to the exterior body with the head of the fastener on the outside of the body in order to limit the amount of drag on the exterior. Each fastener will also be further secured with epoxy in order to prevent the fasteners from loosening during flight. Once closed, the door will be locked using a simple system that consists of two I-bolts and a quicklink, or other self locking carabiner. Both I-bolts will be secured to the airframe in the same fashion as the fasteners for the brackets. An example of the system locked is shown in Figure 7. Please note that Figures are not drawn to scale, and only serve to give visual examples of the design. A simple drag calculation was used to determine the amount of drag the exterior components would create. The following equation was used:

$$F_D = \frac{1}{2} \rho u^2 C_D A \tag{1}$$

In Equation 1, ρ is the fluid density, which would be air. A is the projected area of the object, u is the fluid velocity and C_D is the drag coefficient. With air density being 0.0024 slugs/ft^3, air velocity being 728.3 ft/s, projected area being approximately 0.042 ft^2 and drag coefficient being 0.665 at the maximum velocity the drag force will only be 100 N (22lbs) This number was calculated assuming the fins are locked in a perfectly vertical position.

In order to ensure that the added mass of the subsystem does not affect the stability of the rocket, The roll control system will be placed as close to the center of mass of the rocket as possible, even placing it a small amount closer to the nose cone so the center of gravity stays in the correct spot relative to the center of pressure.

In order to maneuver the rocket through the required rotations, the orientation control subsystem will rely on a triple-axis digital output gyroscope component. This board will track the position of the rocket in terms displacement through real time data, and work in conjunction with the servo motor that will rotate the fins in place. The servo will be connected to the gear assembly mentioned in the beginning of this section.

Safety Plan

Work on the rocket shall not be permitted unless there are at least two general members and the safety officer present in the work area. The safety officer makes the final determinations on who is allowed to use power tools, and ensures proper supervision during the use of power tools. The safety officer is also responsible for making sure that all members make proper use of personal protective equipment (PPE) while working. The minimum necessary PPE required are safety glasses/goggles, with other protective equipment like gloves, earplugs and respirators used when needed for certain tools and materials. Before the first construction session, the safety officer will ensure that all members have been informed of the health hazards associated with different areas of shop work, have taken all safety quizzes required by the University of Iowa and have signed the required paperwork. The University of Iowa adheres to the guidelines of the Occupational Safety and Health Administration (OSHA). An additional form written by the safety officer will be signed by all members, and details rules specific to the building process, to ensure competition rules are followed.

Materials:

-all epoxies will be handled with proper PPE (safety glasses, gloves, ventilation masks) in a well-ventilated area

-all power tools will be used by people trained in their use, with additional supervision

-no power tools will be used without the approval of the safety officer, and all power tools will be inspected before use to ensure that they are in proper working order

-all tools and materials will be stored in their proper places, with drawers and cabinets being labeled

-all electronics work will proceed with some type of grounding to ensure electrical safety

Risks to Successful Completion

-poor rocket design: Proper design of the rocket is crucial. An unsafe design will be prevented by following NAR guidelines for safe rocket design. These guidelines will be read by all members at the first meeting for design. The team mentor will be involved throughout the process, and will be allowed to have final say on the rocket's design.

-injury to members during construction: This will be mitigated by proper instruction of all members prior to use of power tools and/or hazardous materials, and through the proper use of PPE. All members will take safety quizzes as required by the University of Iowa, and will not be permitted into the workspace without successfully completing these quizzes.

-poor construction quality: Poor quality control during the construction phase could lead to the rocket breaking upon launch or while in the air, posing a threat to spectators. This will be mitigated by quality control throughout the construction process. Supervision will be provided, with more experienced members leading the construction process. Detail-oriented tasks will be performed slowly with proper materials to ensure quality.

-electronics failure: If our electronics package fails to work properly and does not send the correct signals through the circuits, then there are risks that the parachutes don't deploy. Proper electronics expertise will be applied in creating the electronics, but sometimes the components and solder do not properly conduct.

-shock cord failure: Our drogue chute is designed to slow the rocket in order to provide an appropriate speed for opening the main chute. The drogue chute must be opened properly, at the point of apogee, in order to provide ample drag and allow the main chute to open without issue.

-data collection: At the risk of our own altimeter failing to work, a secondary altimeter will be put into the rocket that will be able to record the data.

Operations during building and launch

The NAR/TRA mentor will either perform the preparation of the motor on launch day, or will assist team members in this process. Prior to launch, the safety officer and mentor will coordinate on launch day procedures, with the mentor having final say on who performs specific launch-related tasks.

Prior to construction of the rocket, all participating members will be trained in the use of power tools. Explanation of hazards in the work area, including flammable and hazardous materials, will be given in a mandatory meeting to be conducted by the team leader and safety officer. PPE will be worn by all members working on the construction process. Supervision will be provided when working with hazardous materials to ensure the safety of all members.

The pre-launch briefing will be planned by the safety officer and team mentor. This is to ensure that all important details are mentioned during pre-launch briefings. Pre-launch briefings will be conducted by the team safety officer and team mentor and will go over all important details of the assembly and launch process. These briefings will be mandatory for all members attending the launch, even if they will only be spectating. Only a few members will take the rocket to the launch pad, and they will be accompanied by a NAR/TRA member.

All written plans for the rocket will include pertinent safety information regarding the specific materials. Each member will be responsible for reading the given safety information before handling any hazardous materials. Prior to the first construction session, all participating members will be given a sheet detailing safety procedures and rules within the workspace. Members will be asked to sign these sheets as proof that they have read and understand the safety guidelines for the construction space. These sheets will be written by the safety officer, with input given by the team leader. All submitted materials required for the competition will contain the pertinent safety information as prepared by the safety officer.

Prior to the construction process, laws and regulations regarding flammable materials and fire prevention will be read. This is to ensure that safety is kept in mind throughout the construction process. Prior to launch, all regulations concerning airspace, fire prevention, and motor handling will be read through by all participating members, even if they will not be handling the motor. The NAR/TRA mentor will be consulted during this time to ensure that all members and the mentor are in agreement with launch procedures.

Any and all motors needed will be purchased through the NAR/TRA mentor, and will be kept by the mentor until needed for launch. The NAR/TRA mentor will assist the team in preparing the motor for launch to ensure safe use of the motor. Any other energetic devices that will be used in the rocket will be cleared through the mentor before being added to the rocket itself to ensure proper assembly and safe use. Storage and transport of the energetic devices will be coordinated with the mentor as needed.

All members will be given a written statement detailing safety regulations. This will include basic safety during the construction process, as well as details of safety before and during the launch. All members will be informed of the required safety procedures on launch day during the pre-launch briefing, and will be expected to listen to the RSO throughout the launch process and respect the RSO's final decision on the launch. The safety officer will coordinate directly with the RSO during the inspection to answer any questions and ensure that the rocket will be able to be safely launched.

Analysis of Anticipated Performance

This year's competition high powered rocket will perform adequately, and should follow similar calculations that our simulations follow using the OpenRocket software. These simulations are located in Appendix A. The simulations so far indicate that, using the Aerotech JT800-14 motors, we will achieve a maximum altitude of 1052 m, maximum velocity of 171 m/s, a maximum acceleration of 173m/s2, and a velocity off the rod of 18.3m/s. The approximate time to appogee is 14.1s, and the ground hit velocity well be roughly 12.5 m/s. These values were calculated from the simulations we found using OpenRocket.

Budget

The following is the allocated budget for competition in the 2018 Minnesota Space Grant Competition.

Table 3: Planned Budget

Body Frame:	Fiberglass Body Tube	$200
	Nose Cone	$50
	2 Centering Rings	$17.52
	5 Fiberglass Bulkheads	$6.53
	Carbon Fiber Fins	$120
Motors:	JT800-14	$80
	Black Powder	$20
Parachutes:	Main (36”)	$89
	Drogue (15”)	$53.62
	Kevlar Shock Cord	$17.50
Electronics:	Accelerometer	$18
	Batteries (9V)	$7
	Stratologger	$0 (already owned)
	Arduino	$0 (already owned)
	MicroSD card	$5
	Switch	$3
	Gyroscope	$15
	Servo Motor	$13
	Servo Trigger	$17
	Male to Male SMA	$1
	GPS and Antenna	$60

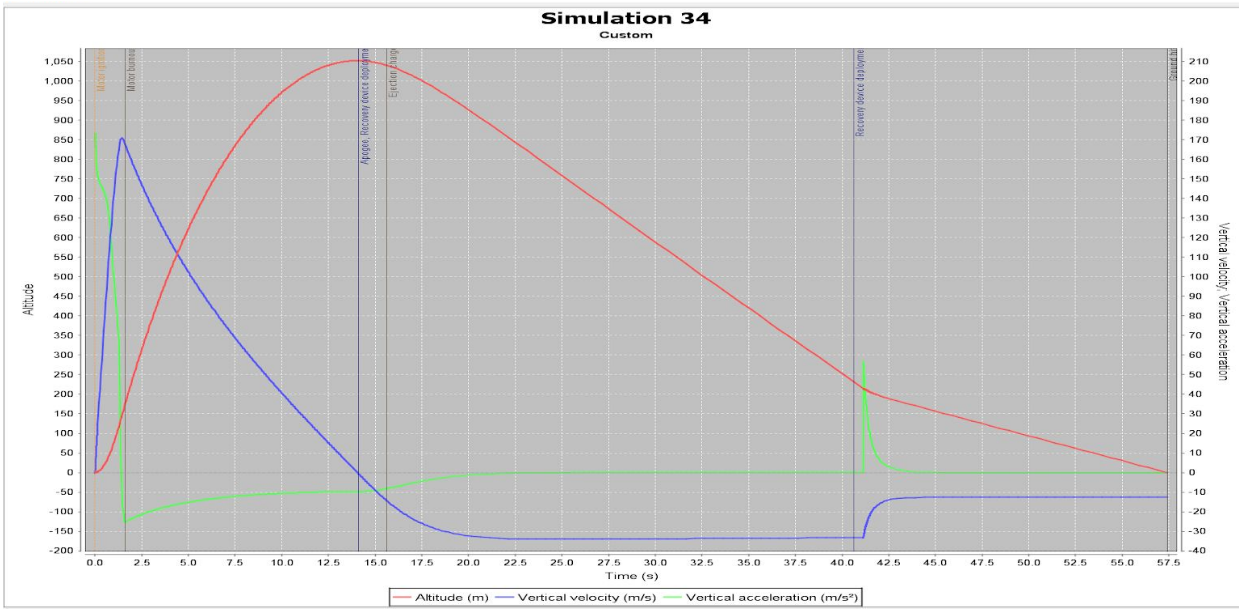
	Camera	$32
ROCKET COST:		$825.17

Travel Expenses:

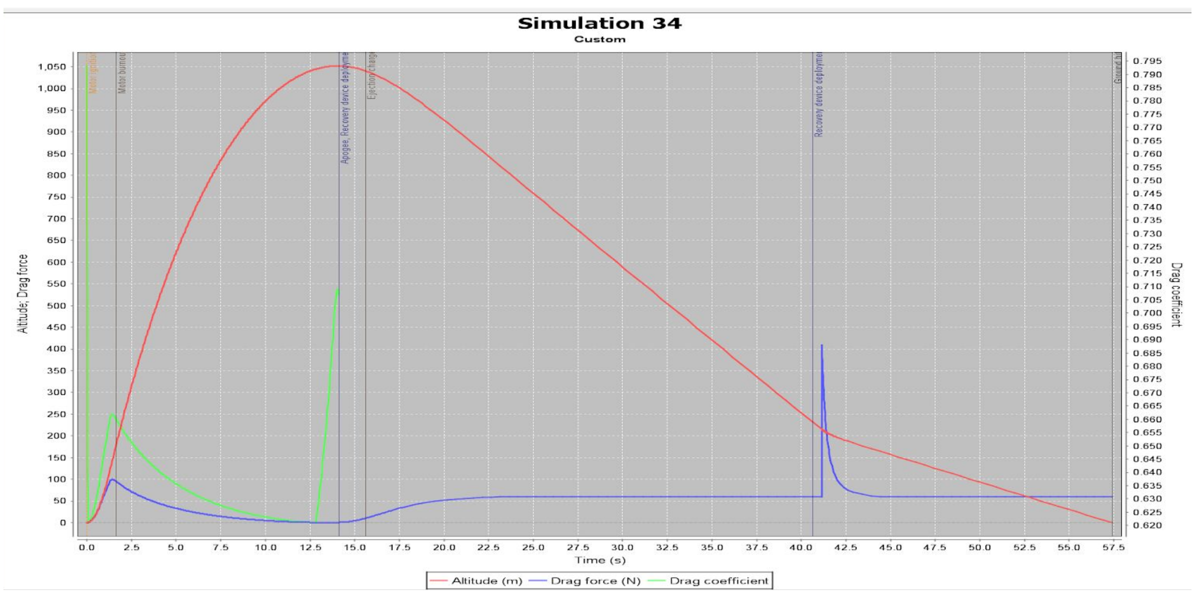
Cambridge, MN	May 19th-20th Crossings by Grandstay	$444.00 per night (for 3 rooms)
TRAVEL COST		$888.00

Total Expenditures: $1713.17

Appendix A



Altitude, Vertical Velocity, and Vertical Acceleration



Altitude, Drag Force, and Drag Coefficient.