University of Iowa AIAA USLI

Preliminary Design Report

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Summary

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Launch Vehicle:

Our launch vehicle will be four feet in length, four inches nominal diameter, made from a fiberglass body tube, polypropylene plastic nose cone. The total weight of the launch vehicle will be approximately 5.2 pounds and will be propelled by a Cesaroni K261-P plugged motor.

The recovery system will be a dual deployment system with the first stage being two 2x20" ripstop nylon streamers. This will control the descent velocity for a set amount of time controlled by a delay charge. The second stage will be a Fruity Chute 36" nylon drogue chute to ensure that the landing velocity is below 5ft/s.

The rocket can be seen in figure 1 created in OpenRocket (OR) simulation software. The flight performance was analyzed for the launch vehicle with and without the drag system active. The actual performance was then deduced from the combination of the two flights. The full fight sheet can be seen in figure 2.

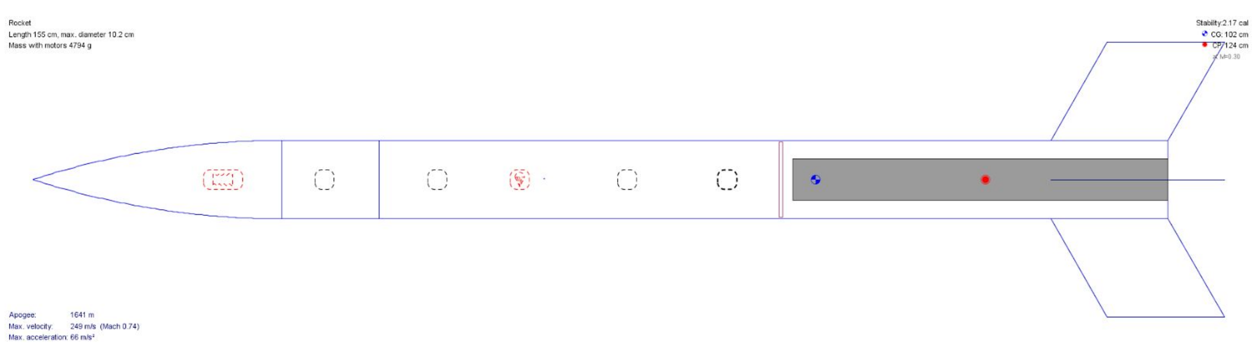


Figure 1: OR rocket design

Launch Conditions	
Temp. (^oC)	15
Humidity	0%
Atmospheric Pressure (mbar)	3
Wind Direction	N/A
Wind Speed (m/s)	0
Recovery Information	
Ejection Occurred	Yes
Descent Speed (m/s)	10.5

Figure 2: Flight Sheet

AGSE Summary:

The ground system is made of extruded aluminum rails with linear actuators to move conveyors in order to grab the payload and load it into the launch vehicle. The packed volume of the AGSE is 8x4x3 ft, under the maximum requirement. This ground system contains controls to safely pause the system, communicate with the launch vehicle, and monitor the stage of the loading process. A 3-D model of the AGSE system is shown in figures 3 and 4.

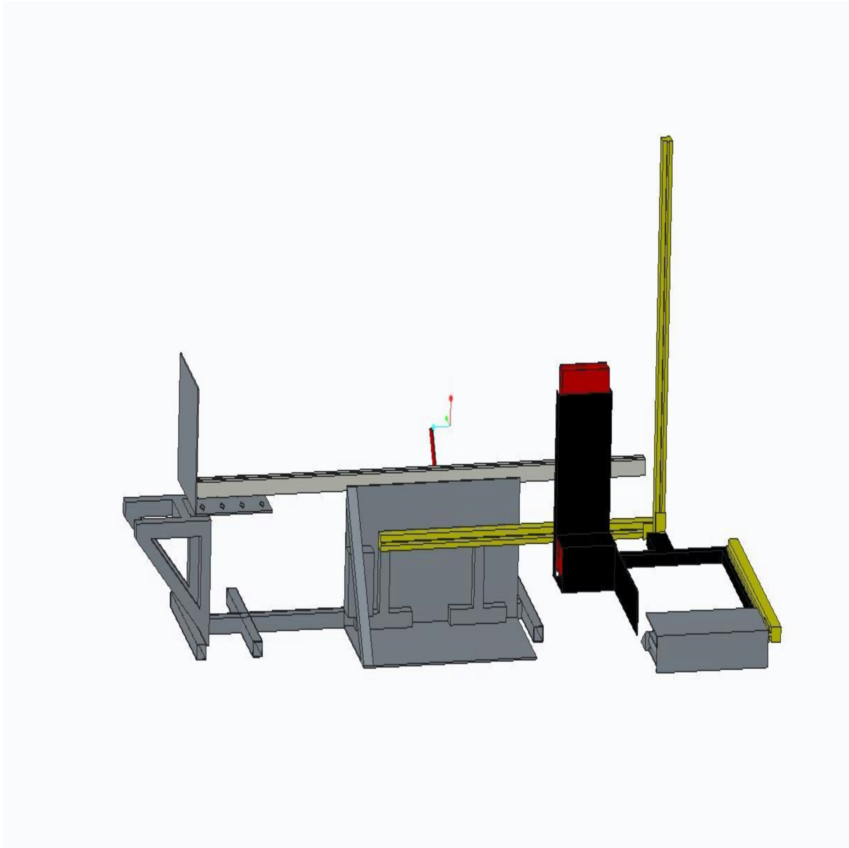


Figure 3: 3-D Model of AGSE System

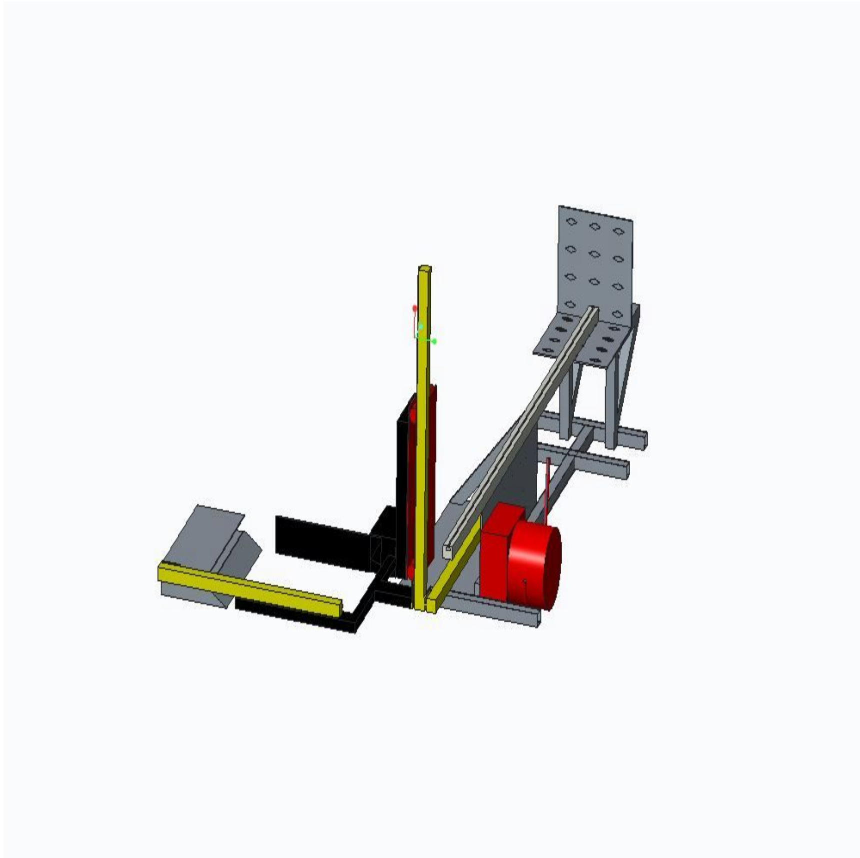


Figure 4: 3-D Alternate View of AGSE System

Payload Summary:

The payload for this launch will be a 4.75” length 1” diameter PVC package containing sand or BB’s for a total mass of 4 ounces. This payload will be inserted autonomously by the AGSE and sealed by the sealing bay system. This system, shown in figure 5, will rotate and open to receive the payload and then rotate again to seal the payload securely and avoid excessive drag on the launch vehicle. The payload also includes controls and sensors to communicate with the AGSE, monitor the status of the PVC payload, and activate a drag system to control the maximum altitude of the launch vehicle.

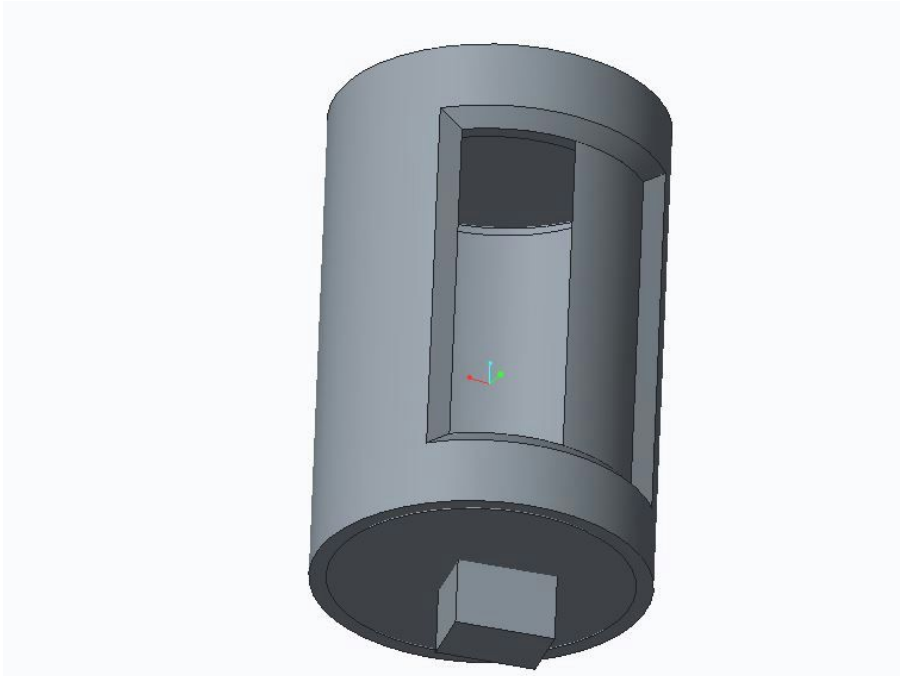


Figure 5: Rotating Cargo Bay

Changes Made Since Proposal

Vehicle Changes:

Many changes were made to the conceptual design of the vehicle proposed. The total length changed from 2.9ft to 5.4ft and the total mass from 3.0lbs to 6.94 lbs. This was due to research on particular sizes and weights of necessary components needed to complete the main objectives of each subsystem.

The motor was changed from a class I to a class K. This allows for better precision when achieving the exact target altitude. The motor will also be a plug motor with no ejection charge, which makes the recovery system easier to control.

Payload Changes:

A drag system was added to the vehicle to control the maximum altitude of 5280 feet exactly. This system includes a servo motor, bi-linear actuator linkage, and hinged airframe.

Electronic control systems were selected including batteries, micro controller, various sensors, small servo motors, and wires. This electronics system will now communicate with the AGSE, control the payload bay and drag system, and monitor flight data.

The rotating cylinder payload bay has been changed to a full cylinder design set into lower and upper tracks. This will ensure the payload is always in place and mitigates the risks of vibrations in the payload bay.

AGSE Changes:
The ground system now has a much smaller conveyor track to save power during activation as well as space and weight when not in use. Sensors were also added in order to establish communication between the ground system and launch vehicle. Finally an ignitor loading system was added so the ground system can safely insert the ignitors into the launch vehicle. All of these changes are discussed in detail in the Payload Criteria Section.

Vehicle Criteria:
Selection, Design, and Verification of Launch Vehicle
The Mars Ascent Vehicle must autonomously acquire load and secure the specified payload into the launch vehicle, raise the vehicle to 90 degrees and safely load ignitors before launching. The Launch vehicle must then reach an altitude of exactly 5280 feet by deploying a drag system for the appropriate length of time before activating an electronic recovery system to return the launch vehicle safely to the ground. A successful mission will be able to load, launch, and recover multiple times and will reach the prescribed altitude. This will be measured using altimeter data.

Structure Subsystem

Overview/System Requirements
The structure system includes the airframe of the rocket, the control surfaces, housing for each other system. This report will include detailed analysis of size, stress, material selection, and center of gravity calculation. The main objectives of the rocket structure system is to withstand all stresses during flight as well as environmental stresses caused by debris or thermal loading. It must also maintain the placement of all other internal systems so external forces do not compromise the payload, electronics, or recovery system. The mass and size of this system will be minimized without compromising the main objectives. The center of gravity will be adjusted to provide achievable stability for the propulsion system.

Material Selection
Several materials were investigated to satisfy the requirements of the structure system. Fiberglass was chosen over cardboard tubing, carbon fiber, and fiberglass on the basis of cost, strength, manufacturability, and environmental resilience.

Cardboard tubing could not be used because of it’s low strength. This will not hold during flight with such large expected accelerations. The rocket must reach an altitude of 5280 ft which will require a motor of at least class I or greater. This will cause stresses that exceed the allowable stress for the cardboard tubing.

Next Bluetube which also has very high strength while relatively low cost was examined. It was determined that the combination of high weight and difficult manufacturing make this material not the ideal choice for this system.

Carbon fiber has the highest strength to weight ratio. Unfortunately it is the most expensive material to obtain with a price of $65/ft. This could potentially be lowered if the fiber was laid in house, but the risk to successful manufacturing and safety is too great. This material also has the same difficulty of workability as bluetube when it comes to manufacturing.

Finally fiberglass was chosen over Bluetube with a cost of approximately $36/foot and density of 1.05 lb/ft is much lighter in weight. This high strength and low weight is ideal for our application.

Size

Fiberglass of diameter 4 inches will be used. This diameter yields the best length to diameter ratio for the rocket. An ogive 4 plastic nose cone will be used with base diameter of 4 inches. This will be aerodynamic and strong enough to survive the flight. The fin selection will be outlined in the propulsion system analysis.

Mass

With estimated weight of all the internal systems of 4.6 pounds and total of this system of 0.74 pounds the total mass of the rocket without payload will be 5.34 pounds. When the payload of 0.33 pounds is inserted into the rocket the center of gravity the center of gravity will be approximately 40.1 in from the tip of the nose cone. The propulsion system analysis outlines this calculation as well as the center of pressure calculation to prove stability during flight.

System Interaction

This system will include pressure sealed bulkheads between the recovery and control systems as well as between the payload and propulsion system. This will ensure no gases reach and compromise these systems. These bulkheads will also protect the electronics and payload in case of a breach of the structure to the environment. The electronics will be shielded from electromagnetic radiation by use of reflective materials around that section of the rocket. This will guarantee effective communication between the rocket, AGSE, and mission control.

Safety Risk

This system has risks to safety in the construction. The epoxies, power tools, and other materials used in the construction must be handled with the proper caution and training. The safety risks are discussed further in the safety section.

There is also risk to the mission if the fiberglass structure fails. This risk is major if it occurs in the electronic or recovery system areas and medium in the other areas. This risk is very unlikely due to the high strength of fiberglass.

Extremely hot or cold temperature could be a risk to the strength of the structure system. This risk is low since it can be mitigated by temperature measurements aboard the control system.

Verification Plan

The materials will be tested once they are purchased to ensure that they can withstand the required maximum acceleration obtained from the simulations. Conventional hardness and strength testing methods will be used on the fiberglass frame.

The verification plan has not been implemented for this system since the materials have not been purchased.

Manufacturing

The structure system will have the most manufacturing than any other system. The fiberglass frame shall be cut to length using thin saws and the cargo and drag system cuts will be made using a dremel tool. Epoxies will be used to secure bulkheads and centering rings to the interior of the airframe and the nose cone will be friction fit.

This design is mature in its material selection, which will be complete after testing. It is less confident in the manufacturing, since there is a large risk of fracture while working with the fiberglass frame.

Drag Subsystem

Overview/System Requirements

The drag system must take in data from the control system and manipulate the coefficient of drag to achieve a specified apogee. It will achieve this by deploying flaps made from sections of the body tube on hinges.

Design Selection

The flap design concept shown in figure 6was chosen over the grid fin design like the one shown in figure 7. The grid fins would provide more drag when not active which would negatively impact our budget and weight by forcing a larger motor selection.

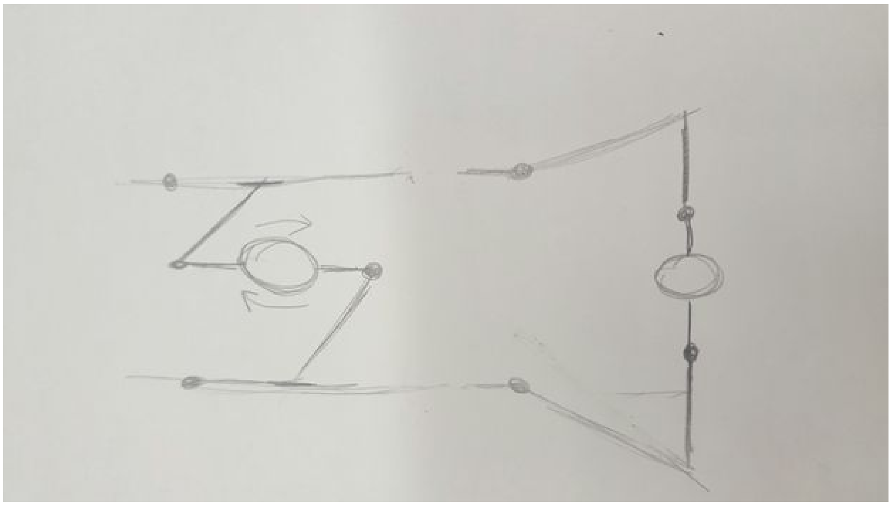


Figure 6: Flap drag system concept

Figure 7: Grid fin design example

Verification
The flap drag design will be verified using CFD techniques. The software package used will be Fluent. The verification process will begin shortly after the PDR presentations as per the schedule.

Size
The drag system will take approximately 5 inches of length for the motors, actuators, and hinges.

Mass
This system will weigh approximately 0.3 pounds. One third of the weight comes from the servo motor, the rest from the linkages and hinge.

System Interaction
The drag system motor will receive power from the control system and it will manipulate the structure system by changing the geometry

Safety Risk
The system could snap at the hinges and break the airframe which would be a risk to budget and human life as well as mission performance.

The electronic connection could also fail which would be a risk to mission performance and budget only.

Manufacturing
The manufacturing for this system will be done with precision dremel tools and epoxies to fix the motors, linkages and hinges into place.

This design is not fully developed. After further CFD analysis, a better plan can be made for the angle and width of the flaps.

Cargo Subsystem

Overview/System Requirements
The cargo system must seal and protect the PVC payload from loads and external debris. It must also successfully tell when the payload is inside and report back to the control system.

Design Selection
The rotating design was kept from the proposal with a slight modification. The light sensor and servo position were chosen to mitigate the risk of wires being sheared or tangled.

Verification
After the PDR presentations the cargo system will be constructed and tested before put inside the airframe. The verification has not been started on this subsystem.

Size
The cargo bay will take approximately 7.5in of length in the airframe. It is two half inch support bulkheads with a gear and motor attached to the top. The diameter will be fit to the approximate inner diameter of the body tube, the material will also be fiberglass to avoid discontinuous roughness on the outside surface of the airframe.

Mass
This system will be approximately 0.728 lb with the 0.3 lb payload inside it, contributing to just over 1 lb of the total mass.

System Interaction
This system will receive power to the servo and light sensor from the controls and send back a signal in the form of a changed voltage to the control system.

Safety Risk
The cargo bay could cause injury if hands or fingers or hair is caught in the motor or door.

The light sensor could also fail which would only be a risk to the mission success.

Manufacturing
This system will be one of the most difficult to manufacture behind the structure. The bay will be cut with the same procedures as the airframe.

This design is mature in its completion of the objectives, but requires more work detailing the manufacturing process.

Control System Overview/Goal/System Requirements

The control system houses all the electronic components as well as the power supply. The goal of the control system is to monitor the rockets status through payload, launch, and recovery. The control system will be powered by an external battery supply that will power our microcontroller. The system must interact with all parts of the rocket as well as ground support. External sensors will be have to connect to our control system. Our control system will have to be optimized to fit in a limited space in our rocket as well as be insulated from outside forces. The schematic is shown in figure 8.

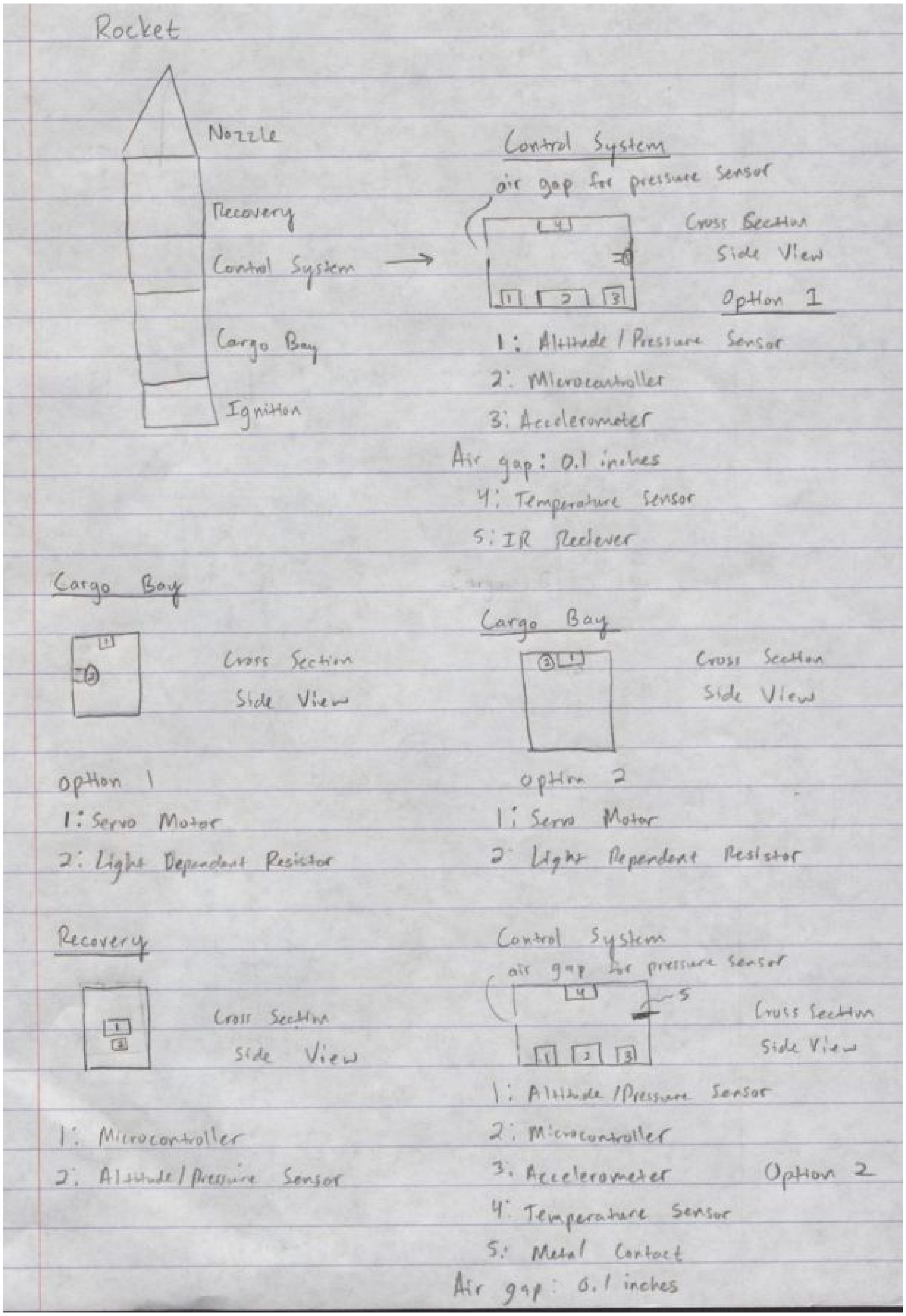


Figure 8: Control System Schematic

Material Selection

The control system will house our power supply and our microcontroller. The sensors will attached to the control system as well as the payload, ignition, and AGES.

The sensors and microcontroller will be mounted on a soldering board to reduce space and to ensure solid connections between the sensors, power supply, and microcontroller.

The control system we be powered by 9V battery. The battery will be an alkaline battery in order to reduce the risk of chemical poisoning. Lead acid batteries are out of the question due to their large size and chemical hazard potential.

The recovery system will be powered by its' own power supply. The power supply that will be use 9V battery.

The microcontroller will be an arduino microcontroller. The use of a microcontroller allows for autonomous operation. The arduino microcontroller has a watchdog and reset capabilities which allows for a reset of the system or a kill switch for the system. The deep sleep mode operation reduces the power consumption leading to a longer lasting power supply.

The temperature sensor, altitude/pressure sensor, and accelerometer sensor will be housed in the control system. The power requirements for these sensors will be to run on <5V due to the output voltage restrictions of the microcontroller.

The light dependent resistor will be housed in the payload and will be tested to determine the appropriate lux range requirement.

Size

The total length required by the electronics package is 5.2 inches inside the 4 inch diameter tube.

Mass

Combined weight of all components, wiring, and servos for the control system is estimated at 1.0 pounds.

System Interaction

The control system interacts will every system in the design through its' sensors or triggers. The light dependent resistor in the payload sends information back to the microcontroller determining if the payload is in the payload bay area. The ignition sensor/trigger relays back to the microcontroller, determining if the ignition is ready to start. The AGES sensor relays back to the system determining if the system is ready for ignition. The microcontroller communicates with the AGES to load the ignition. The control system makes sure that all systems are ready and launches the rocket. The altitude sensor relays the height of the rocket back to the control system. When the rocket has reached its' desired altitude, the recovery system is launched.

The control system interweaves the payload, ignition, AGES, and recovery system to ensure a safe and successful launch and recovery sequence.

Safety

The control system and the sensors may have electrical failures. During building the control system, we will be exposed to lead through soldering. We may also be in contact with alkaline if the batteries are not handled correctly. Soldering iron will be used which poses the threat of severe burns. The safety precautions are listed in appendix.

During the testing of our control system, we can be exposed to high voltage or high current due to a short circuit or open circuit. A rigorous test to check all components to make sure they are in place before the voltage is applied is necessary.

Editing electrical components while they are in contact with the power supply is hazardous and can cause serious injury. We will take the necessary precautions to make sure that all the power supplies are turned off before we edit the electrical circuity. A indicator light may be used as well to indicate if the power supply is connected to the circuit.

The control system may be exposed to hot temperatures which would lead to overheating and exploding sensors, batteries, or even sensors. Heat sinks will be used to dissipate any stray heat through operation or through the environment. The control system may be exposed to cold temperatures which may lead to misreading on sensors which could cause ill-timed triggers. Software checks and insulation of components will reduce these concerns.

Frayed wires may occur due to movement of the rocket or other external sources. This could lead to a short or open circuit, leading to ill-timed triggers. Software checks and open and closed circuit protection of the microcontroller will be used.

Induced magnetic fields will be to be reduced to not cause stray current through our sensors wires.

A kill switch will be used to reduce the safety concerns listed above as well.

Environmental

The control system should be isolated from the environment. Possible malfunction of the alkaline batteries can lead to alkaline being exposed to the air. Also, fire hazards to the environmental can also occur. Sensors will be exposed to the physical nature of mars and could be damaged due to temperature, weather, and earth.

Maturity

The maturity of the control system is very important for a successful launch. The control system is the brains of the operation and is needed in order to trigger the launch sequence. The confidence in the control system is substantial.

Risks

Each electrical component in the control system and the sensors can break due to various factors. If one of our electrical components fails, then we lose time and money and we wait for the component to come in. If the microcontroller fails then the whole operation and testing of components comes to hault. The microcontroller will impact our budget, time and testing. The risk of a damaged microcontroller could lead to a total failure of the launch. The microcontroller has built in failure operation modes that would prevent any stray current or voltage that could flow into the controller and damage the memory.

Selection Rationale

Our control system has two options. The two options to determine the successful AGSE location to the cargo bay were metal contacts or IR diodes. The IR diode is a more reliable method because it doesn't involve mechanical connections between the AGSE and cargo bay. The IR diodes are a safety check determine that the AGSE is in the right location to drop the payload. The metal contacts were not feasible because if they don't come in contact then the AGSE will not be able to deliver the payload. The metal contacts can also be affected by the environment while the IR diodes aren't. The IR diodes will also be flush with the control system structure.

The placement of our light dependent resistor is very important to determine when the cargo bay is full of the payload. If the light dependent resistor is covered too quickly then the system will close the door too early. We decided to go with option 1 and place the light dependent resistor on the side of the cargo bay door to ensure maximum lux on the resistor. The placement allows for a more accurate method to ensure that the cargo bay is full and ready for launch.

Testing

The control system will be tested to ensure a safe launch sequence. We will test the light dependent resistor by varying the light on the resistor and determining the range of resistor values seen by the resistor. This test will also vary that our ADC works properly.

The accelerometer will be tested by simulating the motion of the accelerometer in each direction. We will keep the accelerometer fixed in two axises and vary in the other axis to determine the accuracy of our device.

We will determine the efficiency of our altitude sensor by pre-defining a height and measure the recorded height and pressure of the sensor to verify our device is working properly.

We will test our temperature sensor by monitoring the temperature in the room and determining the output of the temperature given on the microcontroller.

Propulsion Subsystem

Overview/System Requirements
The propulsion system must get the launch vehicle above an altitude of 5280 feet safely.

Design Selection
The motor selected is Cesaroni K261-P. This is a plug type motor which does not have an ejection charge. This is safer for the electronics and cargo system since hot gases will not be ejected towards them. This motor was selected over a J class motor to achieve a max altitude without the drag system active of over 5500 feet.

Verification
Open rocket software will be used to simulate the flight trajectory with this motor under different conditions. The results can be seen in the mission performance predictions section.

Size
The motor is 2.13 inches in diameter and 19.2 inches length

Mass
The motor weighs 4.26 pounds. The casing is approximately 0.36 pounds.

System Interaction
This system will be coordinating with the AGSE system to load the ignitors and launch the launch vehicle.

Safety Risk
Handling the motor is the biggest danger to human safety for this project. A motor failure is also a large impact to budget and mission success. The assembly of the motor is also a risk, although very unlikely to the mission and human safety.

Manufacturing
There is no manufacturing for this system.

This system is fully mature in its design.

Mass Statement
The estimated mass of the launch vehicle is approximately 6.94 pounds. This mass is distributed throughout the rocket, with each system contributing to the overall mass. The Ignition System is

the heaviest at roughly 4.26 pounds. The Electronics Bay System weighs around 1.01 pounds and the Cargo Bay weighs about 0.428 pounds. The Drag System adds an additional 0.3 pounds and the Dual Deployment System will contribute 0.25 pounds. Finally, the parachute adds the last amount of mass with 0.372 pounds. The estimate of the mass of each component and system is within a confidence interval of roughly 25%. Mass estimates are based on the weight of each component, which was researched meticulously. With our chosen motor, the rocket will need to be many times heavier than it currently is in order to be too heavy to launch the vehicle. The only mass in reserve would be for the parachute. In the event that the parachute is too small, a larger one will be used instead which will increase the mass of the overall rocket. This increase in parachute size would be a 38% increase to parachute mass and approximately a 6.1% increase to the mass of the overall rocket mass.

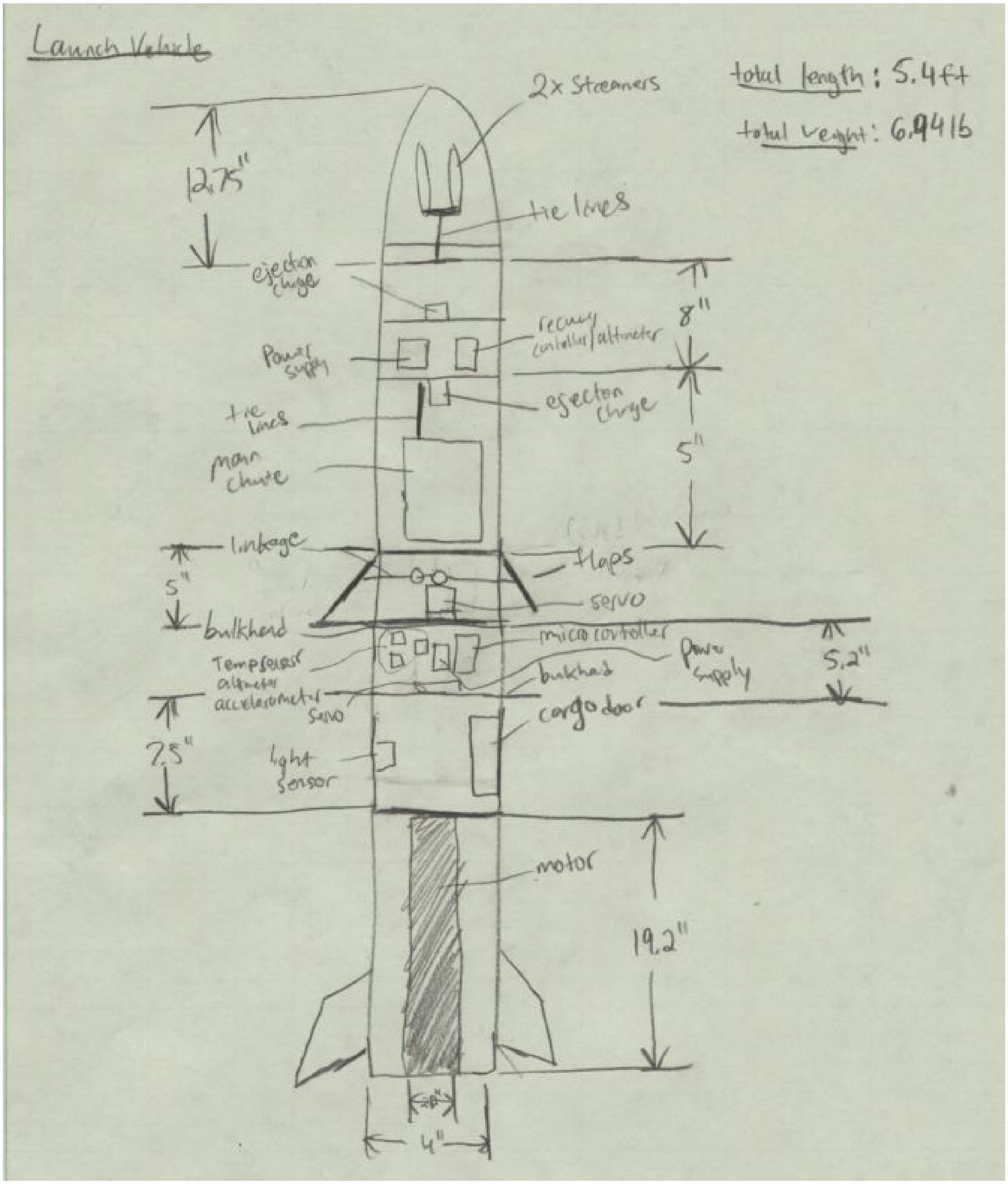


Figure 4: Launch Vehicle Schematic

Recovery Subsystem

The total estimated mass of the system was calculated in an excel file by summing up all expected masses of each component of the system. The parachute size was then determined by the total mass and size of the system. Once each component was included in the overall weight of the system, the targeted weight minus the weight that was calculated was used in determining the parachute sizing. The parachute attaches to an I bolt which is attached to a rod that will be perpendicularly attached inside of the nose cone. Once the launch vehicle reaches the appropriate altitude (near 5280 feet) the deployment will start. Upon approaching the altitude, the streamers will create drag to slow the rocket down and the desired altitude, then once there is enough force, the parachute will deploy. The electronic control schematic is shown in figure 9. The ejection charges will be ground tested by constructing the system as if it was about to be launched including shear pins and rivets. By pulling the shock cord we will use the ejection charges to make sure the parachute comes fully out of the rocket. The electronics will be tested by setting the deployment criteria to ground conditions and make sure that the system triggers. The software will be set to deploy at ground level, then make sure that the system deploys.

The major components of the recovery system include: parachute, parachute harness, attachment hardware, bulkheads, and wadding. The parachute will be used to safely recover the rocket once the rocket has hit maximum altitude and allows the system to slowly approach back to the ground. The parachute harness will be utilized to make sure the parachute is attached to the system securely and will not detach from the system. The hardware will also serve a similar purpose by making sure that the parachute will not detach from the system. The bulkheads will make sure that the compartment stays sealed and does not let any harmful gasses or hot temperatures from destroying the parachute. The wadding will also make sure that the parachute does not get destroyed by the surround hot temperature. The components will be robust enough to withstand any expected loads. By looking at the drag/air resistance and the force of gravity on the system the parachute harness will be able to withstand the forces for the size of the system.

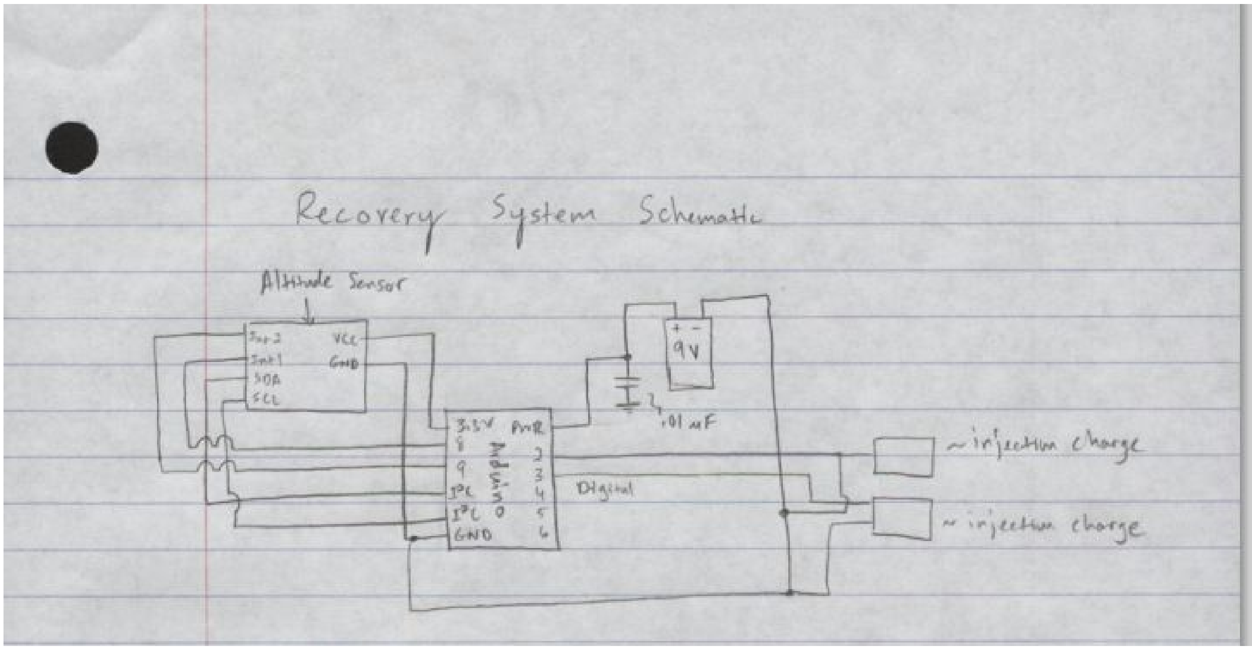


Figure 9: Recovery system schematic

Mission Performance Predictions

The mission requires robot to be able to retrieve a payload located on the ground, and place it into the rocket, sealing the cargo bay when complete. The rocket must then be turned vertically upright and primed for launch. After launch, the rocket must ascend to an altitude of 5280 feet and deploy a recovery system for safe landing some time after the motor has burned out.

The simulated flight profile with predicted altitude and a table of component weights can be found below. The predicted apogee of the rocket is around 5370 feet, which is above the target altitude. However, the simulation does not take the Drag System into account. Figures below also show the thrust curve of the simulation and the simulated center of pressure, center of gravity and stability margin.

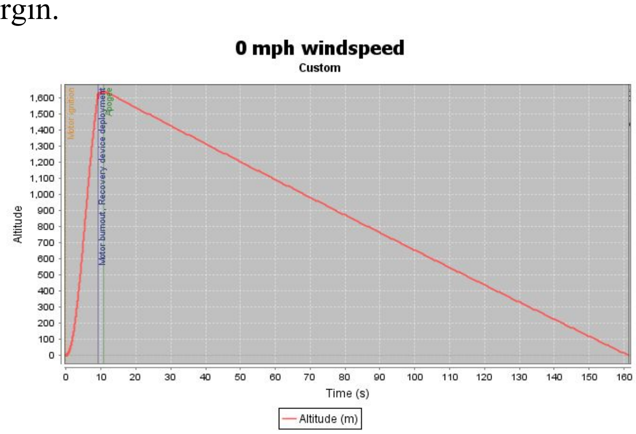


Figure 10: Predicted Altitude of Rocket

Figure 11: Thrust Curve of Rocket

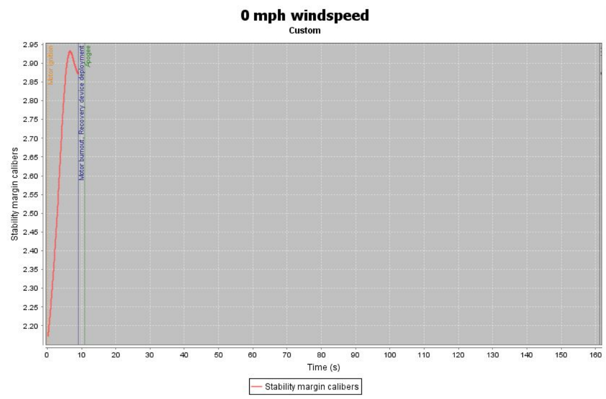


Figure 12: Stability Margin of Rocket

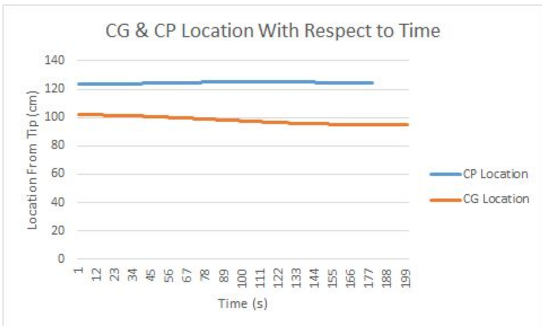


Figure 13: CG & CP Location with Respect to Time

Table 1 below shows the kinetic energy calculations for each piece of the rocket at impact.

Table 1: Kinetic Energy of Rocket Components at Impact

KE Nose Cone (J)	KE Drag System (J)	KE Rest of Rocket
10.96	7.51	246.25

The following figures show the amount of drift the rocket will experience at different wind speeds, starting at zero miles per hour and increasing in increments of five miles per hour until a maximum wind speed of twenty miles per hour is reached. All lateral distances are in units of feet, and these values are plotted with respect to time.

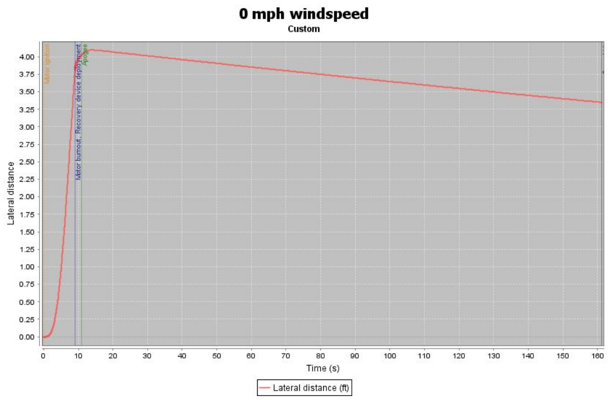


Figure 14: Drift of Rocket with 0 mph Wind Speed   Figure 15: Drift of Rocket with 5 mph Wind Speed

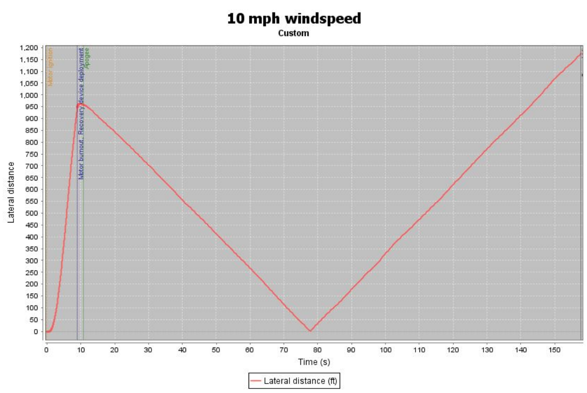


Figure 16: Drift of Rocket with 10 mph Wind Speed Figure 17: Drift of Rocket with 15 mph Wind Speed

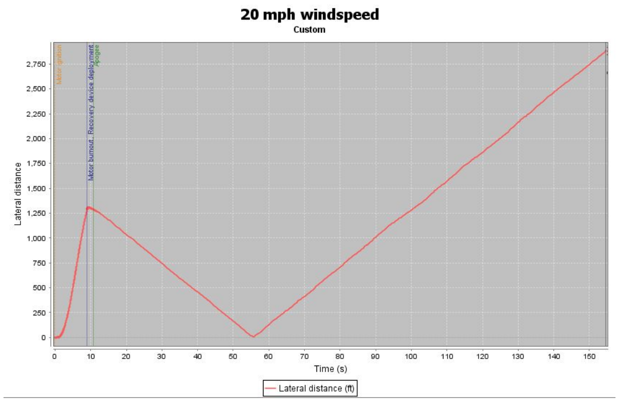


Figure 14: Drift of Rocket with 20 mph Wind Speed

IV) AGSE System Analysis

The system being analyzed is a fully autonomous robotic mechanism. The goal of this autonomous system is to capture, contain, and launch the payload one inch in diameter and 4.75 inches long. In addition to securing the payload in the rocket, the automated system will also erect a rocket from the horizontal position to the vertical position and install igniters. Completion of the step Requirements 3.3.2.1.1 – 3.3.2.1.4 are outlined in the MAV hand book and will be followed within a 10 minute time frame this will verify a successful performance. The Autonomous Ground Support Equipment (AGSE) will follow computer logic code with simple true/false commands to complete a series of tasks that will check, confirm, and carry out steps as the payload is delivered.

The materials required will start with the framework of the base foundation. The base will be made out of square steel perforated tubing, laid and welded together to make a stable launch area in a rough shape in figure 15.

Figure 15: ground base frame, launch rail, launch pad.

The materials for this were decided based on low material costs and low material weight. Next design area was creating a way of erecting the rocket. The rocket will sit on a guide rail with a square launch pad attached on the base near the nozzle of the rocket. The launch pad will be attached to two torsion springs that will be able to create a moment rotating the launch pad to a full 90°. To provide resistance and to make the system able to stop on command there will be an electric winch slowly releasing line as the launch pad rotates to 90°. The guide rail will be made out of extruded aluminum because it will be lightweight and fit the rail guides on the rocket. The bottom plate will be made out of 1/8" thick patterned steel sheet metal because of low material cost, and high structural strength plus welding ease. The torsion spring was an idea to save costs and still provide enough force to rotate the rocket vertical. This eliminated the initial idea of a motorized system that would have lifted the rocket upright. The AGSE main objective to pick up the payload. The process of picking up the payload will consist of linear actuators and servo powered conveyors. In figure 16 the linear actuator is yellow and the conveyors are in red, this is the design of the ground recovery system (GRS).

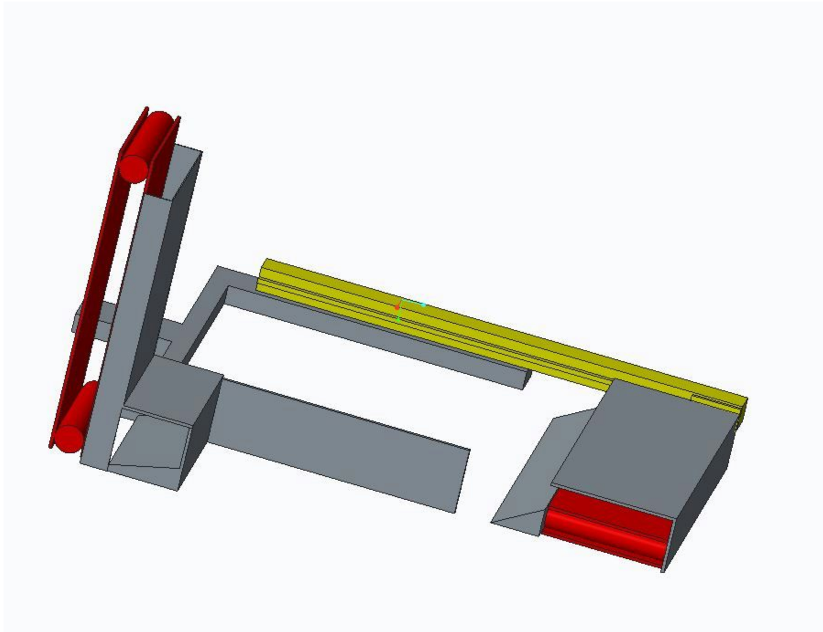


Figure 16: ground recovery system (GRS)

The system in figure 16 will be placed on a X-Y linear actuators, shown earlier in figure 3, this way the system can start inside the AGSE boundary. The X-Y linear actuators will then move the GRS on the away from the main AGSE system and drop the ground recovery system down where the payload fits inside the specific area of the GRS. There will be a wedge on the moving part of the GRS where it will sweep the specific area inside until it collects the payload and it falls on the conveyor where it will be enclosed and carried to the next set of conveyors that will lift the payload up to the cargobay of the rocket. Before the step where the cargo is elevated to the rocket, a proximity switch will turn on the elevated conveyor and move the X-Y linear actuators back to the start position next to the cargo bay. Once the payload has reached the rocket and has been successfully placed inside, the AGSE will send an infrared frequency to the rocket where the cargobay will seal. Then the ground controls will release the slack on the winch and raise the rocket to it's vertical position. When a proximity switch has the reading that the rocket is in vertical position, then the igniters will be placed in the rocket as the last step with servo driven linear actuator. Once the linear actuator reaches the home position, a voltage is applied for a set duration and the rocket is launched. In the event that the rocket does not launch, there will be a disconnect of the battery after the voltage application time and the system is off.

The standard operating procedure starts with laying out the pieces of the AGSE assembly, assembling the system and electronics, testing each electrical component, connect all the electrical systems, get the green light for the ok to start the AGSE on the remote, make sure the pause light will stop the AGSE during any of its steps and then press go.

Mass estimates: 5 lbs for each linear actuator, 10 lbs of metal tubing, 10 lbs of sheet metal, 10 lbs for recovery system, 10 lbs for the winch, 5 lbs for extruded aluminum. Total 65 lbs

Size will be 6ft long, by 5ft wide, 10ft tall with rocket erected.

This system will interact with the rocket and the launch.

Safety will be focused on the electrical setup, the conveyors, linear actuators, winch, proximity switches, and infrared receiver. For the mechanical systems the torsion springs, material failure, and fatigue will be tested. Tests will need to be run to determine the force required to rotate the rocket vertically and the tension needed on the winch cable. The electrical wiring needs to be precise and the procedure needs to follows detailed logic. The power required to run the conveyor motors and winch are also a safety concern, tests need to be done to find the amperage needed. During the construction of the AGSE there will be safety for the machine shop. Every member will complete the necessary safety quizzes to work with power tools. There will be cutting, welding, and drilling to design the AGSE.

Interfaces and Integration

The cargo bay is made to protect the the payload from any stresses due to flight. The controls have to be secured during the full duration of the operation and flight. The cargo and the controls are to not be affected by the ignition system. During the recovery, the cargo and the control have to withstand the g forces and changes in momentum due to loss of acceleration. The dimensions of the payload and the controls have to be relatively close to insure that the payload fits and does not produce drag on the system.

The control system has to link the cargo system to insure successful installation. The recovery system deploys the ejection charges by careful calculations from the altimeter. The recovery system has its own power supply and microcontroller, which insures isolation from the rest of the system which produces a safer, more reliable system.

The payload will be inserted in the cargo via conveyor. The AGSE will move horizontally on a linear actuator to the desired location to release the payload. A mechanical stoppage will determine if the AGSE is in the correct, desired location. An IR system will provide a backup check to see if the AGSE is at the desired location and ready to drop the payload into the system. After the completed payload drop off, the IR system will indicate that the system is ready launch it will tell the AGSE system to return to the home location, away from the launch system.

The interface between the launch vehicle and the ground launch system consists of the ignition system and the AGSE. A linear actuator will push the plug into the ignition. After a few seconds delay, the applied voltage force will launch the rocket. The launch system will then disengaged from the launch system from the ground.

Safety

Safety will be held paramount throughout the process of the competition. The safety officer will be responsible for ensuring that all safety procedures are followed, and will be in charge of the final assembly/launch procedure checklist on the day of the competition. Safety guidelines have been taken from multiple sources, including the University of Iowa and the National Association of Rocketry (NAR). These guidelines will be followed by the team, and many of the NAR guidelines are worked into the design of various systems on the rocket and AGSE. Article 1 of the NAR High Power Rocketry Safety Code will be followed, and all required licenses will be obtained prior to the launch day. The team mentor will assist in obtaining all licenses, and will oversee the flight due to their prior rocketry experience.

Many of the safety rules concerning shop work and the construction process are rules that have been created by the University of Iowa. In order to fully understand these rules, the University of Iowa requires that all students wishing to work in a shop space take online safety courses. For the UI SLI team, the required online courses cover personal protective equipment (PPE), fire safety/fire extinguishers, and tool safety. After taking the online courses, students must take quizzes for each course and pass them. Once passed, forms will be signed by each student and given to the professor who oversees the shop space. A sample form is provided in the appendix of this report. This ensures that all students understand the basic safety rules, and promise to comply with these rules. These rules form the basis for rules surrounding construction, but additional rules specific to the rocket's construction will be enforced by the safety officer to further ensure the safety of all team members.

One of the most important rules defined by the University of Iowa for safety concerns personal protective equipment. All students working in a shop space are required to wear long pants and close-toed shoes while in the lab, along with safety glasses. These items are the bare minimum, with other PPE being worn as needed for specific tasks. The UI SLI team will have other PPE on hand as needed for various tasks. The specific PPE for mitigation of specific risks is detailed below in each section that concerns a certain PPE-requiring risk.

In addition to PPE, the shop itself must be maintained to prevent injury. The shop will be cleaned after every construction session, and cleaning will be done during the sessions to ensure that all work areas are safe. All work areas will be well-lit. All flammable materials will be stored in the flammable cabinet, and will be properly labeled. MSDS for the materials in the cabinet will be stored near the cabinet and will be easily accessible. MSDS for materials that are to be used are given in the appendix of this report. A separate drawer will be maintained for the storage of PPE including respirators, gloves, and safety glasses. Aprons will be available as well.

AGSE Design options

Original designs were made and can be seen in figure 17 below.

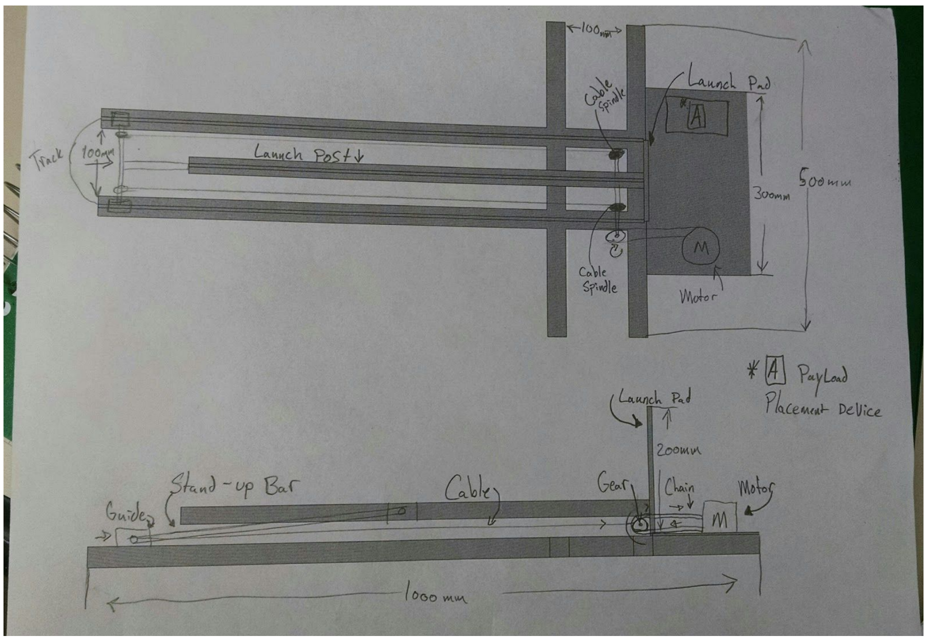


Figure 17: Original AGSE Design

This was the team's first design for erecting the rocket. There was to be a system powered by a motor that would turn a cable and pull guide on a track lifting the launch post into position. The first preconceived payload placement device was to be an automated claw on a angled rod that would swivel down pick up the payload and then swivel up and place it in the cargo bay. This option was replaced by the current 3-D models because the materials and manufacturing options were too hard to design. The newer 3-D models are a simpler way to place the payload into the rocket and the moving parts are easier to control.

Safety

The AGSE system will abide by the NAR High Power Rocket Safety Code, Article 7 (Launchers). This section of the Safety Code states that the launching device must be "a stable device that provides rigid guidance", and states that the launching device must be within 20 degrees of vertical. The system that moves the AGSE system into the vertical launch position will be tested to ensure that it consistently reaches this degree standard, and to ensure that it can be adjusted as needed to counteract potential winds on the day of the launch. The AGSE system will also help mitigate the risks associated with the ignition system. According to Article 7 of the Safety Code, a blast deflector must be used on the launch device to prevent motor exhaust from hitting the ground. More information on the specifics of this risk and its severity are given in the *Ignition* sub-section below. The addition of this blast deflector will greatly mitigate this risk and increase the likelihood of a fully successful launch.

Verification

To test the AGSE, each part of the total assembly will be made separately and tested on it's own. For example the process for erecting the rocket will be made first and verified that the process can pause during rotation and will reach a full 90 degrees. Then the GRS will be made separately and tested that it can recover the payload. The final step will be to check that the igniters will be precisely put into the rock. After all the sub assemblies are checked and verified then a full assembly will be made to assure a completion of the requirements made in the MAV handbook sections 3.3.2.1.1 – 3.3.2.1.4..

Science Value

The MAV project will give valuable insight to the potential problems with an autonomous mission to Mars. If the overall system is able to fulfill the objectives of each sub system then the project will be a total success.

Mission Safety

AGSE Structure

The structure of the AGSE poses safety risks largely during the construction phase of the competition. The frame must be welded together, posing a safety risk to whoever is responsible for the welding. Burn injuries are the most common type of injury from welding, and can range from mild to very severe. To mitigate this risk of burn injury, only team members who have been trained to weld will be allowed to weld the AGSE frame. These members will also be required to wear the proper welding safety gear, including welding aprons/leathers, a welding helmet, and leather gloves. These safety items will be worn in addition to the basic safety gear worn in the shop as defined earlier. The weight of the components also poses a safety risk, as heavy pieces of metal could fall and injure team members while they work on constructing the AGSE system. To mitigate this, heavy items will only be lifted and moved when absolutely necessary, and members will lift and move these items as a team, or use lift assist devices. While these risks are unlikely, they are more severe and can cause severe injury, making them highly important to mitigate. Power tools will also be used in the construction of the AGSE. The team plans to use many tools, including band saws, grinders, drill presses, power drills, hand saws, shear presses, press brakes, and jig saws. In addition, MIG welders and plasma cutters will be used as needed.

Prior to use of any of these tools, the tool will be inspected to ensure that it is in proper working order. Operator manuals for these tools will be kept in the shop, and all team members will be notified of the location of these manuals.

The electronic components of the AGSE system pose risks that are more severe and likely than the risks of construction of the frame. The risk of electrocution during assembly of the full electronics setup is high, meaning that multiple precautions need to be taken.
At the final assembly and launch, the weight and size of the AGSE system again poses a safety risk. While the risk of injury during assembly is small, there are risks that must be mitigated. The weight of the system could cause strain injury to the team, so to mitigate the risk of injuries of this type, the system will be moved with the help of the entire team. During final assembly, the team members who constructed the AGSE will be responsible for assembly. This is to ensure that the system is assembled properly and safely. When doIng the final assembly of the electronics, there is a very large risk of electrocution. This risk is greatest when attaching the power supply and ensuring that power is supplied to all the components. To mitigate this risk, only the team members who constructed the electronics will be allowed to connect the power and test connections. This will ensure that all the connections are properly made and tested.

Rocket Structure

During the design process, materials choices will be made to ensure the highest level of quality. This high level of quality will enhance the safety of the rocket. This falls in line with Article 2 of the Safety Code, which states that only lightweight materials should be used.

The construction phase of the rocket has the highest number of risks from a variety of sources. The materials used pose many of these risks. Any epoxies used pose a health risk if they come into contact with the eyes or skin, and the fumes from epoxies can cause lung irritation. While these risks aren't very severe, they are highly likely due to the high use of epoxies. To mitigate these risks, all epoxies will be used in well-ventilated areas. Team members working with epoxies will be required to wear safety glasses and gloves while working with the epoxies.

Working with materials such as carbon fiber and fiberglass can also pose safety risks. These risks are less likely and much less severe, but the potential for injury still exists. While cutting these materials, gloves will be worn to prevent injury due to loose fibers. Materials will be cut in well-lit, clean areas. Proper tools will be used to cut materials, and the tools will be inspected per general shop rules.

In addition to the use of epoxies, many power tools will be used during the construction process. The likelihood of injury risk from power tools is high, and the severity can range from minor injuries to very severe injuries requiring immediate medical attention. To mitigate the potential risks from the use of power tools, only team members trained in a tool's use will be allowed to use the tools. Tools will be inspected before use, and if they are broken or damaged, they will not be used. These rules fall in line with the safety rules given by the University of Iowa.

Care will also be taken during the construction process to ensure that the rocket is built sturdily. This will ensure a safe flight. All external components will be secured to the rocket prior to launch so that nothing falls off the rocket while it is in flight. Were a component to fall off the rocket, it could cause injury to spectators. This could also cause environmental damage to the launch area. The risk of this occurring is small, but has the potential to be very severe, making it of high importance to ensure the quality of the rocket. A component detaching from the rocket could also lead to a potential catastrophic failure of the rocket, creating a significantly more severe risk of injury and environmental damage. Mitigation of this through proper construction techniques will prevent this failure from occurring.

Ignition

The ignition system has few risks, but these risks are significantly more severe than most. If the motor were to fail, a significant risk to both personnel and the environment would exist, and could lead to severe injury and damage. To prevent a severe incident like this, steps have been taken and will be taken throughout the competition process to ensure the safety of all members involved. Many of the risk mitigation steps overlap with the NAR High Power Rocket Safety Code. Article 3 states that only certified, commercially made motors will be used. The motor selected K261-P is made by Cesaroni, and this motor will not be tampered with by any members of the team. The motor will be launched using an electrical launch system as mandated by Article 4 of the Safety Code. The safety system described in Article 4 will be integrated into the AGSE system, and will ensure that the launch is conducted safely and in accordance with NAR guidelines. This system will also be designed to work in accordance with Article 5. In the case that the rocket does not launch as expected, the AGSE system will ensure that the battery is disconnected. This misfire system will also work with Article 6, which states that the system should have a means to notify team members and spectators in the event of a misfire or another problem. The system will maintain a 5-second countdown prior to launch that will be audible to both the team and spectators. The safety officer will enforce the final aspect of Article 6, making sure that only personnel necessary to the successful setup of the rocket and any arming/disarming procedures are present at the launch pad.

Electronics Recovery

There is a risk of losing power is substantial because we will lose all chances to eject the parachute. Fail ejection charge deployment can lead to loss of control of rocket and possible human harm if wind were to take control of its path of flight. The altitude sensor could lead to no ejection charge deployment because it will never sense the altitude. Include a software pre-check for the battery life level before launching to insure that all systems will deploy at the desired altitude. Altimeter check to insure that live readings are occurring.

Payload

The payload bay poses risks during the construction phase, though these risks are less likely. When constructing the system, care must be taken with the servo motors as they are assembled into the full rocket. The wires must be handled carefully to avoid injury as well. To mitigate this risk, the number of people working on the assembly of the payload bay will be kept to a minimum.

Most of the risks for the payload bay are likely to occur during the launch. If the speed of the servo is too high, it could cause damage to the rocket that could cause structural damage to the rocket. If this were to occur, pieces of the rocket could fall off during flight, and the payload could potentially fall out of the rocket. This would pose a large safety risk and environmental risk. Though this scenario is unlikely, it will still be analyzed to provide preventative solutions. This will include specifying a maximum velocity for the servo motor to prevent excessive speeds that could cause damage. In the event that an aspect of the launch process fails, the servo motor setup will be designed with a way to stop the motor and keep the door from moving.

Final Assembly/Launch Procedures

Final assembly will be conducted by the full team, and the person in charge of each subsystem will be responsible for the assembly and final setup of their systems. The safety officer will oversee the assembly process, and will have a checklist of the finalized assembly procedure to ensure that all steps are completed. A preliminary version of this checklist is included in this report. The checklist will be refined as needed to reflect the final rocket and AGSE system. All team members will be expected to read and understand the checklist and assembly procedures prior to the launch day. This will ensure that all members know their responsibilities, and will be able to work in a timely manner to assemble the rocket and AGSE for launch.

Table 2: Risks

Risk	System	Budget	Mission	Human
Airframe fracture	Structure	2	2	1
Parachute Deployment	Recovery	0	1	2
epoxie contact	strucutre	1	0	2
Power tools misuse	strucutre	0	1	1
blutube structure	structure	1	1	0
temperature range	strucutre	0	1	1
hinge fracture	structure	1	1	1
electronic connection failure	recovery	1	1	1
human contact with servo	strucutre	1	1	1
light sensor failure	recovery	1	1	0
human contact with motor	strucutre	2	1	1

Low severity	0 - not likely
Medium severity	1 - likely
High severity	2 - very likely
Negligible	

V) Project Plan

Funding Plan

The funding will be acquired from the following sources:

$3000	Iowa Space Grant Consortium
$1000	Club Funding-AIAA Fundraising
$500	Company Donations
$4500	**Total Budget**

Budget Plan

Rocket:

altimeter	$50
parachute	$105
fins	$75
nose cone	$40
fiberglass tubing	$130
2 ignition	$140 (2x $70)
nozzle	$60

accelerometer	$70
arduino controls	$60
cargo bay and sealing:	
-360 degree servo for closing,	$25
-light sensor for detection,	$40
-rotation door for cargo bay	$50
photoresistor	$10

Total = $855

AGES:	30ft extruded aluminium	$200
	Screws	$20
	small electric winch	$60
	10ft² 1/8in steel sheet	$100
	3X 1in square steel tubing 8 ft long	$150
	3X servo motors	$50
	3X pneumatic air cylinders	$100
	mini photo cells	$20
	Pressure sensors	$60
	Torsion Spring	$50
	Custom fabrication	$1000
	arduino controls	$60
	electrical assembly	$100

Total = $1970

Travel:	Gas (2 cars 759 miles one way trip)	$400
	Hotels (4 people for 6 nights)	$600
	(4 people for 3 nights)	$300

Total = $1300

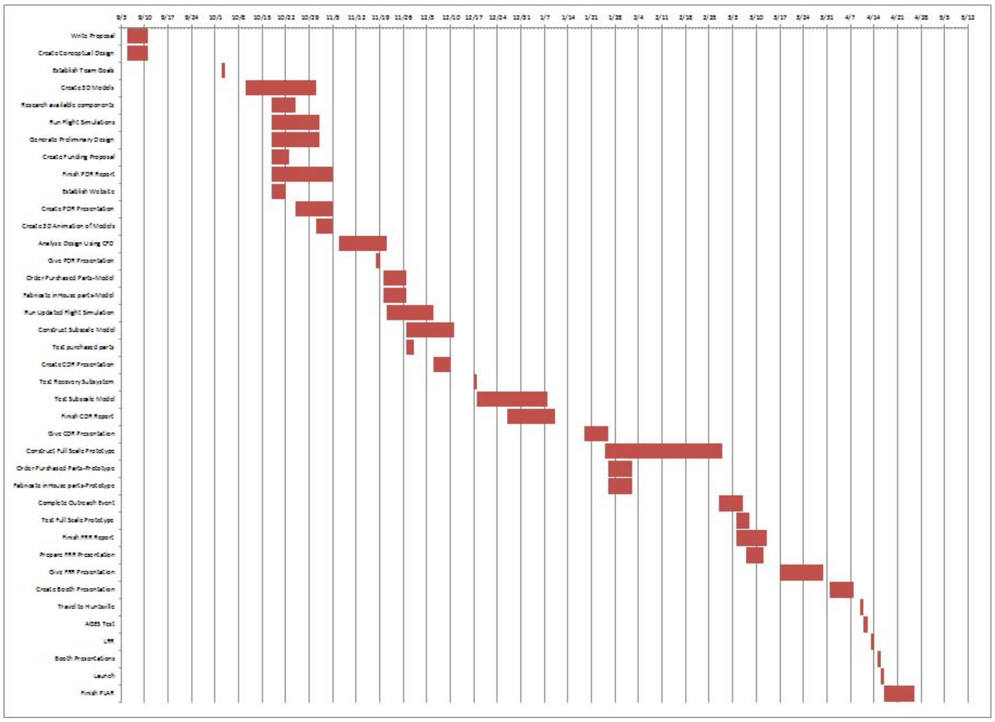
Grand total: $4125

Schedule

The Gantt chart seen below outlines all the major events for this project. The project is on schedule with the exception of the 3D animation. This will be moved to after PDR to allow for more time for presentation preparedness.

The critical path before CDR is to order/create all subscale parts, then build the subscale model and test the model to acquire results. The other tasks involve material and CFD analysis.

Table 3 Gantt Chart



References

http://www.lincolnelectric.com/en-us/education-center/welding-safety/PAGSE/personal-protective-equipment-faqs.aspx

http://ehs.research.uiowa.edu/safety-training-course-guide-what-course-should-i-take

Safety**:**

Welding

http://www.mtcounties.org/insurance/risk-management/safety-corner/welding-safety-checklist

Saws

http://nstea.nstu.ca/imAGSE/Documents/BandSaw2.pdf

Drilling

http://www.aps.anl.gov/APS_Engineering_Support_Division/User_ESH/Machine_Shops_Public/20050816_pdf_files/Evaluation_Checklists/APS_Eval_Checklist_Drill_Press.pdf

Apogee Rockets:

https://www.apogeerockets.com/

Appendix A MSDS:

Cesaroni K261-P Motor MSDS

MSDS – ProX Rocket Motor Reload Kits Page 1/6 Version 2.02

Revision Date. 8 Feb 2010

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MATERIAL SAFETY DATA SHEET

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ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits

Synonyms: Rocket Motor

Proper Shipping Name: Articles, Explosive, N.O.S. (Ammonium Perchlorate)

Part Numbers: Reload kits: P29R-Y-#G-XX, P38R-Y-#G-XX, P54R-Y-#G-XX, P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX,

Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX

Where: Y = reload type (A = adjustable delay, C = C-slot)

= number of grains &

XX = propellant type

Product Use: Solid fuel motor for propelling rockets

Manufacturer: Cesaroni Technology Inc.

P.O. Box 246

2561 Stouffville Rd.

Gormley, Ont.

Canada L0H 1G0

Telephone Numbers:

Product Information: 1-905-887-2370

24 Hour Emergency Telephone Number: 1-613-996-6666 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Propellant

Ingredient Name CAS Number Percentage
-- ----------------- ----------------

Ammonium Perchlorate .... 7790-98-9 40-85 %
Metal Powders .... 1-45 %
Synthetic Rubber .... 10-30 %

Black Powder Ignition pellet

Ingredient Name CAS Number Percentage
-- ----------------- ----------------

Potassium Nitrate .... 7757-79-1 70-76 %
Charcoal .... n/a 8-18 %
Sulphur .... 7704-34-9 9-20 %
Graphite .... 7782-42-5 trace

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

There articles contain cylinders of ammonium perchlorate composite propellant, encased in inert plastic parts.
The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified
as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous
and must be handled carefully and used following approved safety procedures under the direction of competent,
experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid
inhaling exhaust products.

General Appearance:

Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant
(rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:

Eye:
Not a likely route of exposure. May cause eye irritation.
Skin:
Not a likely route of exposure. Low hazard for usual industrial/hobby handling.
Ingestion:
Not a likely route of exposure.
Inhalation:
Not a likely route of exposure. May cause respiratory tract irritation. Do not inhale exhaust products.

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4.0 FIRST AID MEASURES

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Eyes:
Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower
eyelids. Get medical aid.
Skin:
Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and
shoes. Get medical aid if irritation develops or persists.
Ingestion:
Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.
Inhalation:
Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is
difficult, give oxygen. Get medical aid.
Burns: Burns can be treated as per normal first aid procedures.

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5.0 FIRE FIGHTING MEASURES

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Extinguishing Media:
In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam to contain surrounding fire.
Exposure Hazards During Fire:

Exposure to extreme heat may cause ignition.

Combustion Products from Fire:

During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:

Keep all persons and hazardous materials away. Allow material to burn itself out. As in any fire, wear a selfcontained
breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective
gear.

Special Instructions / Notes:

These articles burn rapidly and generate a significant flame for a short period of time. Black powder is a
deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact.
When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight
confinement. Do not inhale exhaust products.

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

Spills: Clean up spills immediately. Replace articles in packaging and boxes and seal securely. Sweep or scoop up
using non-sparking tools.

7.0 HANDLING AND STORAGE

Handling: Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on
clothing. Do not taste or swallow. Avoid prolonged or repeated contact with skin. Follow manufacturer's instructions for use.

Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging
when not in use.

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls:
Use adequate explosion proof ventilation to keep airborne concentrations low. All equipment and working
surfaces must be grounded.
Personal Protective Equipment:
Eyes:
Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and
face protection regulations in 29 CFR 1910.133 or European Standard EN166.
Skin:
Clothing should be appropriate for handling pyrotechnic substances.
Clothing:
Clothing should be appropriate for handling pyrotechnic substances.
Respirators:
A respirator is not typically necessary. Follow the OSHA respirator regulations found in
29CFR1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149
approved respirator when necessary.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State: solid
Appearance: rubber cylinders inside plastic parts
Odour: none
Odour Threshold: Not available.
pH: Not available.
Vapour Pressure: Not available.
Vapour Density: Not available.
Viscosity: Not available.

Evaporation Rate: Not available.
Boiling Point: Not available.
Freezing/Melting Point: Not available.
Coefficient of water/oil distribution: Not available.
Autoignition Temperature: 280°C
Flash Point: Not available.
Explosion Limits, lower (LEL): Not available.
Explosion Limits, upper (UEL): Not available.
Sensitivity to Mechanical Impact: unprotected black powder can be ignited by impact
Sensitivity to Static Discharge: unprotected black powder can be ignited by static discharge
Decomposition Temperature: > 400°C
Solubility in water: black powder is soluble in water
Specific Gravity/Density: black powder = 1.7-2.1
Propellant = not available
Molecular Formula: Not applicable
Molecular Weight: Not applicable.

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10.0 STABILITY AND REACTIVITY

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Chemical Stability:
Stable under normal temperatures and pressures.
Conditions to Avoid:
Heat, static electricity, friction, impact
Incompatibilities with Other Materials:
Combustible or flammable materials, explosive materials
Hazardous Products Of Decomposition:
Oxides of nitrogen
Hazardous Polymerization:
Will not occur.

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11.0 TOXICOLOGICAL INFORMATION

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Routes of Entry: Skin contact – not likely

Skin absorption – not likely
Eye contact – not likely
Inhalation – not likely
Ingestion – not likely

Effects of Acute Exposure to Product:

No data available

Effects of Chronic Exposure to Product:

No data available

Exposure Limits:

Black Powder Pellets

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Potassium Nitrate	7757-79-1	not established	not established
Charcoal	n/a	not established	not established
Sulphur	7704-34-9	not established	not established
Graphite	7782-42-5	2.5 mg/m3	15 mmpct (TWA)

Propellant

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Ammonium Perchlorate	7790-98-9	not established	not established
metal powder		varies	varies
Synthetic Rubber		not established	not established

Irritancy of the Product:

No data available

Sensitization to the Product:

No data available

Carcinogenicity:

Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA

Reproductive Toxicity:

No data available

Teratogenicity:

No data available

Mutagenicity:

No data available

Toxically Synergistic Products:

No data available

LD50:

No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:
Ecotoxicity Data:
Not determined.
EcoFaTE Data:
Not determined.

13.0 DISPOSAL CONSIDERATIONS

Product As Sold: Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe
distance and wait 5 minutes before approaching. Dispose of spent components in inert trash.
Product Packaging: Dispose of used packaging materials in inert trash.
Special Considerations: Consult local regulations about disposal of explosive materials.

14.0 TRANSPORT INFORMATION

Shipping Information – Canada
TDG Classification: Class 1.4 Explosive
Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C
Packing Group: II
UN Packing Instruction: 101
Shipping Information - USA / IMO
Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C

DOT / IMO Label: Class 1 – Explosive – Division 1.4C
Shipping Information - IATA
Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number: 0351
UN Classification Code: 1.4 C
IATA Labels: Class 1 – Explosive – Division 1.4C
Cargo Aircraft Only

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15.0 REGULATORY INFORMATION

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Canada
This product has been classified according to the hazard criteria of the Canadian Controlled Products
Regulations (CPR) and the MSDS contains all of the information required by the CPR.
WHMIS Classification: Not Controlled (explosive)
Domestic Substance List (DSL) Status:
All ingredients are listed on Canada's DSL List.
Canadian Explosives Classification: Class 7.2.5
This product is an authorized explosive in Canada.
These products are not considered “Controlled Good” in Canada under the Controlled Goods Regulations.
United States of America
TSCA Inventory Status:
All ingredients are listed on the TSCA inventory.
Hazardous Chemical Lists
CERCLA Hazardous Substance (40 CFR 302.4) No
SARA Extremely Hazardous Substance (40CFR 355) No
SARA Toxic Chemical (40CFR 372.65) No
European/International Regulations
The product on this MSDS, or all its components, is included on the following countries' chemical inventories:
EINECS – European Inventory of Existing Commercial Chemical Substances
European Labelling in Accordance with EC Directives
Hazard Symbols: Explosive.
Risk Phrases:
R 2 Risk of explosion by shock, friction, fire or other sources of ignition.
R 11 Highly flammable

R 44 Risk of explosion if heated under confinement.
Safety Phrases:
S 1/2 Keep locked up and out of the reach of children.
S 8 Keep container dry.
S 15 Keep away from heat.
S 16 Keep away from sources of ignition -- No smoking.

S 17 Keep away from combustible material.
S 18 Handle and open container with care.
S 33 Take precautionary measures against static discharges.
S 41 In case of fire and/or explosion do not breathe fumes.

16.0 OTHER INFORMATION

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