Iowa State University Rocketry Engineering
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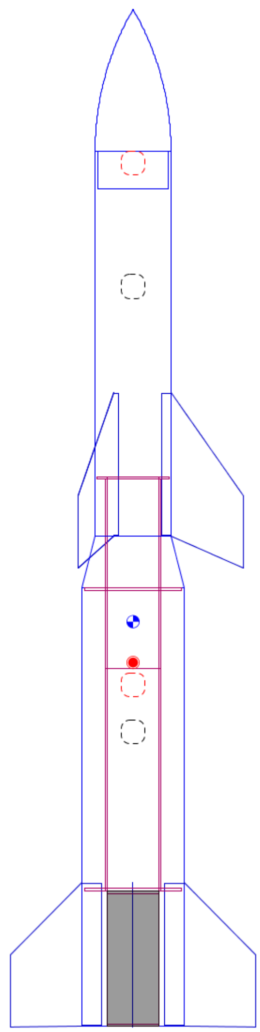

Preliminary Design Report

March 20, 2015

Table of Contents

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General Executive Summary

The goal of this project is to design, test, and produce a rocket that completes and surpasses the competition objectives. In particular, the rocket is designed to attain the highest achievable altitude while having the largest separation between the dart apogee and the booster stage apogee. Secondary goals include: researching and designing the rocket within a given timeline, communicating and operating effectively as a team, and providing experience to newer engineering students.

Research began by attempting to solve the problem of having the booster stage drag separate from the main dart. The process included varying stages of ideas, some of which included air brakes, deployable streamers, and other high drag devices. After a number of discussions, the final design strayed away from adding drag devices and measures, and instead included a transition between the dart and booster stage that will provide a sufficient amount of drag to separate the booster after motor burnout. In addition, the final design includes a connecting tube in both the dart and booster that adds stability to the rocket.

After designing the dart portion of the rocket, the next step was to design and configure a housing unit for all avionics to be used. In an effort to keep all parts safe and secure, a unit (which is now referred to as the avionics bay), was designed to be 3-D printed and hold all avionics, including the mounted camera. The avionics bay is designed to be easily inserted and removed via the addition or removal of a single bolt that secures it to the bulkhead of the dart.

In terms of safety, only team members with the proper level 1 rocketry certification will handle the rocket motor. Also, proper training was done by each person hoping to work in the lab (which includes fire safety and chemical safety among others). The design includes a stable base for the rocket before launch and evenly spaced fins for stability during. There will also be a parachute that is protected by padding from the motor that will eject at apogee and carry the rocket safely to the ground.

Most of the data and calculations that were used in the design came from varying parameters in an open source program called OpenRocket. This allowed the group to make the design once the dimensions were decided upon. After this design was in the program, the weight and dimensions could be changed to better suit the needs of the competition. By allowing this flexibility, the final design was able to encompass a lot of the ideas that had been brought forth in earlier stages by various members of the group.

Now that the design portion of the rocket is done, construction will begin. Numerous parts have been ordered and cut, and the rocket is on schedule to be completed by the competition deadline. After the construction is done, a test launch will be done long before the competition date so that there is enough time to correct any errors that hinder the rocket's performance. Once all of the testing and corrections have been completed, the competition and post-launch analysis is all that remains to round out the project.

Design Features of the Rocket

Overview:

The design process behind the final rocket for this competition was two-fold. The members of the group were split into two sub groups; one group focused on the rocket body while the other group focused on the electronics inside the rocket necessary to meet the data and video recording requirements for the competition. Each group had challenges to overcome, but this section of the report will primarily focus on the former group's efforts and final product.

The rocket body group was given the task of designing the booster and the dart components of the rocket. When designing the rocket body, the first challenge that the group ran into was how to achieve separation between the booster and the dart. Due to the competition rule that momentum cannot be transferred to the dart, it was quickly concluded that inducing drag on the booster after the motor burnt out was going to be the best way to achieve the separation. In order to do this, several ideas were brought forth. Some of these ideas included using parachutes or retractable fins as airbrakes on the booster; all of these ideas were too complicated or too intricate to build with a limited budget. After spending hours trying to come up with a feasible solution, a fellow student and mentor mentioned that a change in diameter between the booster and dart with a transition in the middle could be used to generate enough drag on the booster to separate the two, and that is what the design is now based off of. Once this decision was made, the other specifications for the rocket fell slowly but surely into place, as it will be described below.

Dart:

Description:

The upper portion of the rocket, also known as the dart, must be able to separate from the booster as quickly as possible. To best achieve the goal height, a total length of 406.4 mm fiberglass tube was chosen to serve as the body for the dart to be paired with a nose cone of 110.5 mm atop the dart. A diameter of 76.2 mm is used to hold the necessary electronics as well as keeping aerodynamics in mind. It will sit on top of a transition piece that will be epoxied to the booster but not the dart. The dart will have 3 fins compared to the booster's 4 fins. This is done to generate more drag so that the separation occurs more smoothly. Refer to Fig. 1-1.

Recovery Process:

In order to recover the dart safely, a 15 inch diameter parachute will be deployed shortly after apogee. The ejection of the parachute will occur due to the discharge produced by a black powder charge located underneath the nose cone. To initiate this charge, a signal will be sent by the avionics bay to the charge which will ignite it and ultimately push off the nose cone and deploy the parachute. The parachute will have insulation surrounding it to protect against the heat produced by the black powder discharge.

To keep the parachute connected to the dart, a 1 yard long, 3/8 inch thick string of Kevlar shock cord will be attached to the bottom of the dart. One end of the cord will be attached in between two bulkheads at the bottom of the dart while the other end will be connected to an eye bolt at the top of the nose cone (the nose cone has a phenolic tip which has a metal loop for the shock cord to be tied to). The parachute will then be attached to this shock cord, which will all deploy at once after the discharge. A radio transmitter will then be used to locate the rocket.

Structural Analysis:

The dart fins were designed in order to make the rocket as aerodynamic as possible to achieve maximum apogee height. The material that was chosen for the fins was fiberglass which is lightweight and gives the minimum amount of drag while inflight. The fins will be attached by cutting a slit into the dart body. The fins will be fit into these slits and then sealed with epoxy to prevent moisture and movement. The sweep of the fin is set at 55 degrees and a length of 109 mm was shown to achieve the highest apogee.

To prevent torque from ripping the fins away from the body, they will be epoxied to the inner tube as well as to the slits. These two layers allow the fin to be secured firmly in place and prevent torque from twisting the fins off.

Planned Construction:

For the construction of the dart, the first thing to do is cut the fiberglass tube to the correct length and cut the fins out from a sheet of fiberglass. This will be done by etching the shape of the fins into a sheet of fiberglass, and a water jet saw will be used to cut out each fin. Once everything has been cut to size, slots will then be cut out on the fiberglass tube for the three fins. The fins will be attached in the same way they are for the booster except there will be no motor casing inside. Instead of a motor casing there will be a fiberglass tube directly in the center of the dart that extends below. This tube will be sanded down to easily slide into the inner tube on the top of the booster. By doing this, it will be ensured that the dart will not detach during ascent. To attach this tube fiberglass rings will be used to attach it in the same way the motor casing is attached to the booster. Once everything is in place, epoxy will be used to glue everything in place. Lastly, shock cord will be attached to the nosecone and the dart body.

Dimensions:

Refer to Figure 2-1.

Booster:

Description:

The lower stage of the rocket can be seen in Figure 1-2.Three fiberglass fins are attached to the outside of the booster, providing stability to the rocket through the duration of its flight. The fiberglass booster tube has a length of 463 millimeters, an inner diameter of 102 mm, and an outer diameter of 107 mm with a thickness of 2.54 mm. The booster has a mass of 2.735 lbm or 1240.537 grams. The Cesaroni 475-I445-16A Engine can be inserted through the bottom of the booster itself. A fiberglass washer is placed at a certain point in the booster which holds the engine in place and prevents it from accelerating up through the tube. A metal cap is placed on the bottom and screwed in place which prevents the engine from falling out the bottom end of the tube. A layer of housing insulation has been placed above the fiberglass washer, which prevents heat from being transferred from the engine below to the parachute placed above. The parachute is 15 inches in diameter, with a mass of .10625 lbm or 48.1942 grams and attached via shock cord to the booster. Once separation is achieved, the parachute is deployed through the top end of the booster; serving as the retrieval method for the booster itself.

Recovery Process:

In order to recover the booster safely, a 15 inch parachute will be deployed shortly after apogee. The ejection of the parachute will occur due to the discharge that the engine gives off after burnout. The timing of the discharge depends on the amount of delay charge that is present. For the motor that is used in this competition, the Cesaroni I445, the maximum delay charge is 16 seconds. This time can be changed with a tool allowing the discharge to happen within a specific timeframe.

Within this timeframe, the dart will have left the booster, exposing the top portion. Contained in the inner tube of the booster will be another 15 inch parachute, surrounded by insulation. This insulation will prevent the parachute from being burnt once the ejection charge is ignited. After the ejection goes off, the parachute will be thrust out of this inner tube and will deploy in mid-air causing the booster to safely descend. To keep the parachute attached to the booster, a 1 yard long 3/8 inch thick string of Kevlar shock cord will be attached to the motor casing which will then be epoxied to the body tube. This will guarantee that the shock cord will not slip out of the booster and leave the parachute disconnected from the body. A radio tracker will then be used to locate the rocket.

Structural Analysis:

The booster fins were designed for slightly higher drag in mind to achieve separation in an effective and timely manner. The material that was chosen for the fins was fiberglass to keep a consistent parameter with the dart fins. The fins will be attached by cutting a slit into the the dart body of the thickness of the dart, 3.8 mm and root chord length of 152 mm, and set in between the motor casing housing . They will be then sealed to prevent moisture and movement with epoxy. The sweep of the fin is set at 45 degrees and a length of 109 mm which changes the aerodynamics to be slightly higher in drag. In addition to the sweep and length, the booster will include four fins to increase the drag put on it.

Planned Construction:

The booster body will have to be the same length as the dart body due to the simulations of center of gravity and center of pressure that were used in planning the construction of the rocket. The first step will then be either sanding or machining it down to the correct size. The next part will be to cut slits in the sides of the tube for the location on the tube that the booster fins will fit into. After making sure they are equidistant along the circumference of the tube, fitting in the housing for the motor begins. The motor will be housed in a casing that has the same diameter as the rest of the inner tube inside of the booster (this inner tube is for the coupler that will connect the booster to the dart). Fiberglass rings will be fit inside between the outer wall of the casing and the inner wall of the booster body for stability. The fins will fit in through the aforementioned slits and tightly in between the 2 rings.

The inner tube then must be extended out of the booster body so that the transition cone that the dart will rest on can be attached to the booster (the cone is considered a component of the booster). Figure 3 roughly depicts how this will look. The top part of the transition can be seen in Figure 4, showing how the inner tube is slightly longer than the booster body so that the transition cone can be fit to the top. The complete constructions of the booster along with all of the inner components necessary for launch can be seen in Figure 5.

Overall, the booster's design was decided based on the key performance factor of stability in mind as well as efficiency. Instead of creating a complex mechanism to detach the dart from the booster (which grows increasingly complex when the "no momentum transfer" rule applies), the diameter of the booster was widened so that drag would do the work. The ogive shape of the transition piece lessens the drag on the rocket, but will still provide enough for separation. The maximum height of the rocket's flight is sacrificed for this solution, but because the engine is only providing thrust for less than 2 seconds, it is believed that this sacrifice is negligible and necessary for a more successful flight. The housing of the parachute allows the motor to deploy the parachute instead of, again, another complex mechanism.

Propulsion System:

The propulsion system is a Cesaroni I445 engine of length 14.3 cm and diameter 54.0 mm. It has a total impulse of 479.4 Newton seconds putting it in motor class I. The total weight of this engine is 575 g with a propulsion weight of 213 g. The average thrust of the engine is 442.7 N with a maximum thrust of 526.2 N, and a burn time of 1.1 seconds.

Dimensions:

Refer to Figure 2-2.

Conclusion:

This single-stage, boosted dart was designed to maximize material and time, efficiency, stability, and simplicity. The most successful flights will always be the ones that had the least amount of parts fail. With that in mind, any complexities were thinned down so that Murphy's Law has less access to the rocket. There are fewer things that can go wrong, so fewer things will go wrong. The booster is removed naturally via the force due to drag with the ogive shape of the transition adding an estimated 10 meters to the apogees of both the dart and the booster. The removal of anything mechanical to separate the two, means that there will not be an electrical or mechanical failure for the separation. The charge that sets off the parachute in the booster comes with the motor, so, instead of buying separate black powder charges and running the risk of incorrectly setting the charges, the motor's charge will be set to deploy the parachute 2-3 seconds after the motor finishes burning (the average burn time of the Cesaroni I motor, 1.1 seconds, is what will be used for estimating the time of parachute deployment). The same fiberglass tube that will house the motor will hold both the parachute and the tube that attaches the dart to the transition cone. This is for simplicity of design. There is no need for multiple compartments when the components can be arranged in a way that requires less complicated building.

The tube that attaches the dart to the cone will be made in a fashion that puts the center of pressure as far back in the rocket as possible (the center of pressure moves back the longer this tube is) for more stability. It does have to remain short enough for there to be less friction than drag force pulling the booster body off. The space above this booster will be where the avionics will be housed. This provides a better angle for the camera that will be in the rocket and will keep the avionics out of the way of the shock cord and parachute for the dart. This is to keep the avionics away from any hazardous misfiring of the black powder charges. The shock cord will be rooted on the inside of the dart and to the phenolic tip of the nose cone. The fiberglass nose cone, filled with wet sand, will have the shock cord buried in the sand and have epoxy between its tip and cap, holding all of the sand in a vacuum preventing it from drying by the day of the launch. The reason for having the cone this way is to have it as dense as possible, keeping the center of gravity near the front of the rocket when it is attached to the booster *and* when it is flying dart-only. Through the research conducted, it was concluded that using another material for the nose cone will either fail on the center of gravity spectrum of things or will be too heavy and cut the maximum height and apogees.

In summary, this rocket was built primarily to ensure that the centers of gravity and pressure remained between 1-2 calibers apart for maximum stability in flight. This estimation was given by a knowledgeable high-powered rocketry engineer with a level 2 certification who has flown single-stage boosted darts before. This estimation was used to keep the rocket in an ideal flight path; the rocket must fly completely vertically without veering due to wind for the best apogee. This desired flight path is what led to the other decisions for every other aforementioned component in the rocket, which is why simplicity and efficiency were the top priorities in the final design of the rocket.

Design Features of the Payload System

Overview:

The avionics consists of eight main pieces which will work in tandem to provide data on altitude and rotation. The heart of the operation is the Arduino Uno R3; chosen due to its versatility and inexpensiveness. It has more than enough processing power for the competition needs and is extremely power efficient. Connected to the Uno are three key components used for data collection and storage.

The first is the BMP085, which is a barometric pressure and temperature sensor. This is used to calculate altitude based on pressure. The thought process behind choosing this sensor was that it was easy to work with and met the mission criteria. The next sensor is the L3GD20H, which is a 3-axis gyroscope. This piece will record rotation of the rocket and was chosen again due to its simplicity and low cost. Both of these sensors can be purchased as a single chip; however, due to some unforeseen issues they were bought separately. The result of this will most likely have very little impact in the end besides making the programming a bit more labor intensive. Finally, a place for the data to be stored is required. For this task an SD card, along with a micro-SD card shield, were purchased for the Arduino Uno R3. The SD card will hold the data while the shield will provide easy access to the card. To power these units, a 1000mah lithium-polymer battery will be used. This battery will provide more than enough power for all of the electronics as well as the parachute deployment charge.

An additional competition requirement is to make a video recording of the flight. To accomplish this, a Veho MUVI micro camcorder will be used. This device was chosen because it is a very small self-contained unit that is designed for extreme use scenarios. This is perfect for use in a rocket launch and is why it was chosen. The final electronics component is the competition altitude sensor which is provided and is a standalone unit.

Avionics Bay:

Description:

The avionics bay is the section of the dart body that will contain the avionics housing unit. All other avionics components are affixed to this unit in various ways. Figure 6 shows a CAD rendering of the unit with all other parts attached. Not shown in the figure are holes on top, one that will guide a screw that fixes the housing unit to the inside of the rocket body, the other will allow the wiring to the charge to pass through and a zip tie will go around it so the unit can be pulled out of the rocket after flight. A cavity will be bored out of the bottom disc to allow the unit to pass over the mounting cylinder that the screw will go into on top.

Structural Analysis:

With the dimensions of the inner rocket body being three inches in diameter and with all of the components in hand, a decision had to be made regarding a final housing unit for the electronics. Ideas for housing primarily consisted of a single unit where everything would be attached. The final design is a board with all the electronics attached, and with a circular top and bottom that will lock into pins in the inner tube. Next, a CAD drawing of the housing unit was created in order to 3D printing it. When the housing is constructed, the plan is to slide it down the inner tube, into the avionics bay, twist it to align with holes on the circular top and bottom, and pin it with a bolt.

The way the components are laid out in the bay were chosen to distribute weight so as to keep the rocket stable. The other goal was to ensure that none of the components would be damaged during the various stages of rocket launch. The avionics bay was designed to keep all of the components stable. For example, the camera will kept so that it does not become dislodged during flight, and the SD card shield that was mentioned before will keep the SD card from being ejected. Most of the components in the avionics bay will be placed opposite the battery due to the battery's weight compared to the other electronics.

Planned Construction:

With the housing design finalized, the next step was to arrange the avionics so that the mass is as balanced as possible. The battery is heaviest so it was placed on the opposite side of the other parts. On the same side, the altimeter will be placed above the battery. The altimeter will have its own housing 3D printed on the top of the board. The camera, per competition guidelines, needs to record rotation so it was placed it at a forty-five degree angle looking downwards. It too will have its own housing 3D printed as well. Both the altimeter and camera housing will have compressible foam on the inside lining for security. The Arduino Uno is being mounted on pins that go through the housing unit and with velcro. The SD card along with the gyroscope will mount to the Uno and then be soldered into place. The battery will be velcroed and zip tied. To make sure everything stays put during launch, zip ties will be used along with velcro as needed. ⅛ Inch foam tape will be used to line the inside of the cavities for the camera and altimeter to ensure stable video recordings and accurate altimeter readings.

Dimensions:

Figure 7 shows a sketch of the housing unit with some basic dimensions annotated. The upper and lower discs will be .2 inches, while the center wall will be .25 inches, which is as wide as it can be while remaining centered without pushing components too far out to the side to fit in the body. The casing for the camera and altimeter will be ⅛ of an inch. The group decided this would be adequate for strength, and there was not enough room to make it any thicker. The four pins are placed so that the Arduino Uno is can be mounted centered and touching the bottom, and extend just far enough to not interfere with the SD board. The camera cavity was placed where the entire unit could be as short as possible, while allowing the camera to be facing down at least 45 degrees (since "downward" facing footage must be recorded) without the camera protruding too far out of the side. The corner of the cavity will be sanded down or manufactured as shown to accommodate the diameter of the body. The altimeter cavity was placed on the top because the overall center of gravity needs to be as high as possible.

Avionic Devices:

Description:

Within the avionics bay, a multitude of devices were used to achieve the requirements of data collection and video of the flight in the upward direction. First, and most importantly, an Arduino Uno R3 was chosen to compute the data from the sensors. The avionics will also include a Barometric Pressure/Temperature/Altitude sensor to determine altitude by using the altimeter portion and the barometric pressure proportion to verify the altimeter data. The second sensor is a triple-axis gyroscope to gather data on the rotation of the rocket as it ascends. In order to record the calculations that the Uno makes from the data it receives from the sensors, an SD shield is included that fits over the top of the Uno R3 and also houses the SD card that will store the needed data. Along with sensors data calculation, the Arduino Uno will also be programmed to detonated black powder charges that will eject the parachute when it is calculated that rocket has reached its apogee. In order to make all the needed calculations and record data, a strong battery is needed to power all of the parts. For the power source, a rechargeable lithium-polymer battery with a 1000 mAh capacity was used. The battery will be hooked up via USB to the Arduino Uno which will distribute the needed power to the parts connected to it. Finally, a self-powered video camera will record the flight of the rocket as it ascends. The video footage will then be used to compare to the data received from the gyroscope to determine the rotation of the rocket.

Conclusion:

Overall the avionics bay is designed to be as easy to work with and efficiently designed as possible. To accomplish this, all parts were fitted to a custom-made 3-D printed housing. Within the housing were eight major parts which were designed to work in tandem to accomplish three major goals. These goals were to record altitude, record rotation and to deploy the parachute. Based on the research and planning, this was accomplished in the most cost effective and efficient manner possible.

Analysis of Rocket:

As of yet, the first design of the rocket has not been through a test flight. In an effort to try and analyze the design of the rocket before a test launch, a design analysis program, OpenRocket, was used. To use this program, a model of the rocket using the same dimensions as the design and estimated values for the weight was created to allow the program to test different aspects of the design. OpenRocket uses values such as wind speed, coefficient of drag, and a number of other variables to determine the flight characteristics of the rocket model. Below are the results of the OpenRocket analysis:

Launch Analysis:

Using the Cesaroni I445-16A engine analysis available online, it's estimated that the engine will have a total impulse over 1.07s of 474.9 Ns with an average thrust of 442.7 N.

Flight Analysis:

Using the OpenRocket simulator (see Fig. 8), the rocket will achieve a maximum vertical acceleration of about 575 m/s^2 with all vertical acceleration stopping approximately 1.0s into the flight. Over the same amount of time, the rocket reaches a maximum vertical velocity of approximately 510 m/s. At approximately 1.5s into the flight, the booster will drag separate from the dart and achieves a booster apogee of 395m at 8.2s. Meanwhile, the dart continues for another 1.7s before reaching its own apogee at approximately 600m, 10.9s into flight.

Recovery Analysis:

While the booster achieves apogee 8.2s into flight, an ejection charge is released a full second before apogee to ensure safe deployment of the parachute and subsequently a safe recovery. The booster then glides downward for 12s before hitting the ground at an estimated velocity of 23 m/s. Similarly, the dart's parachute ejection charge is detonated 1s before dart apogee. After which, the dart glides downward for 33s before hitting the ground at an estimated velocity of 28.3 m/s.

Stability Analysis:

Stability, while a main priority for rocket, is still being refined by the team. Currently, the stability of the rocket is at about 0.83 caliber and the team is actively trying to get this number closer to 1 caliber in order to ensure good stability in the rocket. Options that are still being considered include filling the nosecone to add additional weight to the front of the rocket or potentially adjusting the fin size.

Project Budget:

Budget

Capital items	Cost	Qty	Total	Notes
Entrance Fee	$400.00	1	$400.00	Grant provided
Camera	$45.00	1	$45.00	Required for competition
Arduino Uno	$25.00	1	$25.00	Processor
Barometer	$10.00	1	$10.00	For rotation
Engine/motor	$60.00	1	$60.00	Cesaroni Vmax I445 1 grain
Motor Casing	$45.00	1	$45.00	To hold motor/engine
8 GB SD card	$8.00	1	$8.00	To store data
Travel Fees	$600.00	1	$600.00	~100 for each of 5 rooms + Mileage
Nosecone	$35.00	1	$35.00	Fiberglass. May look at heavier option
Fins x 7	$40.00	1	$40.00	Fiberglass
Body Tube	$40.00	2	$80.00	Fiberglass
Black Powder charges	$15.00	1	$15.00	For dart and deployment of parachute
Battery Pack	$10.00	1	$10.00	Power system
Shock Chord	$8.00	3	$24.00	For parachute
Parachutes	$14.00	2	$28.00	1 for dart, 1 for booster
Capital Subtotal	**$1,425.00**			

Our current budget is valued at $1,425. The amount that is allotted to this project is $1,600. This will allow for shipping costs and other unforeseen circumstances.

Safety:

Material-Handling Procedure:

Throughout the entire process, safety was always considered the highest priority. First, the group will ensure that only members with 1st level rocket certification handle the level I motor in the lab and at the competition. Second, all members will be lab certified via training before working on the rocket in the lab. This means proper personal protective equipment during lab time such as: gloves, goggles, proper shoes, etc. In conclusion, all rules will be followed in and out of the lab to ensure everyone's safety.

Planned Assembly Procedure:

Refer to planned construction portion for individual assembly procedures.

Designed for safe flight and recovery:

For a safe flight the booster was designed with four fins to increase stability and, in addition, three fins were installed on the dart to ensure a straight and safe flight during separation. The choice in nose cone material (fiberglass over metal), was also made partly due to safety issues. Recovery is based off of both being able to retrieve the rocket in one piece and in fit condition, as well as being able to find it if eye contact is lost (which will most likely happen with the altitudes being planned). Both the booster and the dart have their own parachutes which were made more than large enough to slow the rocket so that the body tube and fins would not be damaged as well as preserving the electronics. The biggest worry was that the accidental ejection of the SD card recording all of the data, so a seal and case will hold it all together to make sure the data remains usable. The transmitter that will be used produces radio frequencies that bounce off of a chip placed inside of our rocket. The receiver will then beep when it is placed in the direction of the rocket. This method is going to be used in order to track and locate our rocket after launch.

Pre- & Post- Launch Procedures:

Electronics:

The electronics pre-launch procedures are as follows. First and foremost, all components are hooked up and properly mounted to their respective housing. Secondly, the altitude recording apparatus must be zeroed on site to ensure accurate altitude data. Lastly, the camera must be checked to ensure that it is set up and recording. Once all equipment has been confirmed secure and properly hooked up, the avionics housing may be placed in the rocket bay. Once inserted, the housing must be twisted into place and secured with locking pins to hold it in place.

The post launch procedures are as follows: upon retrieval of rocket, the housing must be disassembled to remove the avionics housing from the bay. Once this is accomplished, all electronics must be powered down, and then all data extracted from the micro-SD card and the competition altimeter and off loaded to a designated computer for review.

Rocket:

The pre-launch procedure for the rocket body team will consist of preparing the parachutes, checking black powder charges, inspecting the booster and engine containment unit, and loading both bodies with insulation. The first step will be to make sure that the parachutes are secured tightly to the shock cord. The next step will be to make sure that black powder charges located below the nose cone in the dart are connected in a safe manner and will not go off mistakenly. After this has been done, both of the inner tubes will be inspected for loose material, or anything that is not supposed to be inside. Once the tubes are clear, the electronics (see section about electronics) will be loaded into the dart. Then, insulation will be inserted in both the booster and dart tubes to protect against burning. The parachutes will be folded and put inside after that. After everything has been connected and inserted, the engine will be inserted into the motor mount and secured by a screw on bottom. This will allow the group to then go on the launch pad and hook up the electronics to the motor, thereby arming the rocket. This will conclude the rocket body team's pre-launch procedure. Documentation will occur over all parts of this procedure.

After the parachutes have deployed and both parts of the rocket have landed, the group will use a radio tracker to locate the precise location of the rocket. Upon finding the rocket, inspection of the engine and black powder charges will ensue. This will prevent the accidental injury of team members if these explosives still have residual substance left over. After that is cleared, the electronics will be removed, in order to be analyzed. The engine will also be carefully removed to ensure that handling of the body will not cause injury. The rocket will then be taken back to the group's base in order to be further analyzed. Once it is back at base, the individual teams (body and avionics) will examine the individual parts of the rocket to see if any damage has occurred. When the inspection is complete, and the data has been recorded, the post-launch procedure will be complete. Documentation will occur over all parts of this procedure.

Conclusion

Overall, this rocket should cover and surpass all of the objectives set before it. The body (both booster and dart) was designed with simplicity and stability in mind. The avionics were programmed to be as accurate and quick as possible, as well as being safe from impact or any other harm that may befall them. The analysis of the different components before and during planning and building has led to the final product the team hopes to create. And finally, the safety precautions taken include both equipment and certification standards.

The body is meant, as mentioned several times, to be as efficient as possible. Gravity and drag do most of the work, mostly revolving around the separation of the booster from the dart. The weight of the rocket has also been taken into account by using fiberglass as a light, but still strong, material. The charges and other forceful components have been arranged in a way for the protective padding to be minimized. The team also had the option to go with a metallic nose cone, but went with fiberglass instead. However, to keep the center of gravity above center of pressure, the nose cone will be filled with sand and enough water only to the point where it puts the center of gravity where desired, while still trying to keep weight minimal. The shape of the fins and center of pressure position also ensure stability so that the rocket will fly as vertically as possible and therefore, as high as possible.

The avionics were designed to ensure that there was not a significant amount of weight “tilting” the rocket as well as designing the avionics bay to ensure the SD card and other equipment remained secure. The bay (interchangeable with housing) will be 3D printed for low-cost and low-weight purposes. This means it was no longer necessary to machine fiberglass into a complicated structure. It also allowed the team to gain valuable CAD software experience. Once built the battery for the motherboard and other instruments will be placed one side alone (due to its weight) while all other equipment will be on the other side, including the camera. The camera will be placed in a way that it points 45 degrees downward to measure the rotation of the rocket. This, paired with the gyroscope, will accomplish the x,y, and z axis rotation measurement requirement for the competition.

The analyses focused on finding the centers of gravity and pressure and then manipulating them into the position that gave the most stability. This is what inspired changes in the nose cone (hollow fiberglass with sand), and the position of the avionics, as well as the length of the booster body tube, dart body tube, and inner tubes. Analyzing the windy, flat terrain of the launch site reveals that stability is of utmost importance which led to the specific constructed of all components aforementioned as well as parachute size and fin shape. The flight procedure was developed to keep the rocket simple and therefore more reliable seeing as how there are less components that can fail through human error or machine error or both. The recovery relies on the parachutes deploying reliably. This means they have to be large enough to decrease the landing velocity of both parts of the rocket by enough to keep the parts undamaged, while small enough to avoid jamming inside the respective body tubes.

Finally, the safety procedures revolved around the stages of lab work and field safety. For safety in the lab, 4 training programs offered at Iowa State were required to be taken by every group member. Each member was also required to purchase a pair of lab glasses. The last piece to this safety preparation relies on reminding groups the potentially hazardous properties of the materials that may be encountered. For example, the epoxy can heat up enough to cause pain which means it requires thick gloves; fiberglass can also cause injury either by breathing in shavings during the sanding process or by splintering during handling which in turn leads to the need for a face mask in addition to the gloves. Field safety is handled by the fact that several members have received, or plan to receive, level 1 rocketry certifications to give them experience in rocket launches and launch procedure. This means there will be people at the launch that know how to safely watch and prepare a rocket launch.

Thus concludes the ISURE rocket. This rocket will perform under the parameters of maximized stability and simplicity, as well as designed for the launch site and for collecting data quickly and safely. The rocket should be able to perform in a way that at least completes every objective successfully, even if not winning the competition.

Figures

Figure 1-1

SolidWorks model of dart.

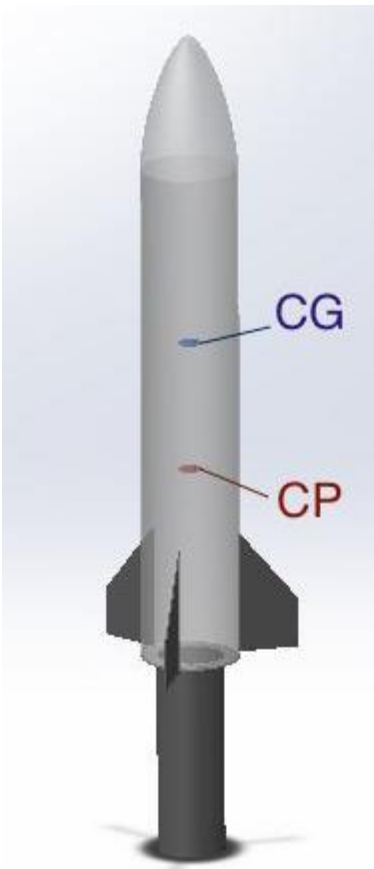


Figure 1-2

SolidWorks model of booster.

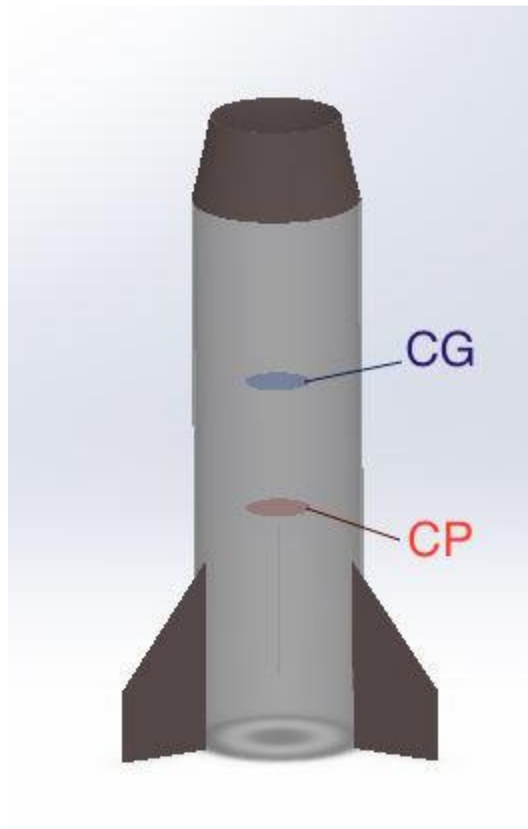


Figure 2

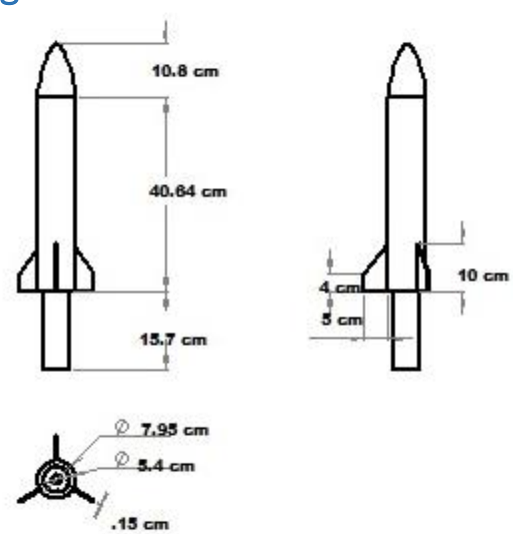


Figure 2-2

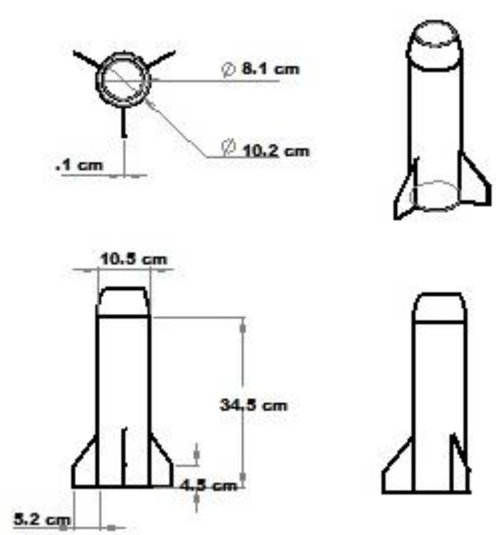


Figure 3

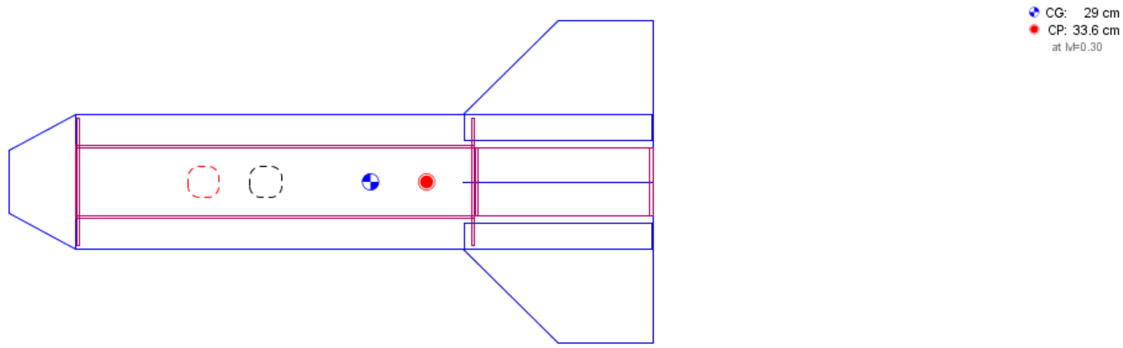
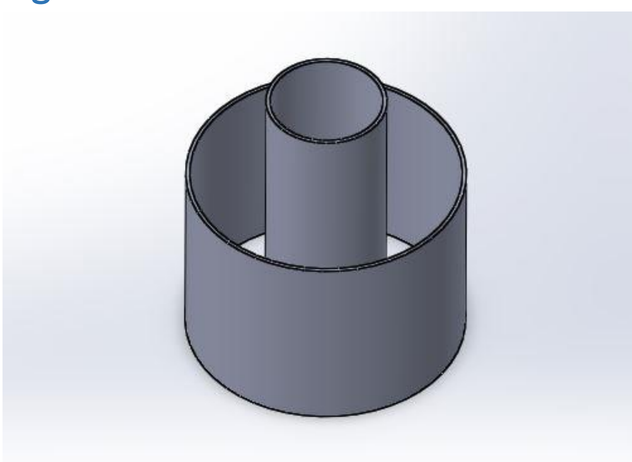


Image of booster from OpenRocket software.

Figure 4



Cross section of the booster from SolidWorks software. Shows how the inner tube will extend into the transition part.

Figure 5

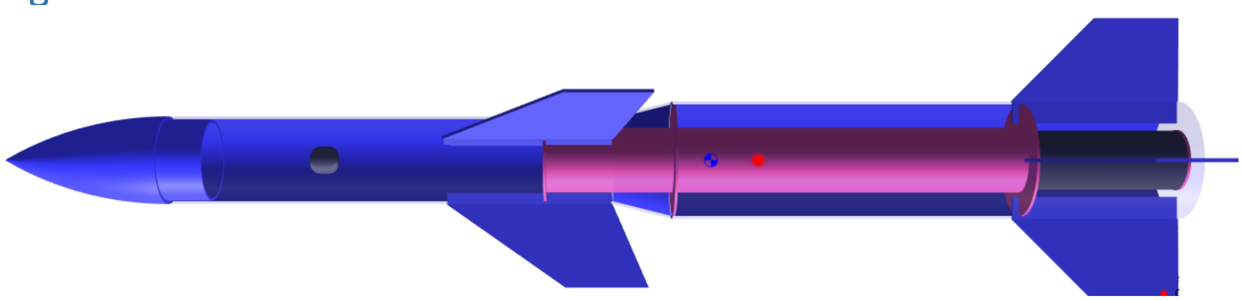
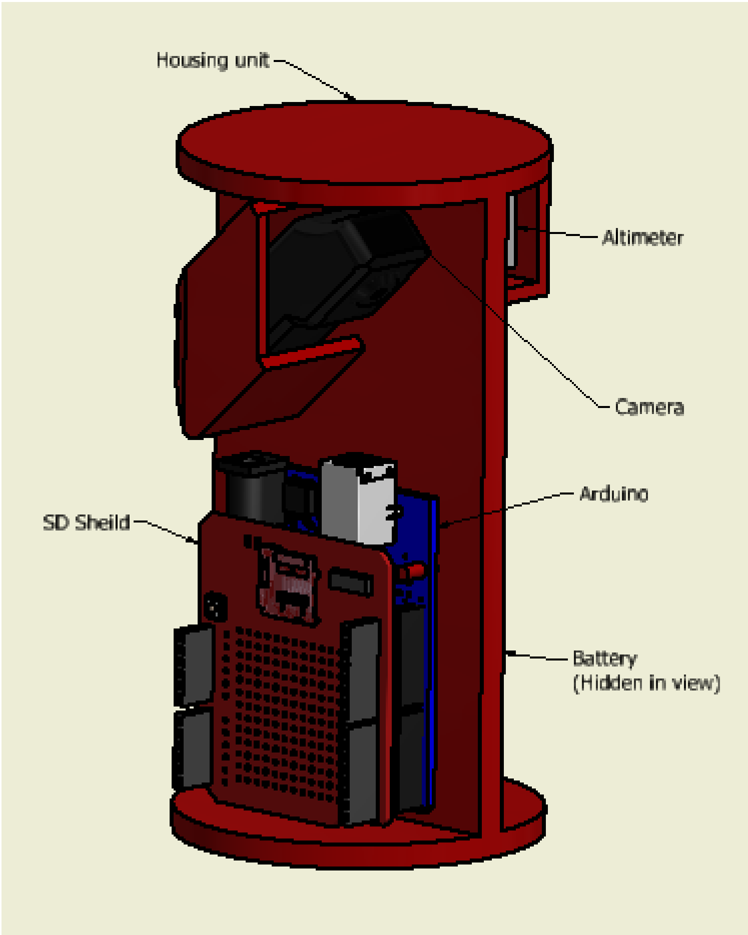


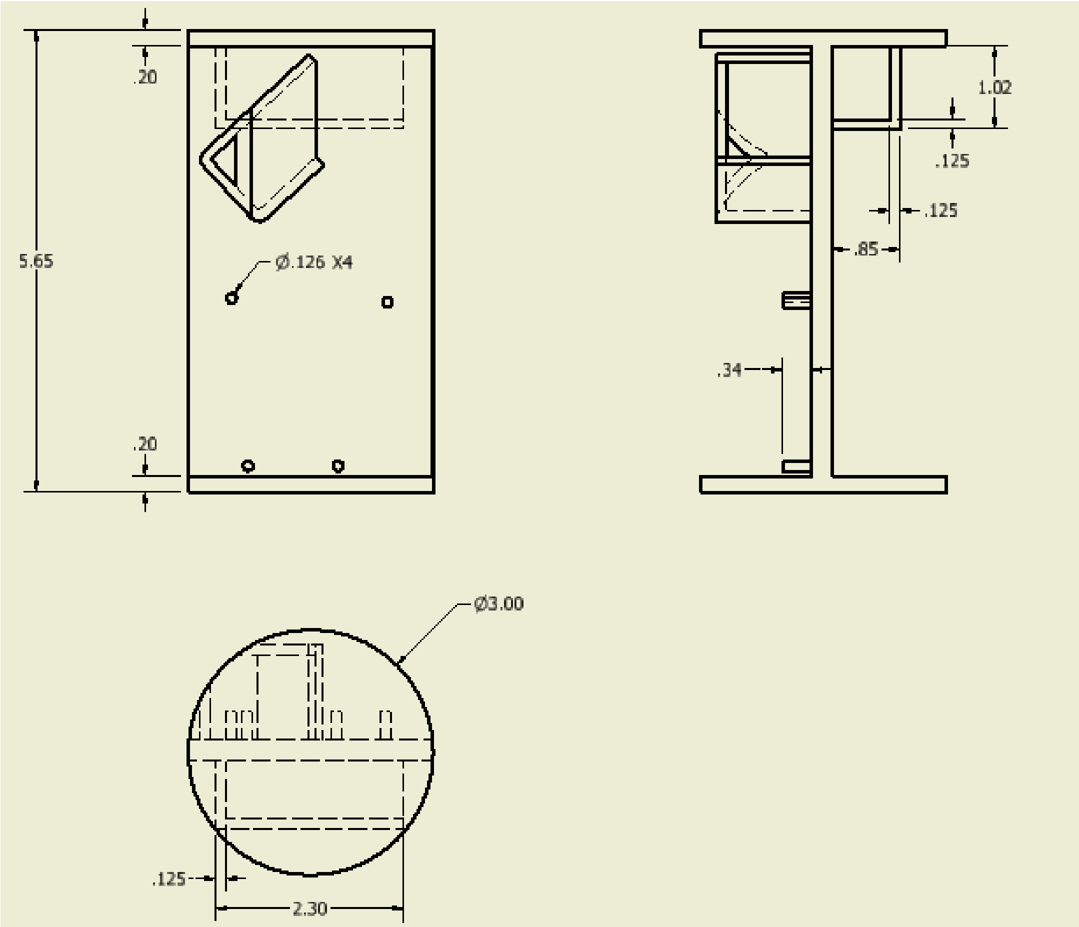
Image of entire rocket taken from OpenRocket.

Figure 6



CAD drawing of electronics and the housing unit.

Figure 7



CAD drawing of the electronics housing unit with dimensions.

Figure 8

Graph displaying altitude, velocity, and acceleration taken from OpenRocket. (Placed vertically to comply with the report guidelines)