PRELIMINARY DESIGN REPORT

UST Rocketry (RUST)

University of St. Thomas

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Table of Contents

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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. and recovering safely. Our teams' design implements the use of moveable flaps on the fins to control and minimize roll. These flaps will be manipulated by control rods that are then moved by servos.

Introduction

UST Rocketry (RUST) is a team of undergraduate engineering students who strive to gain experience on a large-scale project, make connections, and expand their engineering knowledge. The Space Grant Midwest High-Power Rocket Competition is a competition that gives students the chance to put their engineering knowledge and skills to the test. This competition requires student teams to design and build a high-power rocket based on certain engineering parameters and goals. This year's objective is to design and construct a roll-orientable high-powered rocket. This rocket must be able to minimize the natural tendency to roll on the first launch, and to control roll into certain configurations on the second run. Teams must be able to record direction of roll using a downward facing camera, as well as collect other performance data of each flight. Our team is still in the early stages of the design process and am eager to continue developing the final design of our rocket. We are planning to use a custom-built rocket with moveable flaps on the fins to control roll. Flight simulations will be done with OpenRocket and other simulations may be done using software such as SolidWorks, MATLAB, and ANSYS.

Mechanical Design Features

The rocket will be a single stage rocket that has four major compartments/sections including: the nose cone, the avionics bay, the parachute bay, and the tail. The nose cone is made of a durable poly-propylene plastic and is ~17 inches long and has an outer diameter to match the rocket (4 in). The avionics bay (aka. The electronics bay) will contain all the needed electronic systems to control our rocket. These electronics must be able to be easily accessible for competition and for ease of use during construction of rocket and for launch preparation. The avionics bay will be approximately 10 inches long with the outer body diameter of 4 inches and be made of blue cardboard material. The electronics bay in our rocket will contain a gyro to recognize roll orientation during flight. It will also contain a unit with servos that will control the flaps on the fins, to minimize and control roll. The parachute bay will also be made of 4 in. diameter blue cardboard material. This section will extend from the distance between the avionics bay and the bulkhead before the motor (approx. 20 inches on inside). The parachute bay will contain a parachute that is of the correct dimension for the size of our rocket. The parachute bay will contain a 60inch diameter parachute necessary to maintain a descent speed under 24ft/s. The system that we are thinking of controlling roll with uses some sort of connecting rods between the servos in the avionics bay and the fins in the tail area. These rods will have to pass freely and without interference by the parachute and the shock cords. The tail area of the rocket will contain the motor casing, the motor, centering rings, and the fins. The motor that we will be using is the Cesaroni J295. This motor is 54mm in diameter and is 329 mm long. This motor also weighs 1119.0 g. This motor was chosen because it fit the needs of the competition requirements as well as our rocket requirements. The fins of this rocket will likely be made of a durable plastic like the nose cone or fiberglass. The fins will have to be redesigned and made so that they can have moveable flaps. This will be part of the mechanism that controls roll. The flaps on the bottoms of the fins will be connected to a servo unit and gyroscope by connecting rods of some sort. These flaps will allow the rocket to adjust to minimize roll and to control roll in a way that is very unlikely to interfere with the yaw and pitch balance of the rocket.

Electronic Design Features

As stated in the engineering parameters of this competition, teams must put together a data collection electronics unit that is made up of components that are non-commercially sold for rocketry. This array of electronic components includes a camera to catch visual data, an SD card, a raspberry pi or Arduino processing unit, an altimeter, GPS Tracking, an accelerometer, a gyroscope to detect roll orientation, and some source of power such as a battery. The details of each of these components has not been determined at this time.

The Rocket Design

The preliminary rocket design that we have is a rocket that will safely meet our requirement needs. The team decided to design a custom rocket with some components than can be bought separately instead of a kit. We chose not to go with a kit because we thought that we would end up changing too much of the kit to fit our needs. With a custom rocket, we can focus on making sure the components will work for our needs and won't require changes being made to a kit. This rocket is 68.5 inches long and has a diameter of 4 in. The estimated weight of this rocket is 9.9 lbs., including the weight of the J295 motor. The team decided to go with this rocket design and motor configuration because it meets our requirements such as the need to go at least 3000 ft. This rockets apogee is at a height of 4117 ft. Off the rod our rocket design will have a velocity of 44.7 ft./s and reach a maximum velocity of 645 ft./s. The maximum acceleration of this design is 297 ft./s^2. The ground hit velocity is also very close to the required ground hit velocity of 24- ft./s. The ground hit velocity of this rocket with the use of a 60-in. parachute is 26 ft./s. The rocket has three identical fins located each 120° radially around the 4-in. diameter body tube. These fins are tentatively going to be made of a durable plastic like the poly-propylene in the nose cone or of fiberglass. The team will also attach moveable flaps to these fins to control roll. A video camera will be located towards the top half of the rocket, behind the nose cone to record visual data of the rocket's roll. Given the weight of our rocket as 10 lbs. The weight given in Newtons is 44.5 N. This value is important as our thrust to weight ratio should be 5:1. With the Cesaroni J295 motor we chose, the thrust is 295 N. Our thrust to weight ratio is then 6.6.

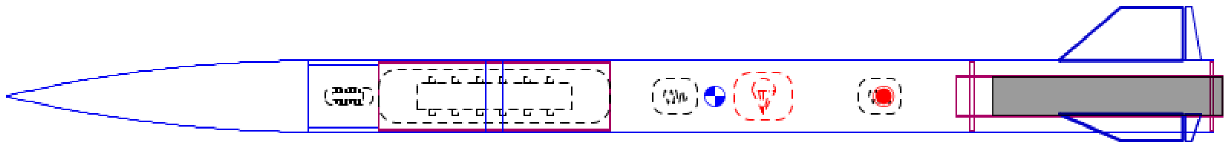

Figure 1: OpenRocket Preliminary Design

To determine many of the values listed above, we chose to simulate our rocket design in OpenRocket as this is a free and reputable software for rocketry. This figure 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 rolling flaps that we will be 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. A rocket that is too stable when acted on by wind may turn into the wind, causing it to possibly travel laterally and too low to the ground when the explosive charges for the parachute go off. A rocket that is unstable is also an issue, as unstable rockets often rotate too much causing it to flip into a direction that is not vertically up. This rocket design has a stability of 2.37, which is comfortably in the middle of the 1 to 5 requirements. The stability is a factor that is determined based on the locations of the center of pressure and the center of gravity in relation to each other and in proportion of the whole length of the rocket. 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

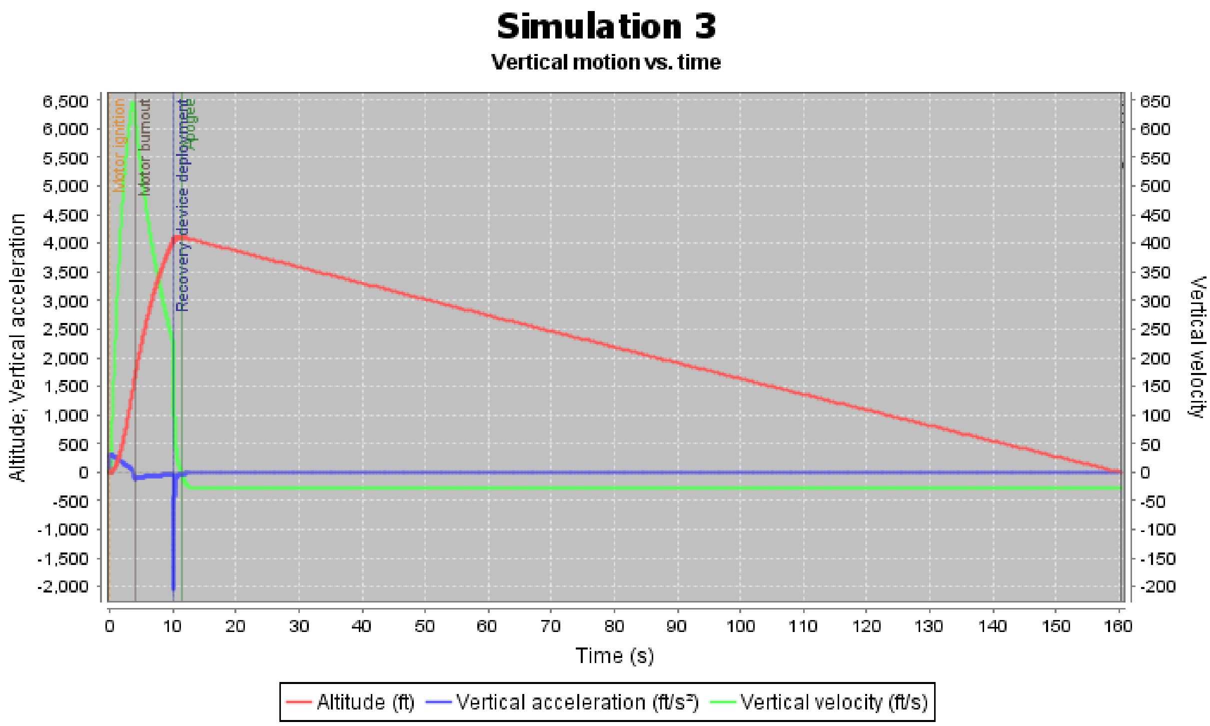

Figure 2: Flight data of rocket with J295 motor.

As a rocket cannot be tested merely from physical launches, simulations need to be run to ensure the safety of the rocket that is going to launch. The simulation software that the team will be using throughout the construction of the rocket leading up to competition is OpenRocket. OpenRocket allows users to design and simulate all aspects of a rocket. The simulations provide users with graphs of specified variables. Figure 2 is one of these 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. During the first seconds during burnout, the rolling mechanism is not allowed to be activated. The rolling mechanism must be activated within three seconds after burnout. This data was calculated by running a simulation under normal conditions on OpenRocket. As this team is new to rocketry and open rocket, we believe that there is likely to be some discrepancies and error but these errors will resolve as we start to build our rocket and are able to put in more accurate information about the rocket.

Budget

The money to fund this project and the competition for this team will be coming from a couple different locations. The major source of the money will be coming from USG, the University of St. Thomas 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. We will be asking for about $2,500.00 to cover the cost of the rocket parts as well as the hotel and registration expenses. Another source of money that we plan on utilizing is the NASA Space Grant matching money. NASA Space Grant money will match the school provided money up to $1000.00. This will in total provide the team with approximately $3,500.00 to cover all expenses of the rocket and the competition expenses. We do not have an itemized and finalized budget for each part of the rocket yet, but will be working on that right away. Some items that we may need include the following. If prices and details are known, the price is also attached.

- Nose cone - Apogee – 4” OD. – Length 16.5” – Poly-propylene plastic – 298.1 g – $21.95
- Parachute – 60 in.
- Motor Casing – Cesaroni 3-Grain Case (PN: 71032)- 54mm – Length: 12.21 in. - $69.39
- Motor – Cesaroni J295 – Length 329mm –Mass: 1119.0 g – Size: 54 mm - $91.50/ea.
- Fins – made of a durable plastic or fiberglass
- Blue Tube - ~10 in. section and ~40 in. section– Diameter: 4 in.
- Electronics Bay/Coupler Tube - ~$30.00
- 2 Centering Rings – Plywood – ~$15.00 X 2 = ~$30.00
- 4 Bulkheads – Fiberglass - ~7.00 X 4 = ~32.00
- Hooks – Forged Eye-hooks
- Electronic components
- Epoxy
- Shock Cords

- Connecting Rods – Metal

Competition Fees:

Registration (Paid) --$400.00

Rocket Components --- ----~ $700.00

Hotel Rooms (2) --~$400.00

2 Competition Motors --- $183.00

Travel Expenses -- ~$100.00