FLIGHT READINESS REPORT

UST Rocket Team (RUST)

University of St. Thomas, MN

Mueller, Janelle M.Rajeep Lamichhane, Anthony Buchanan, Thomas Freas, Matthew Delk, Taig Volante, Adam Zopf, Nick Pumper, Stephen Bourne

Mentor: Dr. James Flaten
Advisors: Dr. David Forliti and Dr. Hassan Salamy

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Table of Contents

Team Information

Team Name: UST Rocketry (RUST)

School Name: University of St. Thomas

Team Mentor: Dr. James Flaten

Team Faculty Advisers:

Dr. David Forliti

dforliti@stthomas.edu

School: (651)-962-5750

Dr. Hassan Salamy

hsalamy@stthomas.edu

School: (651)-962-5758

Student Team Lead:

Janelle Mueller

Muel0119@stthomas.edu

Cell: (507)-450-2963

Student Team Members:

Janelle Mueller, Tristin Leonard, Justin Klassen, Tommy Pietsch, Rajeep Lamichhane, Anthony Buchanan, Thomas Freas, Matthew Delk, Taig Volante, Adam Zopf, Stephen Bourne

Executive Summary

For the 2018 Space Grant Midwest High-Powered Rocket Competition teams are required to design and construct a high-power rocket that 1) minimizes roll and 2) controls roll while flying to at least 3000 ft., recovering safely and in a flyable condition. Our teams design implements the use of moveable flaps on the fins to minimize and control roll. These fins are directed using servos secured into the base of the rocket which actuate based on sensors in the avionics bay (AV Bay). Our rocket, as seen in Figure 1, has a length from tip of the nose cone to bottom of the motor mount of 61 in., has an overall weight of 7.54 lbs., and an outer diameter of 4 in At our test launch (Saturday, May 5th) the rocket reached an altitude of 4980 ft.

Figure 1: Rocket on launch pad.

Teams are required to meet specific guidelines that include having a minimum altitude of 3000 ft., a landing speed < 24 ft/s, static margin of 0 < s < 5, and an onboard downward facing camera in addition to controlling roll. At our test launch, we were able to successfully fulfill most of these requirements. Our test flight altitude was 4980 ft., landing speed was 19 ft./s and had a static margin of 3. During our test flight we were unfortunately not able to retrieve video footage from our camera for unknown reasons. During our test flight, we were not able to track our rolling orientation or control it due to issues with coding. Another team did inform us, through their own pictures and video that our rocket was rotating (without rolling system activated) about 1 revolution per second. This information will be beneficial to the electrical members of our team for further coding and configurations. When working correctly our system will use rotational data from a gyroscope and magnetometer to measure rotation and correct it by actuating the servos. There were a few issues that occurred with our test flight that we will need fix before competition. Extra weight needed to be added to the nose cone before flight, which will be made more permanently. Our ejection charge did not go off at the proper time causing our shock cord to rip through about 12 inches of the lower rocket body and it drifted about a mile from the launch pad due to over-correcting the launch angle to avoid a newly planted field. Between now and competition we plan to fix and replace the damaged parts of the rocket and add more weight to the design to bring the apogee lower. At competition we will also angle the rocket into the wind more so that it will not drift as far as it did on our test launch. We will also be adding a more accurate GPS tracking system to track the rocket in addition to the radio beeper.

Rocket Mechanical and Electrical Design Features

The rocket is a custom-made single stage rocket that has five major compartments/sections including: the nose cone, top section, the avionics bay, the parachute bay, and the tail. Details of these areas are described below. The team decided to buy components separately and use a custom design because we thought that we would end up changing too much of a kit to fit our needs. With a custom rocket, we could focus on making sure the components will work for our needs and didn’t require changes to be made to a kit.

Nose Cone

The nose cone (Figure 2) is an ogive style nose cone ordered from Apogee Rockets. The nose cone is made of a durable poly-propylene plastic, is 12.5 inches long and has an outer diameter to match the rocket (4 in). The length of the nose itself is 9.5 inched and the shoulder length is 3 inches.

Figure 2: Nose cone. Photo credit to Apogee Rockets.

Top Section

The top section, as seen in Figure 3, is an empty compartment that houses the camera mount, the Altimeter, and the radio tracking antenna. This compartment is 9.65 inches long and made of Blue Tube. The top section rigidly attaches to the nose cone and to the AV Bay with removable plastic rivets.

Figure 3: Top section as attached to nose cone with removeable plastic rivets.

The top section has three hole locations for rivets to attach to the AV Bay and three holes for rivets to attach to the nose cone. The top section also has a wooden block (1.5 in. X 1.0 in.) epoxied to the inside of the tube for backing of the camera mount. There are then holes in the block and camera mount for screws as well as for the camera wires.

Avionics Bay

Our rockets main control system is a Raspberry Pi that works with a GPS, gyroscope, magnetometer, and altimeter to minimize and control roll. The avionics bay as fully assembled is depicted below in Figures 4 and 5.

Figure 4: Top of electronics sled comprising of the raspberry pi, camera, beeper circuit and raven.

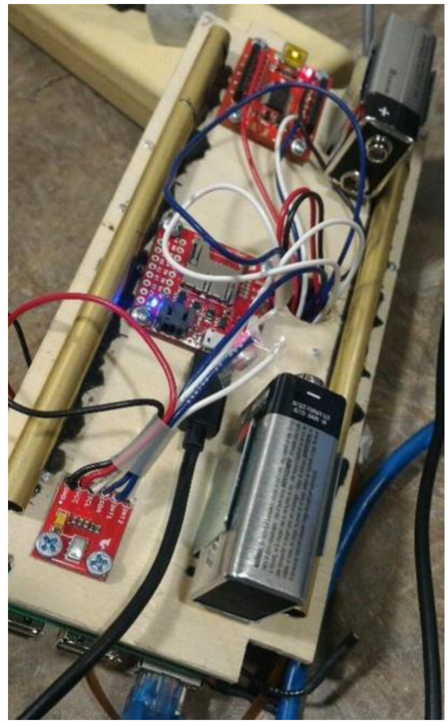

Figure 5: Bottom of electronics sled comprising of power sources (9V Batteries), altimeter, magnetometer, gyroscope, and GPS unit.

Active Roll/ Orientation System

The control system that is utilized in our rocket will be a Raspberry Pi with a 9DoF Razor IMU M0. This IMU offers up to 16g of accelerometer reading with up to 2000 deg/s for the gyroscope and has a 15µT/LSB accuracy. This amount of accuracy will be utilized in calculating the pitch of the wings and the current amount of rotation. This information will then be transmitted and manipulated within the Raspberry Pi, where the system will compensate current gyroscopic changes and rotations to the desired orientation through a PID controller. The following Figure 6 depicts the layout of our system. The gyroscope will be used to calculate the current change in direction, which can be compared against current rotation, measured by the magnetometer.

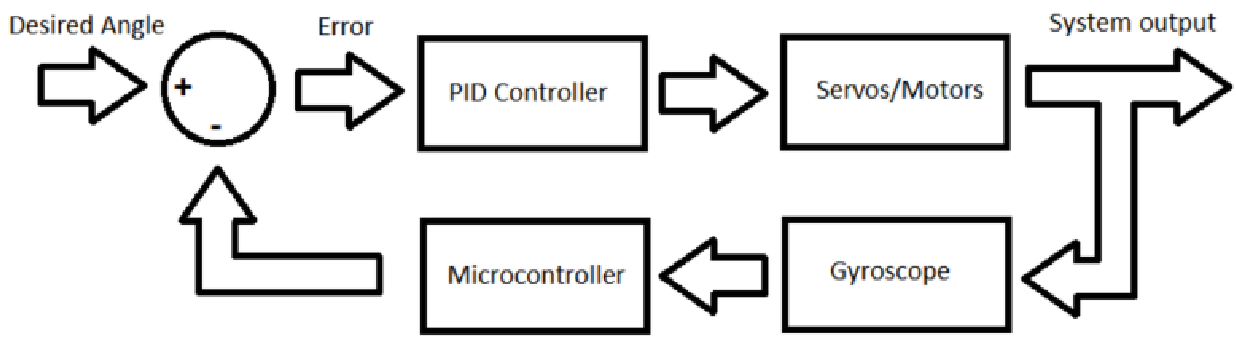

Figure 6: Layout of PID controlled roll system.

Rocket Recovery System

The recovery system of this rocket utilizes a two-part system to ensure fast, safe, and efficient recovery of the rocket. The first part of the design utilizes a small GPS module. The GPS information is then fed into the Raspberry Pi and transmitted to the control station. This will feed live positioning data analytics to the station, enabling us to predict landing location. This will give us enough information on relative location. The second part of the recovery system utilizes a piezo buzzer with a separate battery system. Upon parachute deployment, the buzzer will emit a loud tone to alert recovery team of its location. This will help to locate the rocket if landing in brush or weeded/ tall grassy areas. We will also have a radio tracking antenna attached to the inside of the rocket as a back-up recovery system to track down the rocket after the launch if it does drift out of sight.

Parachute Bay

The parachute bay (aka. The main body), as seen in Figure 7, is made of 40.16 in. of Blue Tube (98 mm/ 4 in OD). The parachute bay houses the 9ft long shock cord, the detaching servo wires, the 48 in. High Drag Toroidal Parachute. The parachute bay also includes two 1/8 in. vent holes to allow proper pressurization. One of the two rail buttons are located toward the top of the parachute bay as well.

Figure 7: Parachute (lower) bay of rocket.

Tail End (Servos and Fins)

The tail end of the rocket is very essential to the success and completion of this competitions parameters. The tail end of the rocket is where the motor mount, four fins, and two servos are located.

To secure the motor inside the base of the rocket, the motor mount tube and motor casing must be securely attached to the rocket main body. The motor mount tube for our rocket is a 54 mm Blue Tube motor mount tube (MMT) to fit our 54-mm motor and its casing. The motor used in this rocket is a Cesaroni J295 -16 A. The J295 -16A is a J-class high-powered rocket motor that is 2.13 in. in diameter, length of 12.95 in. and 2.47 lbs. This motor has a burn time of approximately 4.0 sec., a max thrust of 450.5 Newtons, and a delay of 16 sec. before motor ejection.

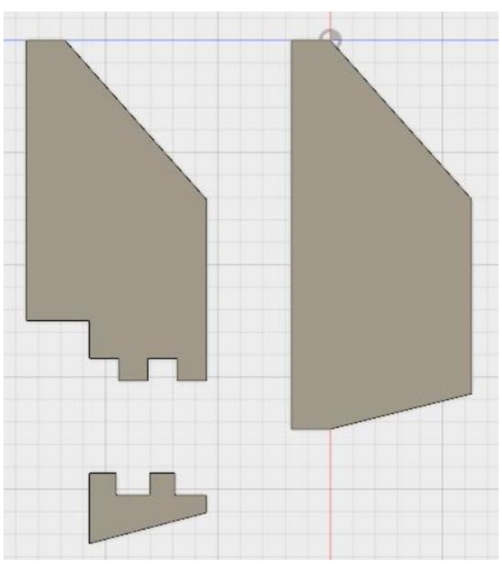

Figure 5: Fin design as to be cut-out in a laser cutter.

Each of the four fins for this rocket are custom-made and designed by the members of our team. Two fins have moveable flaps and the other two do not. As seen in Figure 8, there are two different styles of fins for our rocket.

Two servos are located inside the body tube between the motor mount tube and the fin locations in the main body tube. These servos are attached to moveable fins and are actuated to minimize and control the roll of the rocket.

Rocket Simulations

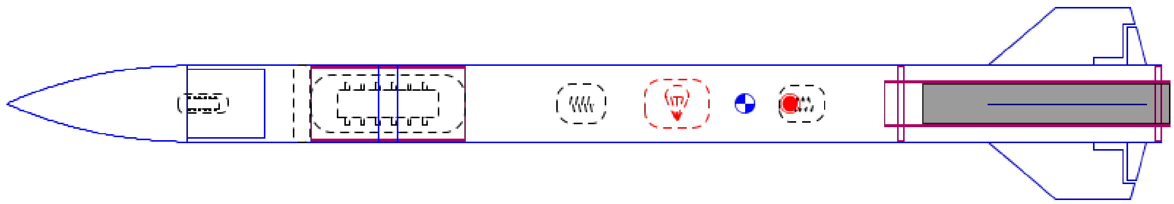

Figure 9: OpenRocket Preliminary Design

To determine many of the data values for our rocket we chose to simulate our rocket design in OpenRocket as this is a free and reputable software for rocketry. This Figure (9) distinctly shows the locations of the nose cone (far left), the avionics bay (behind nose cone), the parachute, motor housing, motor, and fins. It also provides a better visual for the shape and size of the fins in proportion to the entire rocket length. As seen behind the main fins, are smaller fins which represent the moveable flaps that we are using to minimize and control roll. The engineering parameters of this competition require each rocket to have a static margin between 1 and 5. This is a safety consideration so that a rocket that is too stable will not be flown in the competition. This rocket design has a stability of 2.37, which is comfortably in the middle of the 1 to 5 requirements. The center of gravity for this rocket is depicted in Figure 1 as the blue and white circle in the center area of the rocket. Our CG is located at 39.908 inches from the tip of the nose cone. The center of pressure for this rocket is depicted in Figure 1 as the red circle. The CP for this rocket is located at 49.404 inches from the tip of the nose cone. These two values result in the 2.37 stability value.

Preliminary Flight Analysis

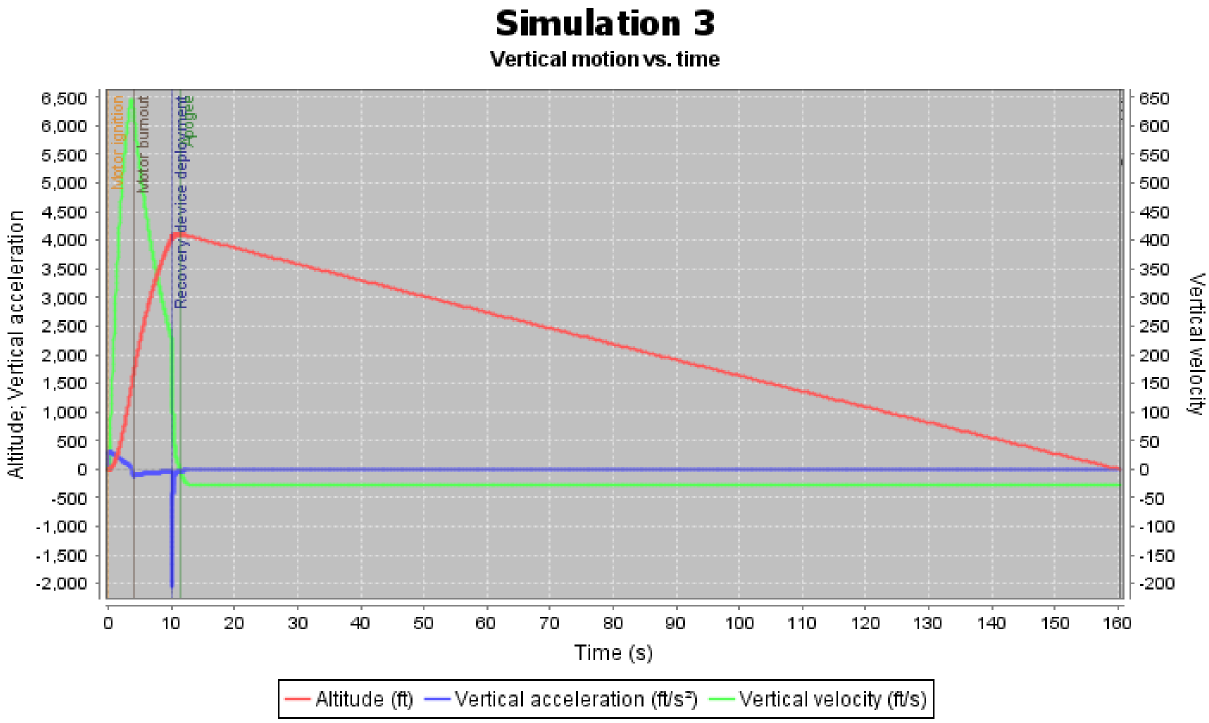

Figure 11: Flight data of rocket with J295 motor.

We used OpenRocket to simulate the characteristics of our rocket throughout the entire construction and leading up to competition. Figure 11, above, is one of the plots that was created using our current rocket design. From this plot one can see the altitude (red), vertical acceleration (blue), and vertical velocity of the rocket (green) vs. time. It is shown that the total time for this launch is approximately 160 seconds. The estimated maximum altitude is 4097 ft. in this simulation. The estimated peak velocity is 645 ft./s and the estimated peak acceleration is 297 ft./s^2. The vertical velocity off the rod is 65 ft./s. The estimated ground hit velocity is 26.8 ft./s. Coast time is approximately 12.36 seconds. This data was calculated by running a simulation under normal conditions on OpenRocket. As our team is fairly new to rocketry and OpenRocket, we were aware that there would be some discrepancies and error but we tried to update it frequently to make it as accurate as possible.

Budget

The funding for this project is coming from multiple sources. The major source of the money comes from USG, the University of St. Tomas Student Government. This is where money for clubs and events comes from. To get money from USG a club must request money to be transferred to the clubs account and can then be used for projects, club events, and other expenses. The student lead for this team has been coordinating with one of the lab faculty members to order most of the parts and have them shipped directly to the labs. This allows for the faculty member to use his credit card and get reimbursed from the clubs' funds and from the engineering department. This budget, as seen below in Table 1, was calculated from the total costs of materials, launch-related items, as well as competition-related costs. The total budget for this rocket is $1,869.22. The details are described below.

Table 1: Budget by item.

Item	***Cost***	***Quantity***	***Total Price***	***Comments***
MECHANICAL PARTS				
Cesaroni P54-3G Classic (J295 Motor)	$ 91.50	4 – $100 from registration	$ 266.00	
Cesaroni 54mm 3-Grain Motor Case	$ 69.39	1	$ 69.39	
Nose Cone	$ 19.95	1	$ 19.95	
Parachute	$ 146.59	1	$ 146.59	
Forged Eye Bolt	$ 5.51	2	$ 11.02	
Rail Button	$ 3.22	2	$ 3.22	
54 mm motor mount tube	$ 23.95	1	$ 23.95	
Aero Pack Motor Retainer	$ 39.02	1	$ 39.02	
Airframe (Blue Tube)	$ 38.95	2	$ 77.90	
Standard Coupler (Blue Tube)	$ 10.95	1	$ 10.95	
Blue Tube Electronics Bay (+bulkheads)	$ 41.95	1	$ 41.95	
Centering rings for the motor	$ 4.25	2	$ 8.50	
Fire Retardant Blanket (24 in. square)	$ 15.85	1	$ 15.85	
Shock Cord	$ 22.50	1	$ 22.50	
JB Weld	$ -	1	$ -	
3M DP-420 Black Epoxy Adhesive	$ 23.64	3	$ 70.92	
ELECTRICAL PARTS				
Metal Gear Servo	$ 23.90	2	$ 23.90	
Spy Camera for Raspberry Pi	$ 39.95	1	$ 39.95	
Raspberry Pi 3	$ 39.95	1	$ 39.95	
SparkFun 9DoF Razor IMU MO	$ 34.95	1	$ 34.95	
Altimeter/Pressure Sensor	$ 14.95	1	$ 14.95	
SparkFun XBee Explorer USB	$ 24.95	1	$ 24.95	
SparkFun XBee Explorer Dongle	$ 24.95	1	$ 24.95	
USB Mini-B Cable - 6"	$ 1.95	1	$ 1.95	

Xbee	$	39.00	2	$	78.00	
900MHz antenna	$	7.63	2	$	15.26	
Buzzer	$	3.55	1	$	3.55	
MISCELLANIOUS MATERIALS						
Modeling Clay/ "Dough"	$	3.76	1	$	3.76	
Latex Gloves	$	3.59	1	$	3.59	
9V batteries	$	12.99	1	$	12.99	
Reynolds Wax Paper	$	1.49	1	$	1.49	
Up and Up Paper Towels	$	0.99	1	$	0.99	
Up and Up Disposable Cups	$	3.49	1	$	3.49	
"Craft Sticks" (Popsicle Sticks)	$	1.99	1	$	1.99	
Satin Paprika Spray Paint (Rust colored)	$	3.85	1	$	3.85	
Gloss Grape Purple Spray Paint (UST color)	$	3.85	2	$	7.70	
Ult. Lithium 9V Battery	$	7.97	1	$	7.97	
Head of Cabbage	$	1.48	1	$	1.48	
OTHER EXPENSES						
Competition Registration Fee	$	400.00	1	$	400.00	
Gas	$	45.41	52.4 mi*6	$	45.41	
Hotel Cost (1 night)	$	85.00	1 night * 2 rooms	$	170.00	
New Fire Blanket	$	13.99	1	$	13.99	Ripped during test
New Rail Buttons	$	3.22	2	$	3.22	Lost during test
New/Longer Shock Cord	$	17.00	1	$	17.00	Ripped during test flight and was slightly too short
Metal Shot	$	15.59	1 lb	$	15.59	To add weight
Frosting Bag	$	5.00	2	$	10.00	To add weight
9V Batteries	$	12.99	3	$	12.99	New Batteries
			Total	**$**	**1,869.22**	

Rocket Construction

Figure 12: Beginning stages of the construction/building process.

Construction of this rocket from top to bottom was as follows (did not build necessarily in this order).

The nose cone is made of a poly-propylene durable plastic and was manufactured by Madcow Rocketry. The nose cone has three holes located equally, 120° radially, around the shoulder of the nose cone to insert removeable rivets between the nose cone and the top section.

The top section was cut out of 4 in. OD Blue Tube like most of the rocket body. This top section connects the nose cone and the top of the avionics bay. While our rocket is a single-deploy, this section is held onto the nose cone and AV Bay by removeable rivets as it does not need to disconnect. A wooden block was epoxied on the inside diameter of the top section to provide a strong backing for the camera mount.

The camera mount (as seen in Figures 13 - 15) was made of PLA plastic and 3D printed using the school's 3D printers. The camera mount is designed to hold the camera snuggly into the mount for optimal viewing of video footage and to fit snuggly against the outside of the rocket while being aerodynamic. For added support to keep the camera in its desired location and minimize rattling, modeling clay is pushed into the open compartment of the camera mount. This camera mount is rather small, as our camera is very small, which minimizes extra drag from the camera mount. The camera mount is fastened onto the body with four wood screws that screw into the wooden backing block.

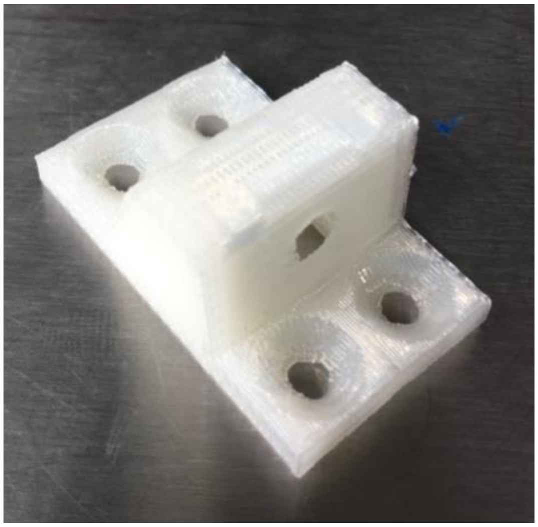

Figure 13: Front view of camera mount. Four holes for placement of wood screws to secure to rocket body and an angled hole for the camera lens.

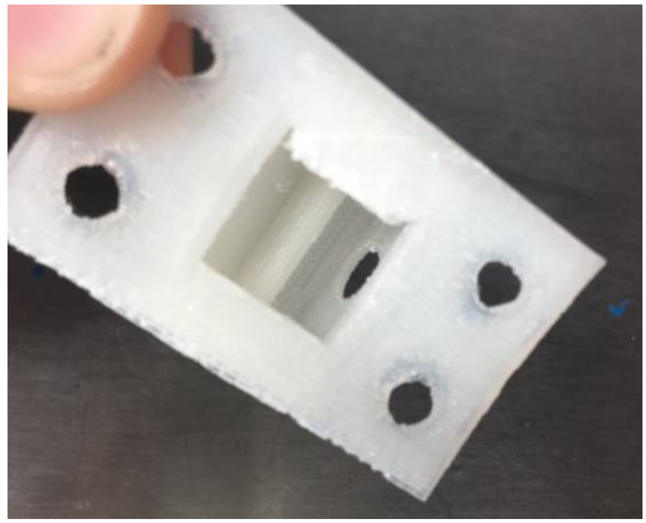

Figure 14: Back side of camera mount. Small shelf to hole camera into place.

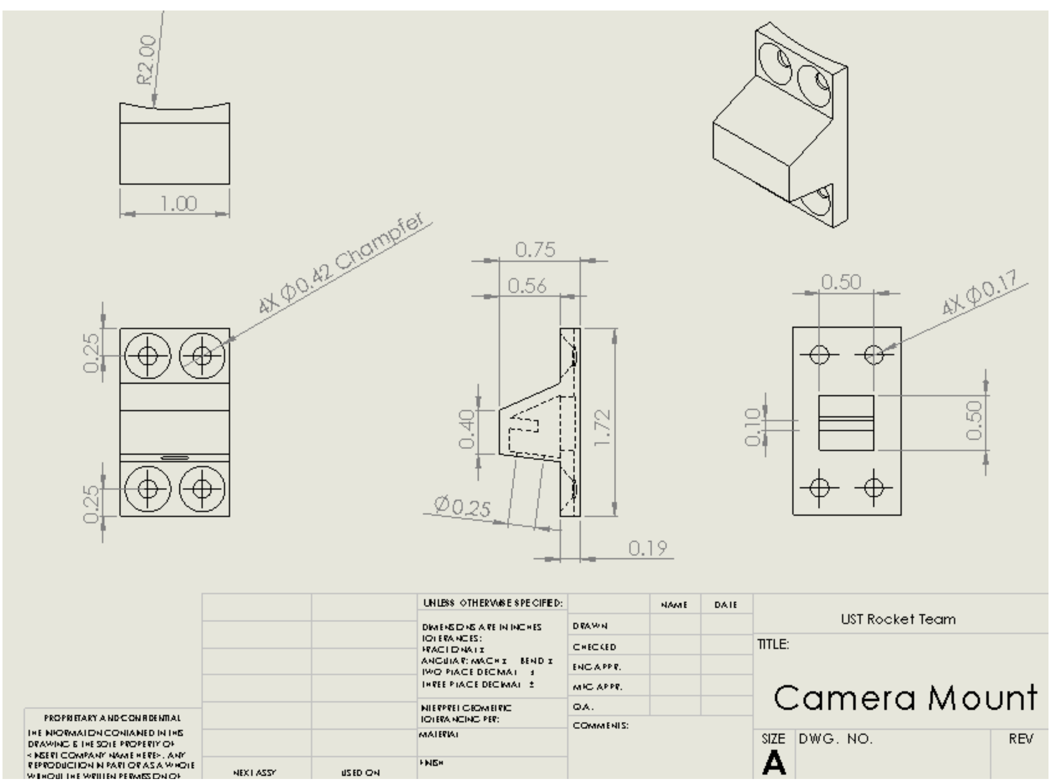

Figure 15: SolidWorks drawing of camera mount.

The avionics bay was built and assembled using Always Ready Rocketry's Blue Tube 2.0 Electronics Bay. The electronics bay physically consists of a coupler, outside band, bulkheads, altimeter sled, threaded rods, and brass tubing. We modified and cut a new altimeter sled to create more space for the electronics to sit within the AV Bay. We decided to use a pre-made electronics bay because this is the first time that our team has built a high-powered rocket and it would save us time by using a pre-existing AV Bay design.

The parachute bay (aka the main body) was also constructed from 98 mm (4 in. OD) Blue Tube. The team decided to use Blue Tube as our main material for the body of the rocket as it is inexpensive, easy to work with, and strong. We also do not have the proper facilities to work with fiberglass and carbon fiber and wanted to have a material that we could do in house at the University of St. Thomas. The parachute bay has two 1/8 in. pressure vent holes to help the parachute bay pressurize properly as well as locations for the two rail buttons. The parachute bay houses the ejection charge, the disconnecting servo wires, the shock cord, and the parachute.

The ejection charge is controlled by the Raven 3 and is set to activate no earlier than apogee is reached. If the required electronic charge fails, the motor eject will go off shortly after as a fail-safe if the first charge doesn't go. Because of the size of our rocket, the ejection charge requires 2.4 grams of Pyrodex gun powder. Also, due to our maximum altitude and time to reach apogee, the secondary motor charge (fail-safe) requires that 0.8 grams of Pyrodex be added to the motor ignition. In Figure 16 below, Justin works to connect electrical components.

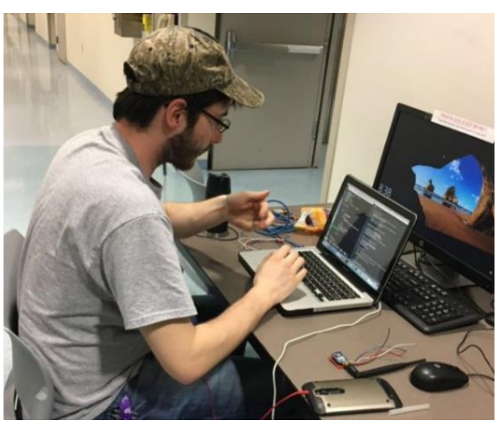

Figure 16: Justin configuring certain electical components.

The disconnecting servo wires that are held within the parachute bay connect to the servos in the very bottom of the rocket. These wires are rigidly connected to part of the shock cord with tape and epoxy. The shock cord is folded down and the wires are connected to the servo wires that go up to the AV Bay by a quick release clip. This design allows for the wires to safely disconnect from each other when the ejection charge goes off and the rocket separated between the parachute bay and the AV Bay. The wires and their connectors are epoxied to the shock cord when it is slightly folded is so that when the shock cord is pulled out (with lots of force) the wires are not pulled taught, instead they still have a little slack and will also not get tangled in other things like the parachute.

The parachute that we are using for this rocket is a large 48 in. toroidal parachute from Fruity Chutes. This parachute is slightly too large for our rocket and therefore drifts a lot during its flight, however with the time we had, we were not able to find one better for the specific size and weight of our rocket. It does, however, bring our landing speed down to 19 ft/sec which meets the requirement for landing speed < 24 ft/sec.

Two wooden bulkheads are epoxied to the MMT and the outer body to keep the motor mount tube in place. A motor casing is slid into the MMT and includes a rear motor closure and a motor retainer that keep the motor inside and attached to the MMT as well as provide a heat barrier between the motor and the Blue Tube materials.

Figure 17: Final installation of the motor mount tube and motor retainer.

For symmetry, there are four fins that are located 90° away from each other around the rocket base. These fins, as seen in Figure 18 are made from 0.25 in. plywood and were precisely cut using a laser cutter. A fin alignment jig (as seen in Figure 19) was created to aid in position accuracy of the fins once epoxy was added. Two of the fins have a moveable flap that are controlled by the servos and held on with a small steel rod and the other two fins are regular sized without the moveable flap. The alike fins are 180° from each other. Therefore, as the rocket is turned the fins alternate between regular fin, moveable fin, regular fin, and moveable fin. This design allowed for smaller forces and movement requirements of each fin as well as the ability to keep stability if the servos fail. The fins are attached to the Blue Tube by sliding through slots and epoxied to both the motor mount tube and the main body tube. The slots for the fins and servos was cut into the Blue Tube body using a mill. For extra reinforcement, epoxy fillets were added along connection points between fins and Blue Tube.

Figure 18: Custom-made laser cut wooden fins.

Figure 19: Use of fin alignment jig to align fins while epoxy dries.

Two servos are also attached to the main body tube as well as the MMT. Figure 20 depicts how the servos are connected and fit together with the fin. These servos are attached to the moveable fin flaps on the corresponding fins by epoxying the servo horn to the wooden fin. A small hole was drilled through the fins to create a hinge that allows the moveable flaps to move freely once actuated by the servos. The servos themselves are rigidly attached to the main body tube and the MMT by sliding into fitted slots in the body tube and using strong epoxy all around. The cords that are required to actuate the servos are snaked through a small hole in the top bulk head of the MMT and up through the parachute bay. This small hole was then filled the rest of the way with modeling clay to close off the area from the motor burnout.

Figure 20: Servo and fin attachment.

Test Flight and Assessment

Our test launch was performed on Saturday, May 5th. We were only able to complete one test flight as there were a few issues during our flight. Right before launching, we noticed that the Center of Gravity (CG) and the Center of Pressure (CP) were too close to each other, leading to instability. To counteract this, we added extra lead sinkers into the nose cone on the spot and packed them full and tight with packing peanuts. Because of this added weight, our rocket didn't reach the same altitude we had originally seen on the Open Rocket simulations. This lead to the possibility that our ejection charge delay on the motor was too long and wasn't corrected after the additional weight. Possible because of this, the rocket started falling after apogee about 200 ft. before the ejection charge. We are unsure why it happened late as our electronic charge should have gone off right away after reaching apogee. After recovering the rocket post-flight, we noticed that indeed both the electronic charge and the motor charge did go off but are not sure as to which went first and why the electronic charge didn't go off at apogee. Because of the rocket rapidly descending after apogee, the shock cord ripped through the upper half of the parachute bay causing a zipper in the side of the main body tube. The damage from this incident is seen in Figures 22 and 23. This also caused the fire blanket and the shock cord to scrape their way down the side of the rocket and to partially tear. As seen above in the budget, these two components will need to be replaced before competition. During this event the raspberry pi's cords got yanked and we were not able to record any rotational data or other information from the pi. For unknown reasons, maybe related to the yanking of the pi, were also not able to retrieve camera data unfortunately. Another team, however took pictures/video footage and

Figure 21: Recalculating and marking CP and CG.

said that the rocket was rotating about 1 rotation per second.

Figure 22: Close-up of zipper caused by the shock cord.

Figure 23: Length of zipper in proportion to the rest of the rocket.

Figure 24: Angle of departure for the rocket as angled to avoid newly planted field.

Another, slightly less critical, issue that we ran into during our test flight was the very long drift after the rockets parachute was deployed. Because this rocket is a single-deploy and has one larger parachute it reaches the ground much slower than others who have a dual-deploy. However, because our parachute is slightly too big for the size and weight of our rocket, the rocket drifts very far. We also over corrected the angle of launch, as seen in Figure 24, as we were trying to avoid landing the rocket in a newly planted field. Because we were trying to avoid this field, we moved the launch pad and angled the rocket slightly with the wind instead of into the wind. This overcorrection also caused the rocket to drift even further, reaching a total drift distance of 1.1 miles. After the flight it was difficult to find the rocket and had to spend almost an hour finding it with a radio beeper. For the competition we will be adding a more accurate GPS tracking system so that recovering the rocket will be easier. Changing to dual-deploy isn’t a viable option for us with so little time, so at competition we will make sure to angle the rocket into the wind a bit before launching to minimize the length that it drifts. We will also be fixing and replacing the broken parts of the rocket and adding more weight to help lower the altitude, thus making it less likely to catch the high winds.

The data retrieved from the test flight as included below in Table 2.

Table 2: Data collected from Altimeter Two and the Raven 3.

Data collected from Altimeter Two:	**Data collected from Raven 3:**
Apogee: 4980 ft.	Average PreLaunch Altitude (ft) = Val: 794.00
Top Speed: 521 mph	Average PreLaunch Axial (Gs) = Val: 1.15
Thrust: 3.6 sec.	Average PreLaunch Axial Offset = Val: 1.15
Peak Acceleration: 9.2 G's	Axial Accel (Gs) = Min: -3.61 Max: 18.10
Average Acceleration 6.6 G's	Baro (Atm) = Min: 0.8082 Max: 0.9716
Coast to Apogee: 13.3 sec.	Current Draw (A) = Min: 0.06 Max: 0.13
Apogee to Parachute Deployment Charge: 3.8 sec. ***This is an issue.	Flight Count = Val: 25.00
Ejection Charge Altitude: 4788 ft. *** ~200 < Apogee	Lateral Accel (Gs) = Min: -1.58 Max: 1.49
Descent speed: 13 mph	Motor Ignition Time (sec) = Val: 0.180
Total Flight Time: 271.7 sec.	Temperature (F) = Min: 105.27 Max: 105.48
	Time (sec) = Min: 0.000 Max: 20.330
	Velocity (Accel-Ft/Sec) = Min: 0 Max: 962
	Volts Battery (V) = Min: 8.72 Max: 8.96
	Volts Pyro Apogee (V) = Min: 0.00 Max: 8.98
	Volts Pyro Main (V) = Min: 0.00 Max: 0.00
	[Altitude (Accel-Ft)] = Min: 0 Max: 7882
	[Altitude (Baro-Ft-AGL)] = Min: 0 Max: 4981
	[Altitude (Baro-Ft-ASL)] = Min: 794 Max: 5775
	[Velocity (Accel-Ft/Sec)] = Min: -87 Max: 948
	[Velocity (Accel-MPH)] = Min: -59 Max: 646

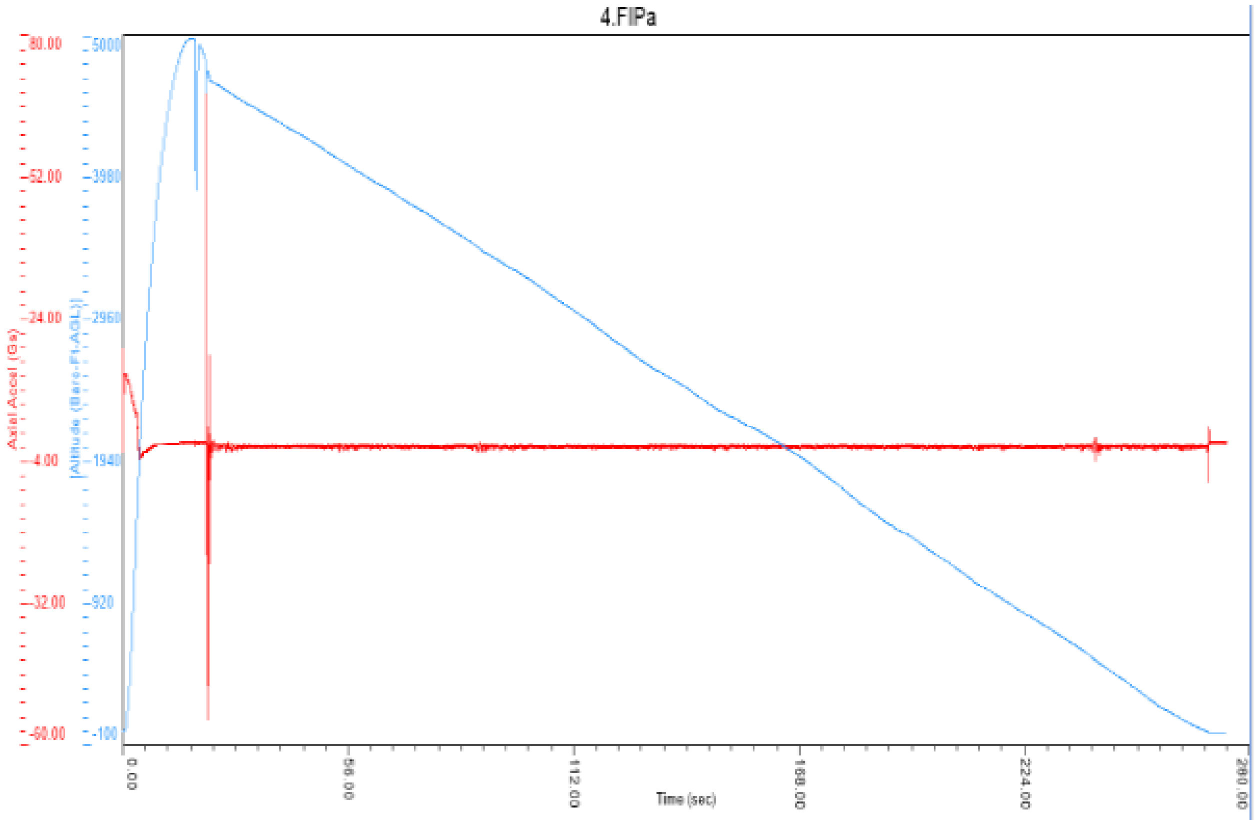

Figure 25: Graph of acceleration (red) and altitude (blue) during course of the flight.

One big concern that we have found with the raven data is the minimum velocity. According to the raven, the minimum velocity that our rocket achieved is 59 mph. This is not what is supposed to happen as the rocket reaches its apogee. When a rocket reaches apogee, it should ideally reach a value of 0 mph as it peaks. We will also need to more accurate calculations and simulations in Open Rocket before the competition launch to make sure that our information of CG and CP are accurate as they were not before our test flight.

Another concern that we have found in the data from the test flight is the altitude drop between apogee and when the chute deployed. Our total apogee was 4980 feet according to the raven and the parachute deployed at an altitude of 4200 feet. The 700 feet drop in altitude allowed our rocket to reach a velocity of approximately 60 mph. This data contradicts the data received the Altimeter 2, which says that the rocket only dropped 200 - 300 feet from apogee to parachute deployment.

There was no roll orientation data retrieved during this test launch as the raspberry pi was yanked and disconnected before the end of the flight.