University of Iowa AIAA USLI
Critical Design Review
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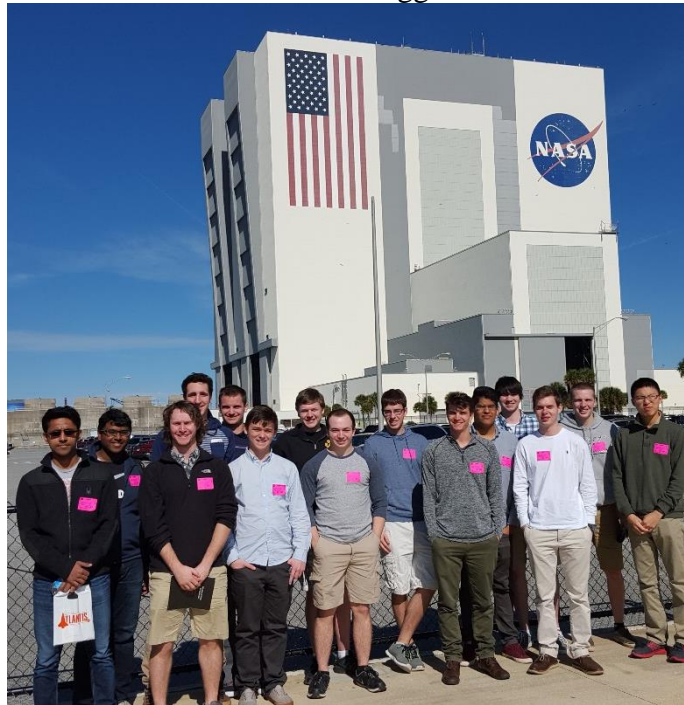Victoria Trojanowski
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Section 1: Summary of CDR Report
Team Summary

School: University of Iowa
Organization: American Institute of Aeronautics and Astronautics, Iowa Student Section
Location: Seamans Center
          103 South Capitol Street
          Iowa City, IA 52242
Project Title: Mars Ascent Vehicle
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Certification: Tripoli, NAR Level 3
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Launch Vehicle Summary

The launch vehicle has been designed to be lightweight and is centered around safely carrying a given payload. The vehicle airframe will be constructed from fiberglass, with various lightweight materials being used for other external and internal components as detailed later in this report. Table 1 gives an overview of the vehicle's main parameters.

Table 1: Launch Vehicle Overview

| Overall Length ft	6.7
Diameter in	4
Mass lb	14.06lb
Motor	Cesaroni K490
Recovery System parachute, streamers	52in, 2x50in streamers
Milestone Review Flysheet	See Appendix A
Payload Title	Mars Ascent Vehicle
Experiment Description	Autonomous acquisition, containment, and launch of payload through ground support system to launch vehicle and target altitude
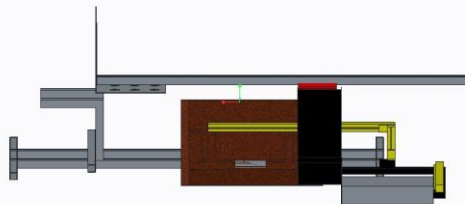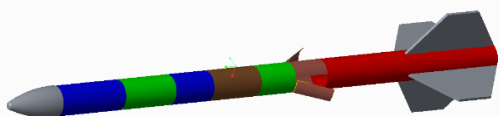
Figure 1: Full Launch Vehicle and AGSE Creo Model

Section 2: Changes Made Since PDR
Changes to Vehicle Criteria
    System Arrangement
    The new vehicle diagram is shown in figure 2. The subsystems were rearranged since the PDR. First the parachute and streamers positions swapped. This increases the margin of stability by lowering the center of gravity and reduced the risk of recovery system failure. With the separation point for the first charge lower the ejected portion has more mass and will separate easier.
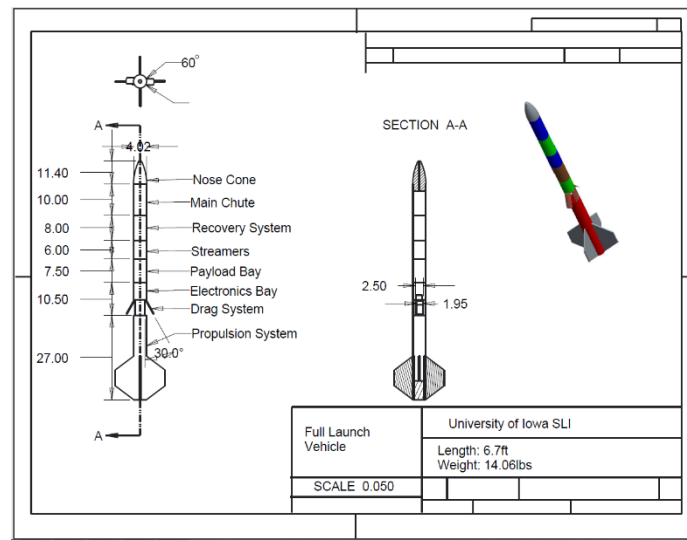
Figure 2: Launch Vehicle Drawing

    The drag system and payload bay was also be switched. This will increase the stability during drag system deployment by having the new center of pressure closer to the base of the rocket.
    Recovery system
    First the parachute size was increased to an angel 52" chute. This is required to keep the landing kinetic energy under 75lb*ft/s^2 of energy. The tie lines were also increased to 18' to ensure a stable decent after recovery system deployment. Lastly redundant ejection charges and altimeters were added to ensure system success.
    The size of the parachute system was increased to 10 inches ( ) to ensure a larger parachute will fit. The propulsion system was also increased to 27 inches ( ) to allow for a larger motor casing.
    Motor reselection
    The motor was changed from a K261-P to a K490. This will achieve a higher total altitude with the updated weight.

    Fin geometry change
    The fin material was changed from 1/16th in carbon fiber to G10 custom fiberglass. The thickness will then be increased to 3/16th in and a new geometry shown in the figure below. This will prevent fin flutter and durability. A ½ in shoulder was also added so the fins can be imbedded into the centering ring of the propulsion system section.
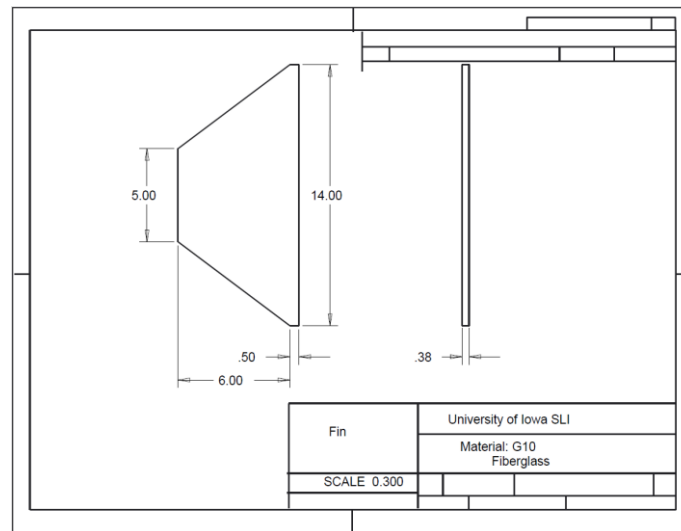
Figure 3: Fin Drawing

Changes to AGSE Criteria

The size of the AGSE has decreased in length, width and height for a lighter design, but has increased in mass to compensate for underestimated weight of mechanical systems and material weight at PDR. There have also been design changes to qualify the AGSE for more simple construction. The construction process has been changed so that the mechanical systems like the winch, linear actuators and conveyors will be custom purchased from vendors to be determine some options are Oriental Motor, and Automation Supplies Ltd. these custom fabrications will extend the initial timeline because of communication with outside companies.

Section 3: Launch Vehicle Criteria
Design and Verification of Launch Vehicle
A scale model of the full rocket was created with the following parameters:
Table 2: Launch Vehicle Overview

Overall Length ft	6.7
Diameter in	4
Mass lb	14.06lb
Motor	Cesaroni K490
Recovery System parachute, streamers	52in, 2x50in streamers

The locations of the center of gravity and pressures were kept in the same positions relative to the nose cone and total length to test the stability of the vehicle during flight.

Figure 4: First Model Rocket

Primary Flight
The first test flight of the subscale rocket ended in failure. As seen in the following figure of the rocket after launch.

Figure 5: First model after flight

It was determined that the motor was not mounted securely which caused allowed the motor to slide up inside the airframe while firing. The hot gases destroyed the airframe and detached all of the fins. This made the rocket unstable. The rocket landed only a few feet from the pad. Due to proper safety precautions no injuries occurred during the flight.

The motor mount for the second test flight was secured as seen in the next figure.

Figure 6: Motor Mount

<u>Recovery Subsystem</u>
Overview
      The recovery subsystem harnesses the steamers and the main parachute. The steamers and the main parachute will be deployed electronically. The electronic devices are dual deployment, one for the steamers and the other for the main parachute. The recovery system will have redundancy in order to ensure deployment of the steamers and the main parachute for a safe recovery of the vehicle and the cargo.

Redundancy/Safety
      There will be two Perfectflite Stratologger altimeter CF. The streamer/drogue parachute will be deployed at apogee and the main parachute will be deployed at a predefined altitude of 500 feet. The redundancy altimeter will deploy the streamer/drogue parachute at 2 seconds delayed from apogee and the main parachute will deploy at 450 feet. The use of two dual deployment systems ensures a safe recovery of the vehicle. The use of dual deployment keeps the vehicle from drifting due to the wind and the height the vehicle will be reaching. Each dual deployment system will have their own 9 V power supply to ensure that each dual deployment will be isolated and independent. Each dual deployment system will have an external switch that will turn the dual deployment on. The switch ensures safe setup of the vehicle and any premature ejections.

Equipment
      The Perfectflite Stratologger altimeter CF will be the device used for the dual deployment. The first detonation is deployed at apogee and the second detonation occurs at a predefined height. There will be two Perflectflite Stratologger altimeters, one as the primary and the other as the redundancy dual deployment system. The two dual deployment systems will be housed in an avionics bay. The avionics will fit snug and create an air tight seal and isolate the dual deployment systems from the rest of the vehicle.
      The holes cut into the avionics bay will be allow the barometer to obtain the necessary readings to determine when apogee is achieved. The following table below from the manual of the Perfectflite Stratologger determines the necessary hole size for a single or 4 holes.

Table 3: Port Hole Sizes for Dual Deployment

AvBay Diameter	AvBay Length	Single Port Hole Size	Four Port Hole Size
1.6"	6"	.032"	.020" (small pinholes)
2.1"	6"	.048"	.025"
3.0"	8"	.113"	.057"
3.0"	12"	.170"	.085"
3.9"	8"	.202"	.101"
3.9"	12"	.302"	.151"
5.5"	12"	—	.286"
7.5"	12"	—	.5"

Single Port, hole size = Diameter * Diameter * Length * 0.0016
Four Ports, each hole = Diameter * Diameter * Length * 0.0008

Table of port hole sizes -
https://www.apogeerockets.com/downloads/PDFs/StratoLoggerCF_manual.pdf

Using the table above, the desired diameter is between .101" to .151". The use of 4 holes creates at 90 degrees apart helps to create an even pressure through the avionics bay for the barometer.

Block Diagram of the Dual Deployment System
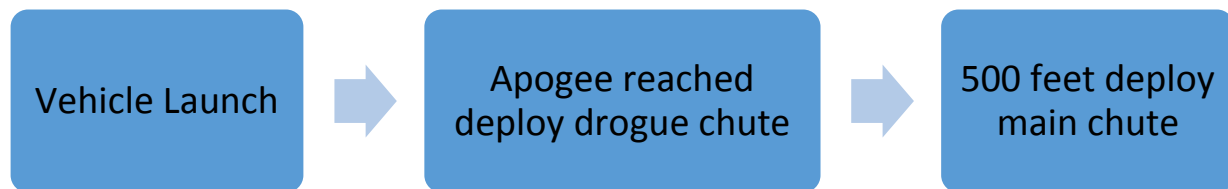
Primary dual deployment block diagram
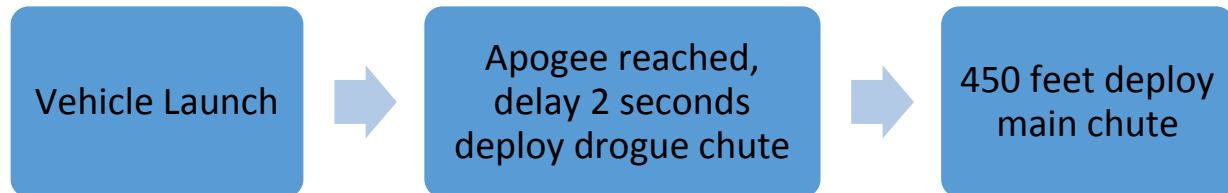
Secondary/Redundancy dual deployment block diagram

Mission Performance Predictions
Criteria

This mission requires a few key instances to occur for this mission to be considered a success. First, the AGSE system must successfully locate, recover and load the payload into the launch vehicle. Once the vehicle receives the payload, it must then be positioned correctly for launch. The rocket must then be launched and fly exactly one mile (5280 feet) into the air and safely be recovered with the payload intact. Only when these requirements are met will this mission be a success.

Rocket
Length 204 cm, max. diameter 10.2 cm
Mass with motors 6377 g

Stability:1.29 cal
CG:139 cm
CP:152 cm
at M=0.30

Apogee: 1635 m
Max. velocity: 246 m/s (Mach 0.73)
Max. acceleration: 82.1 m/s²
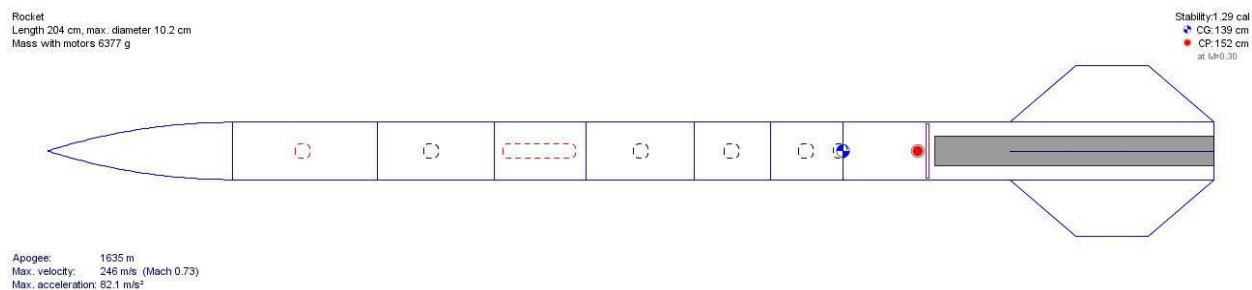
Figure 7: Simulated Rocket Built in
Openrocket
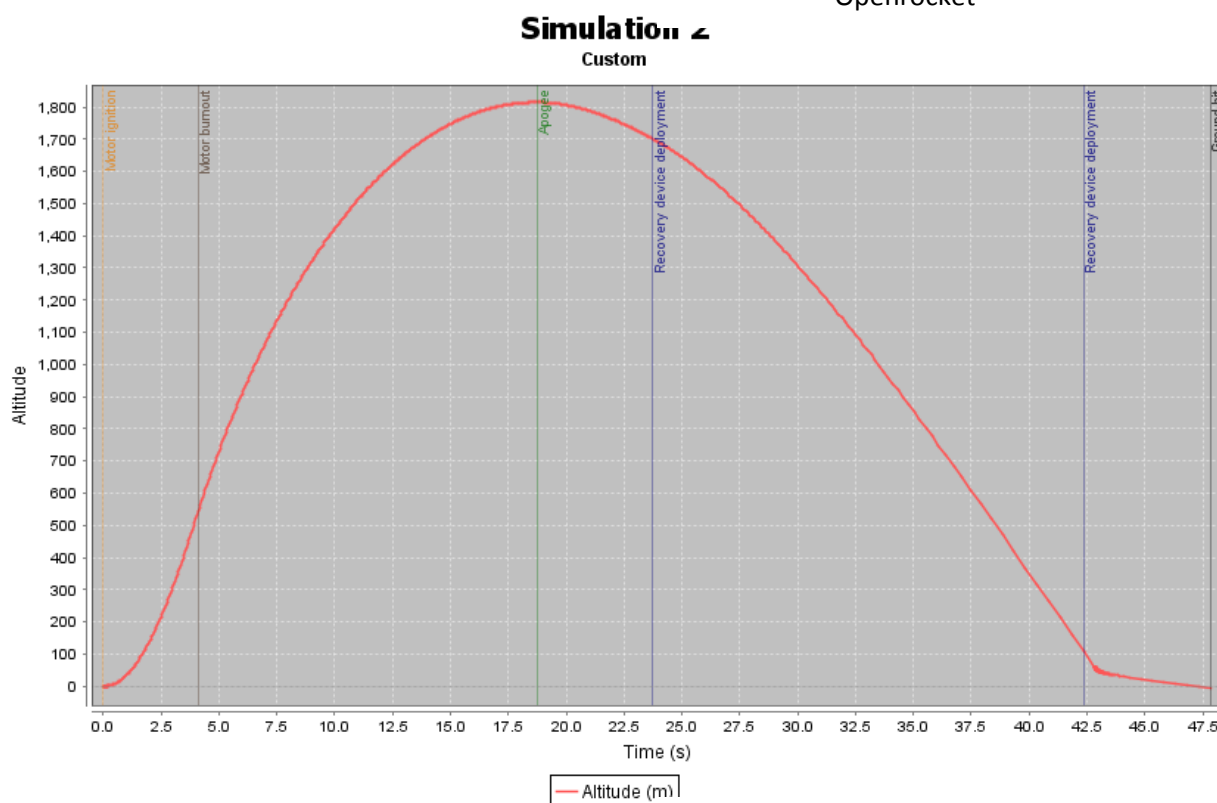
Figure 8: Altitude Curve from
Openrocket

Table 4: Drift calculation

wind speed (mi/h)	5	10	15	20
Flight time (s)	47.5	47.5	47.5	47.5
distance (ft)	348.3333	696.6667	1045	1393.333

Simulation 1
Custom

Figure 9: Stability Curve from Openrocket

Simulation 1
Custom

Figure 10: Motor Thrust Curve from Openrocket
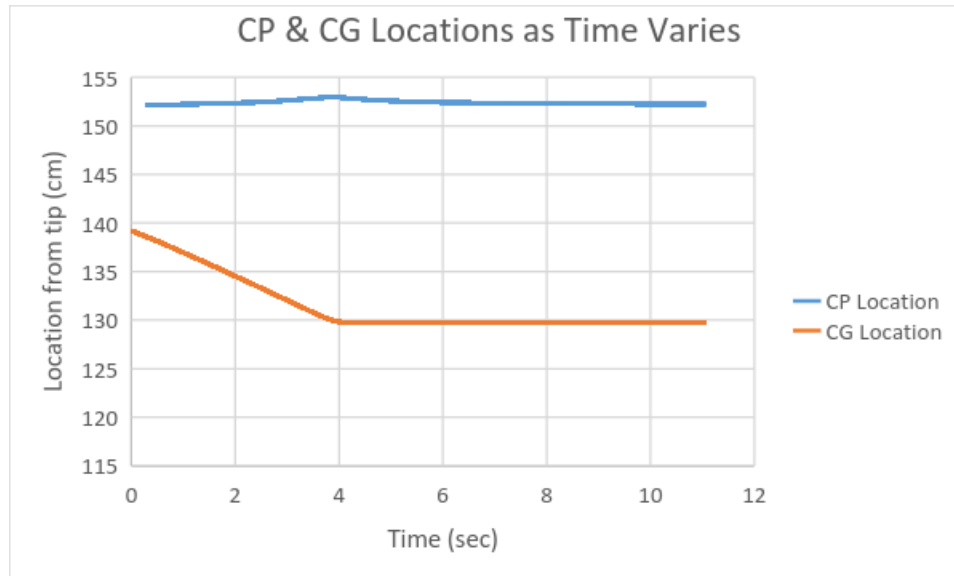
Figure 11: CP and CG Location
Relationship as Simulated From
Openrocket

Figure 7 shows the design of the launch vehicle simulated in the Openrocket software. This vehicle has a total weight of approximately 13 pounds and a length of a little less than 5.5 feet from tip to tail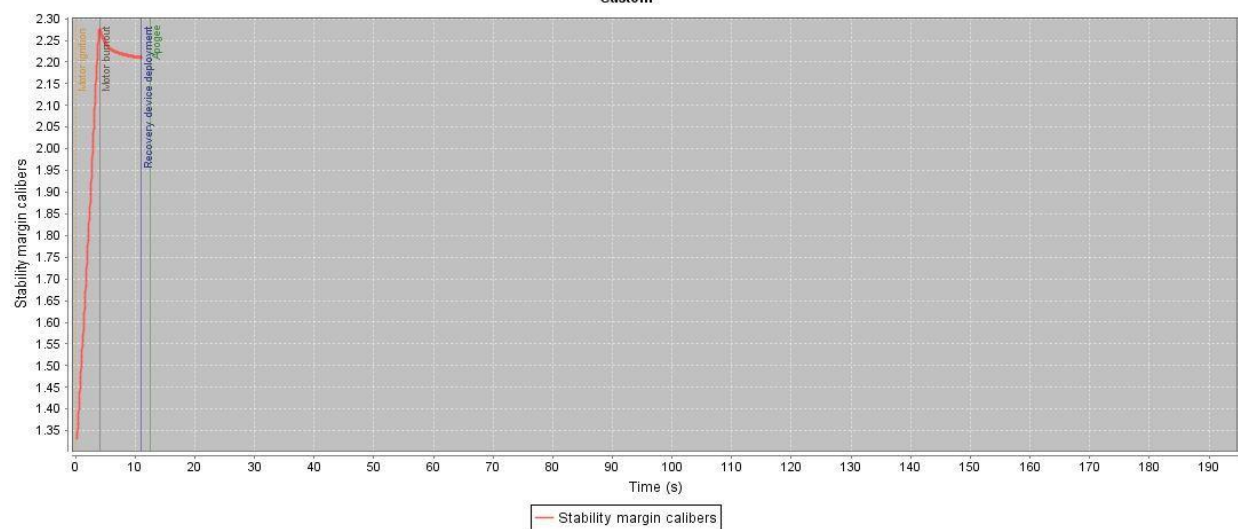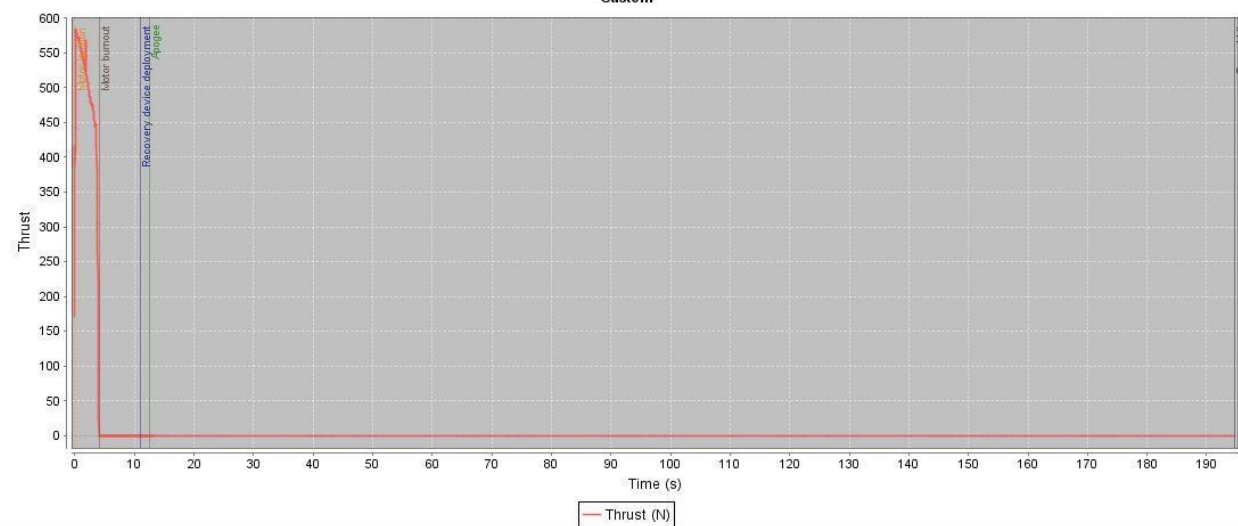. With the current motor selection referencing Figure 8, the apogee of this rocket is predicted to be about 1634 meters (5360 feet) which is slightly above the target altitude of 5280 feet. Even with this altitude slightly too high, the active drag system will be able to lower the apogee to a more favorable height. Referencing Figure 11, the CP is below the CG throughout the duration of the flight meaning that the rocket is stable during its flight.

Interfaces and Integration

The cargo bay is made to protect 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.

Connection pins were designed for the connection between the deployable drag flaps and the main airframe body. The design can be seen in the next figure. These pin connections shown in yellow all have the same geometry to make manufacturing and replacement easier. The hinges will all be made of aluminum
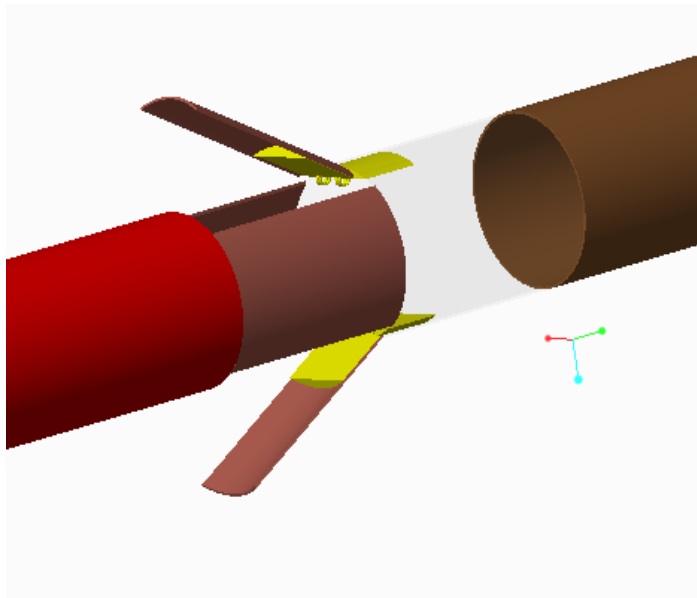
Figure 12: Drag flap connections

Electronic Subsystem
Overview

The control subsystem houses the electronics that monitor the vehicle from launch to recovery. The control subsystem is a separate bay that house its' own power supply and Arduino microcontroller. The control subsystem will be placed adjacent to the drag subsystem and the cargo bay subsystem. This subsystem will consist of 6 components: accelerometer, altitude/pressure sensor, temperature sensor, IR receiver, Arduino Nano microcontroller, and a 9 V battery. An air gap will be introduced on the side of the control system in order to obtain the correct pressure readings.

System Level Requirements

1) The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.

The batteries used for the electronics on the vehicle and the payload will have at least 12 hours of battery life. The battery life will be tested to ensure that all electronic systems are ready and don't lose power while sitting for at least 1 hour. New batteries will be used for all electronics on the day of launch and they will be tested to ensure that they all have sufficient battery life to sit and operate for at least 1 hour.

Component Analysis

Temperature sensor

The temperature sensor that will be used is a tmp36 used to monitor the temperature of the vehicle and the control subsystem. The temperature sensor is uses an analog voltage which then can be translated into a readable temperature. The temperature sensor is not used with any other part of the vehicle, but is instead used as a safety measure to insure that the vehicles' temperature isn't increasing unexpectedly.

The test setup and test procedure can be seen in the electronics test procedures section.

IR Receiver

The IR receiver will be connected to the Arduino Nano controller while the IR transmitter will be connected to the AGSE system. The IR transmitter will send a high frequency wave that the IR receiver on the in the control system will detect. IR communication between the control subsystem and the AGSE system acts as a backup system to ensure the cargo is placed correctly into the cargo bay subsystem. A block diagram demonstrates the interaction between the control subsystem and the AGSE in figure 13.

The test setup and test procedure can be seen in the electronics test procedures section.

Figure 13: AGSE and Cargo interaction

Arduino Nano Microcontroller

The Arduino Nano microcontroller controls and monitors all the sensors in the control subsystem. The choice of the Nano microcontroller was determined due to the size and capacity of the device. The microcontroller can be operated on an external power supply and it efficient in size thus allowing more room for wires and other sensors.

The test setup and test procedure can be seen in the electronics test procedures section.

9 V battery

The 9 V battery was chosen because the microcontroller can be operated at 9 V. The 9 V battery is easy to work with and has been proven to work with microcontroller operation. The 9 V battery will be connected the external power supply pin on the microcontroller.

Accelerometer

The accelerometer used for the control subsystem is a triple axis accelerometer, ADXL335 from adafruit. Only one axis of the device will be utilized for the drag subsystem deployment as vertical acceleration is the desired direction of acceleration. The accelerometer uses analog voltage values that are then translated into practical values of acceleration. The accelerometer was chosen due to its' g force ratings and the accuracy of the accelerometer. Accurate accelerometer readings are needed for proper deployment of the drag subsystem. The accelerometer will be used to determine the velocity of the vehicle. The accelerometer is used to retract the flaps of the subsystem once the desired velocity is reached, so that the vehicle can reach a more precise altitude.

The block diagram/flowchart in figure 14 shows the interaction between the drag subsystem and the control subsystem.

The test setup and test procedure can be seen in the electronics test procedures section.

Altitude/Pressure Sensor

The altitude/pressure sensor used in the control subsystem is a sparkfun product model number MPL3115A2. The sensor uses I2C communication to relay the pressure, altitude and temperature. The primary use of the sensor is the altitude measurement. The altitude measurement will be used to determine the deployment of the flaps of the drag subsystem. Once a desired altitude, below apogee has been reached, the microcontroller will deploy the drag system to slow the descent. The pressure sensor will act as a secondary safety check for the drag subsystem if the altitude sensor malfunctions during flight.

At this time, we haven't looked into the temperature sensor portion. If the temperature sensor is sufficient then the temperature sensor tmp36 will be disregarded and thus save space in the control subsystem.

The block diagram/flowchart in figure 14 shows the interaction between the drag subsystem and the control subsystem.

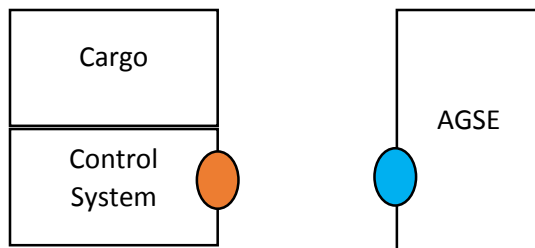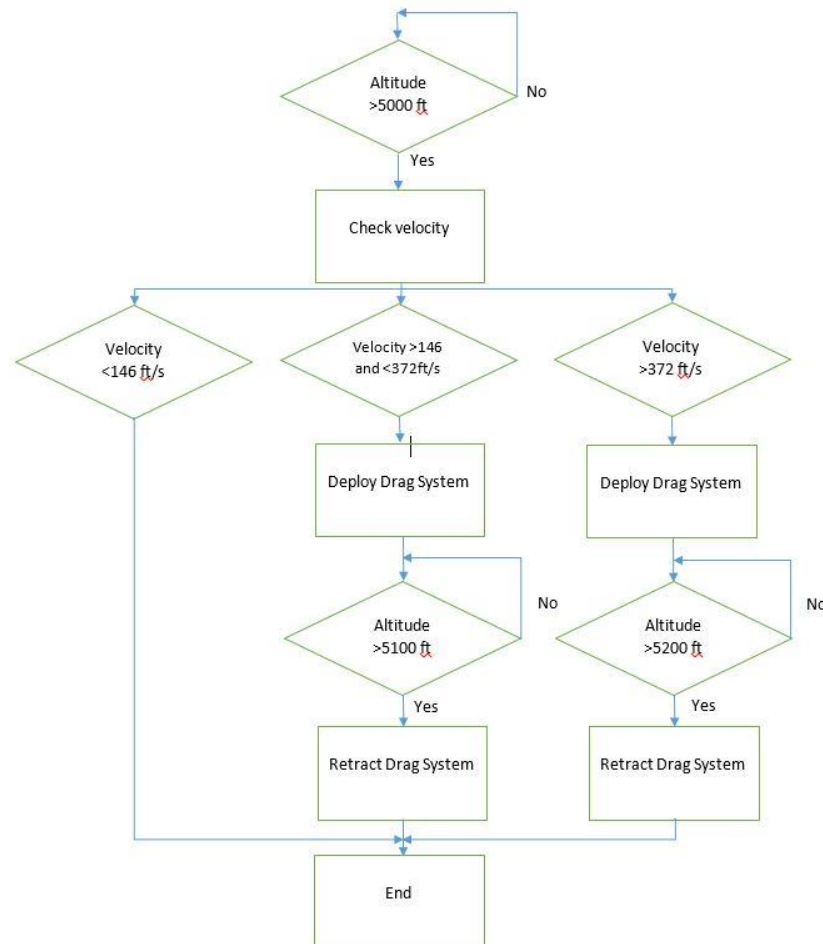The test setup and test procedure can be seen in the electronics test procedures section.

Figure 14: Drag Subsystem and Control Subsystem Interaction

1. Safety

Safety Plan

The team safety officer is Victoria. It is her responsibility to create safety plans and to ensure that these plans are followed throughout the project. These safety plans detail potential hazards to the health of the team members, as well as hazards to the success of the project. Along with hazard identification, mitigations for each risk have been determined and will be applied as the project progresses. By identifying these risks, the team has been able to pursue a proactive design process, rather than a reactive design process. As risks are further studied, the design or construction processes can be updated to reflect these new risks and the mitigations used. A full list of Victoria's duties as safety officer are given below.

● Write and distribute safety documents for the team, including hazard analyses, PPE requirements, MSDS and operator manuals, FAA/NAR/TRA regulations, safety plans, and procedures for construction, testing, and launch.
● Confirm that all team members have access to and have read all safety documents.
● Identify risks to the project and create mitigation strategies for each risk.
● Create safety plans for construction, testing, and launch, and brief team members on these plans.
● Oversee all testing to ensure that safety plans are being followed.
● Maintain an active role in the design, construction, testing, and flight phases of the project to ensure that all safety procedures are being followed.
● Enforce use of proper PPE during construction, testing, and flight.
● Ensure that all applicable MSDS and operator manuals are accessible to the team.
● Provide plans for purchasing, storing, transport, and use of all energetic devices.
● Ensure compliance with all laws and regulations, including local, state, and federal laws, and NAR/TRA regulations.
● Ensure safety during hands-on educational outreach activities and provide PPE as needed for these activities.

Hazard Analysis

A hazard analysis has been done for the project. This analysis was done by the entire team, and led by the safety officer. The team analyzed all subsystems of the launch vehicle, as well as specific components. Each component/subsystem was analyzed in three areas: human safety, mission success, and environment. The severity of each risk was analyzed using Table XX, shown below. The probability of each risk was analyzed using Table YY.

Table 5: Severity Definitions for Hazard Analysis

Description	Human Safety	Mission Success	Environment
1-Catastrophic	Death or permanent injury that causes disability.	Total loss of component(s); inability to complete given aspect of mission.	Severe damage that violates laws/regulations and is irreversible.
2-Critical	Severe injury.	Major damage to component that has	Severe damage that violates

		significant effect on mission success.	laws/regulations that is reversible.
3-Marginal	Minor injury that requires medical attention.	Minor damage to component that has a small effect on mission success.	Some environmental damage that does not violate laws/regulations; can be cleaned up.
4-Negligible	Minor injury that only requires first aid.	Minimal damage to component that has almost no effect on mission success.	Minimal environmental damage.

Description	Definition
A-Frequent	High likelihood; expected to occur immediately.
B-Probable	Likely to occur at some point.
C-Occasional	Expected to occur occasionally.
D-Remote	Unlikely, but likely to occur at some point.
E-Improbable	Very unlikely and not expected.

The full risk levels and hazards are shown in the table below

Table 6: Risk and Hazards

Risk Levels				
Probability	Severity			
	1-Catastrophic	2-Critical	3-Marginal	4-Negligible
A-Frequent	1A	2A	3A	4A
B-Probable	1B	2B	3B	4B
C-Occasional	1C	2C	3C	4C
D-Remote	1D	2D	3D	4D
E-Improbable	1E	2E	3E	4E

Red-High Risk
Yellow-Moderate Risk
Green-Low Risk
White-Minimal Risk

Launch Vehicle Risk Assessment						
Hazard	Cause	Outcome	Severity Value	Probability Value	Risk Level	Mitigation
Use of chemicals such as epoxies, cleaning solutions,etc.	1. Chemical Fumes. 2. Chemical splash.	1. Lung irritation or damage. 2. Chemical burns (mild to severe) on skin/eyes.	3	B	Moderate	1. Team members will consult MSDS before working with a chemical. 2. Proper PPE will be worn at all times as dictated by MSDS. 3. Team members will be aware of safety features such as eye wash stations and showers.

AGSE Risk Assessment						
Hazard	Cause	Outcome	Severity Value	Probability Value	Risk Level	Mitigation
Use of power tools.	1. Improper use or lack of use of PPE. 2. Lack of or improper training. 3. Use of damaged power tools.	1. Minor to severe injury, including lacerations. 2. Damage to rocket structure due to use of damaged power tools.	2	B	High	1. Team members will wear proper PPE when working with power tools. 2. Team members will be trained on power tool use and will have operator manuals for consultation. 3. Power tools will be inspected prior to use, and damaged tools will not be used.
Use of welding equipment.	1. Improper use or lack of use of PPE. 2. Lack of or improper training. 3. Use of damaged welding equipment.	1. Minor to severe burns. 2. Vision damage. 3. Damage to AGSE structure due to use of damaged equipment.	2	B	High	1. Only members properly trained in use of welding equipment will be allowed to weld. 2. Proper PPE will be worn when welding or working near welding areas. 3. Welding equipment will be inspected prior to use and damaged equipment will not be used.
Linear actuators.	1. Improper setup of linear actuators.	1. Inability of AGSE to move payload into launch vehicle. 2. Inability of launch vehicle to move launch vehicle into upright position.	1	E	Low	1. Team members will read manuals prior to installation of linear actuators. 2. Linear actuators will be tested prior to launch. 3. At launch, the actuators will be inspected to ensure that they are in proper working order.
Use of power tools.	1. Improper use or lack of use of PPE. 2. Lack of or improper training. 3. Use of damaged power tools.	1. Minor to severe injury, including lacerations. 2. Damage to rocket structure due to use of damaged power tools.	2	B	High	1. Team members will wear proper PPE when working with power tools. 2. Team members will be trained on power tool use and will have operator manuals for consultation. 3. Power tools will be inspected prior to use, and damaged tools will not be used.
Use of composite fabrics such as fiberglass.	1. Improper use of PPE.	1. Splinters from composite fibers.	4	A	Low	1. Proper PPE (specifically gloves) will be worn when cutting/working with composite fibers.
Use of servo motor.	1. Improper setup of servo motor. 2. Human interaction with system.	1. Damage to system that could lead to failure. 2. Fingers/hair caught in system.	3	C	Moderate	1. Servo motor manual will be read by team prior to installation. 2. Team members will take care to ensure that hair/fingers are out of the way during setup/testing of system.
Rotation of payload bay.	1. Items getting caught in path of bay.	1. Damage to payload bay that may compromise mission. 2. Inability of payload bay to rotate to fully closed position.	2	D	Moderate	1. Bay will be tested to ensure that no other components interfere with operation of door. 2. Team members will take care to not leave extra items in payload bay area.
Disintegration of launch vehicle during flight.	1. Improper construction of launch vehicle.	1. Catastrophic failure of mission.	1	E	Low	1. Proper construction techniques will be used during construction process. 2. Quality materials will be used, and

	2. Poor material quality. 3. Improper manufacturing methods.	2. Damage to environment (ranging from minor to severe) due to falling debris.				damaged components will not be used in launch vehicle.

Section 4: AGSE/Payload Criteria
AGSE Overview

The ground system is made of steel tubing, extruded aluminum, linear actuators and conveyors, all used in order to capture, contain and the launch vehicle. The ground system contains controls to safely pause the system, communicate with the launch vehicle, and monitor the stage of the loading process. The size is 8 ft long, 3 ft tall, 8 ft when vertical, and 3 ft wide. The weight of the materials will be 150 lbs. Electronics will be controlled by an Arduino and powered by batteries to release the winch, move the linear actuators and turn the conveyors.
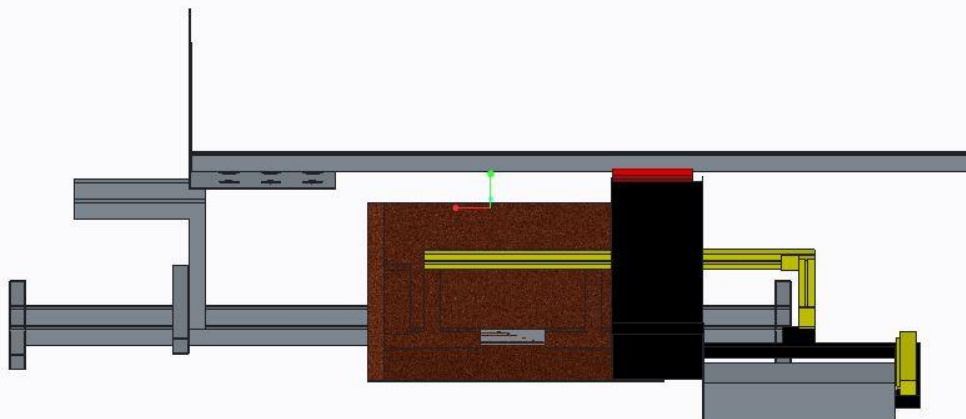
Figure 15: AGSE

Payload Capture and Contain

The fully autonomous robotic mechanism has an objective to capture, contain, and launch the payload of one inch in diameter and 4.75 inches long cylinder. 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 autonomously. 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 a PLC on an Arduino board along with batteries to supply power to release the winch, move the linear actuators and turn the conveyors. The code will follow a series of tasks that will check, confirm, and carry out steps as the payload is delivered, there will also be proximity switches and infrared sensors to ensure security between each step and provide safety of progress. To engage the AGSE there will be a master switch given to the operator. It

will have two lights on it, one will be a flashing orange light of 1Hz to symbolize the AGSE is powered on then will be a solid orange when the power is on and AGSE is paused. The second light will be a green light to indicate that the AGSE has passed the verification and ready for start.

Milestones

Proposed schedule of milestones are part ordering, construction, testing, redesign, assembly, program control coding, control testing, safety controls coding and testing, and report writing. The subscale tests for the AGSE will include each part being tested and verified to work in the environment. Tests will include: torsion spring strength, release speed of the winch, movement of the linear actuators and turn strength of the conveyors.

Materials

The materials required will start with the framework of the base foundation. The base will be made out of 1 inch square steel tubing welded together in the same general shape in figure 16.
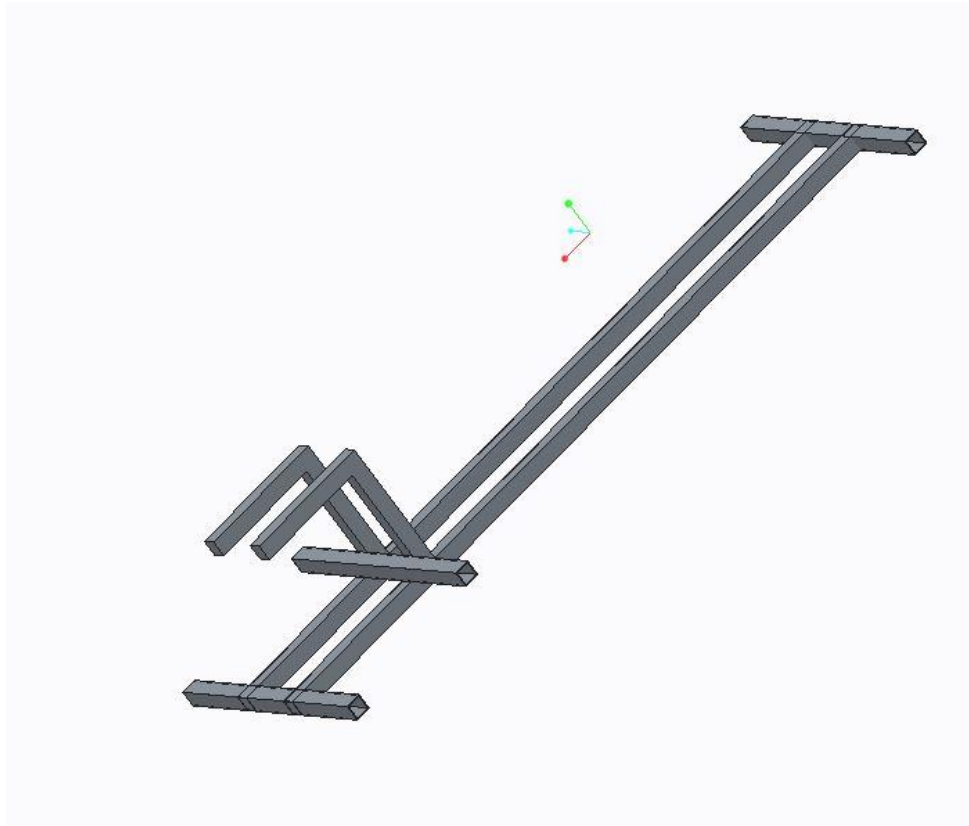
Figure 16: ground base frame.

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 1 inch square extruded aluminum because it will be lightweight and fit the rail guides on the rocket. The bottom plate will be made out of 2 square 8 inch and 1/8" thick 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 17 the linear actuator is yellow and the conveyors are in red, this is the design of the ground recovery system (GRS).

Figure 17: ground recovery system (GRS)

The system in figure 17 will be placed on a X-Y linear actuators, shown earlier in figure 1, this way the system can start inside the AGSE boundary. The X-Y linear actuators will then move the GRS 12 inches away from the AGSE outer mold line and will dro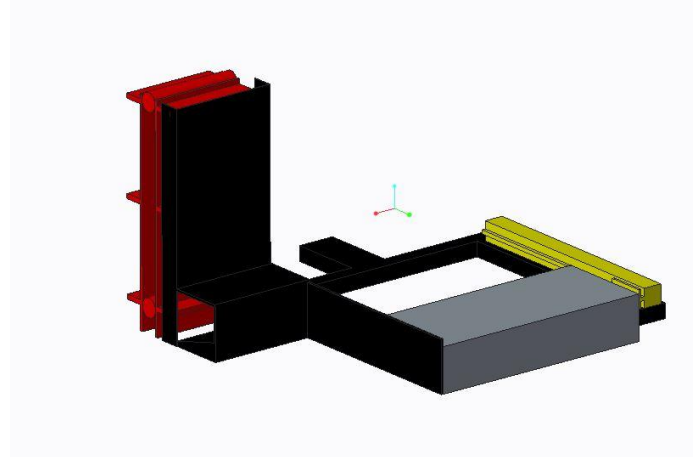p the ground recovery system down where the payload is placed inside the specific area reachable by the GRS. There will be a wedge on the moving part of the GRS where it will sweep the specific area inside until it collects the payload and it falls on the conveyor where it will be enclosed and carried to the next set of conveyors that will lift the payload up to the cargo bay 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 cargo bay 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.

Operating and Construction

The standard operating procedure starts with laying out the pieces of the AGSE framed assembly, then assembling the mechanical system and wiring the electronics, testing each electrical component, and getting the green light for the ok to start the AGSE on the remote.

The construction of the AGSE frame is nearly completed shown in figure below.

Figure 18: AGSE Frame

There is still construction left to be made for the launch plate, the rail attached, and torsion springs. In addition to construction of the frame there will be assembly and testing of the conveyors and linear actuators. Finally there is construction of the GRS which will be made in house at Iowa with the remaining supplies from the AGSE frame and some new material purchased like thin sheet metal to create the enclosure.

Safety

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.

Section 5: 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	$80
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 = $890

```
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

Timeline 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, recovery system full test. These two items are now shown in yellow with the new dates which will still be complete before CDR Presentation. The 3D animation was moved back considerably since it was determined that it will be of most value for the final presentation and not intermediate presentations.

The critical path before FRR is to order/create all prototype parts, then build the systems and test the model to acquire results
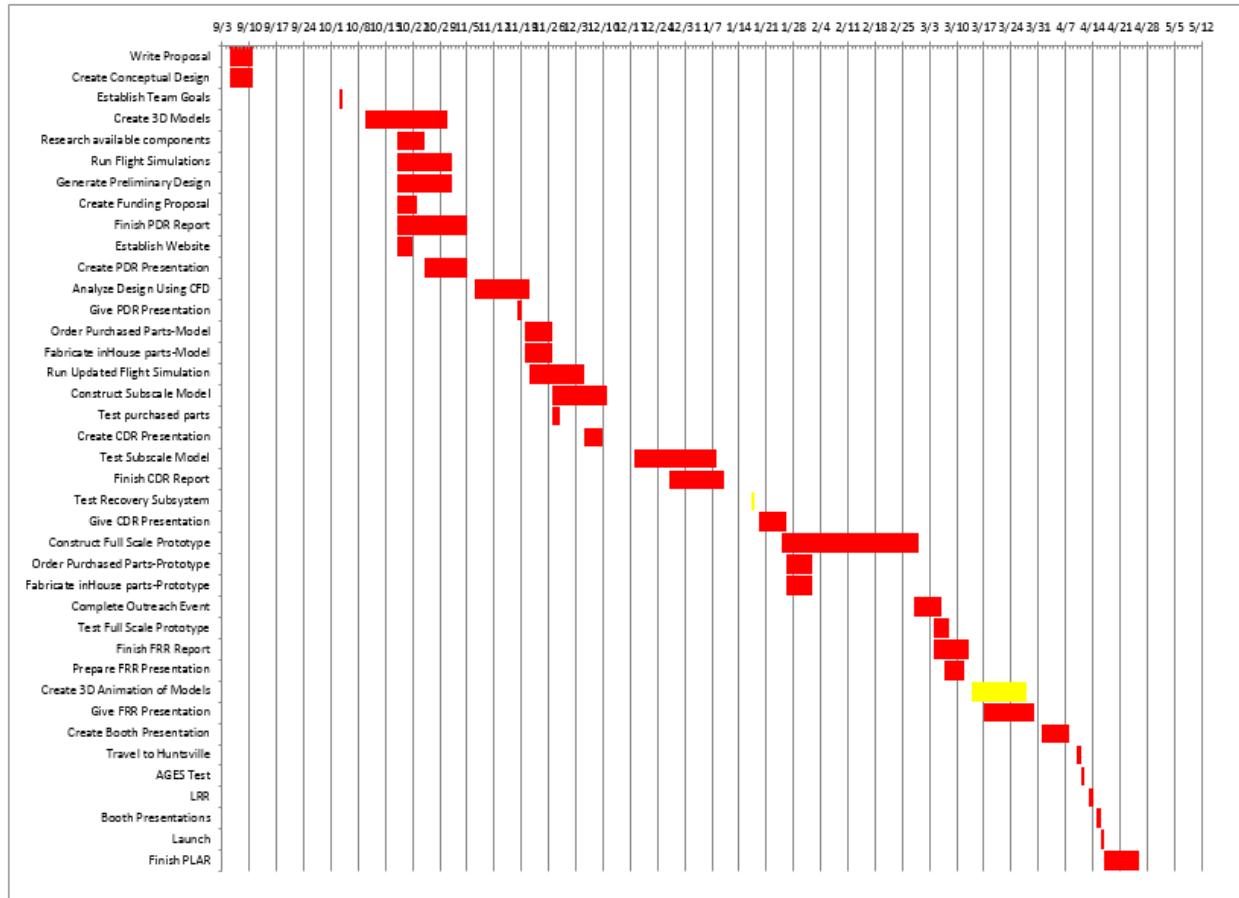
Figure 19 Gantt Chart

Educational Outreach.

The University of Iowa AIAA will be doing educational outreach to the local high schools and junior high schools of Iowa City. The goal is to have four large group events that will involve 200+ high school students from around Iowa City. We have groups members mentoring students as they learn about the aerodynamics of rockets and the use today. We plan to make interactive stomp rockets integrate the experience. The plan is to contact the University of Iowa's outreach department where we will be assisted in finding the schools available and planning the time to be late February. Our group will use this outreach to also help our other teams in AIAA that need educational outreach for their own competitions.

Appendix A: Subscale Testing Procedures
Test Plans & Test Results

1. **Sub-Systems Being Tested**
   Recovery Subsystem

2. **Approval**
   Approved by:
   Team Members - Austin Brenner and Vicki Trojanowski
   Guide – Kevin Trojanowski

3. **Test Strategy**
   1. *We will test the dual deployment electronics, the drogue chute deployment at apogee and main chute deployment at a desired altitude. We will also test the competition altimeter to ensure its' accuracy. We will not test the dual deployment system with black powder, as this will be a static and isolated test. At this time, the altimeter will not be tested in an on board flight, but it will be a static controlled test.*
   2. *Equipment/Materials*

   Perfectflite Stratologger altimeter CF (1)
   Perfectflite Firefly altimeter   (1)
   Alkaline 9 V battery   (1)
   Battery terminal leads   (1)
   Red LED   (2)
   Pressure Chamber   (1)
   Small Breadboard   (1)
   Electrical Wire

   Test configuration - Stratologger
   - *Connect the battery terminal leads to the 9 V battery*
   - *Connect the battery to the Perfectflite Stratologger altimeter and keep the jumper in place*
   - *Connect the blue LEDs to the drogue and main chute screw terminals using the electrical wires*
   - *Using the preset main chute altitude adjustment, set the height to 500 feet*
   - *Place assembly into the pressure chamber*

   Pre-Checks - Stratologger
   - *Ensure battery in fully charged*
   - *Ensure that the LEDs work by checking with a battery and current limiting resistor*

   Test configuration - Firefly
   - *Wait for last series of flashes, indicating last flight*
   - *Wait 30 seconds, then altimeter to ready to use*

   Pre-Checks - Firefly
   - *Ensure battery is fully charged*
   - *Check status LED*

   3. *Responsibilities include: Ensuring the battery is not leaking and fully charged, the pressure chamber is depressurized before installing the dual deployment system, all electrical connections are secure, and that all the jumper is secure.*

The altimeter responsibilities include: ensuring the status LED is on and that the altimeter is ready to record, waiting for the 30 second delay.

4. *Test risks include the explosion of the alkaline battery due to battery leakage, high current draw leading to explosion of LED, and loss of control of pressure chamber*

5. *The purpose of this test is to determine the hardware functionality of the dual deployment system and its' accuracy. The altimeter hardware is being tested for reliability and accuracy of recorded altitude. The software functionality is being tested by changing the main chute deployment height and the drogue chute delay from apogee feature.*

4. Test Procedure

1.4.1 - Primary Dual Deployment Test

1) Using the preset program button, change the main chute altitude to the desired height for testing purposes

2) Place the dual deployment system into a pressure chamber

3) Decrease the pressure to mimic flight and increase pressure to mimic the descent back to the ground

4) Determine if the lamps turn on at apogee and the desired height

5) Repeat with different presets

1.4.2 - Secondary Dual Deployment Test

Before test configuration

- Set the apogee delay to 2 seconds

1. Using the preset program button, change the main chute altitude to the desired height for testing purposes

2) Place the dual deployment system into a pressure chamber

3) Decrease the pressure to mimic flight and increase pressure to mimic the descent back to the ground

4) Determine if the lamps turn on at apogee and the desired height

5) Repeat with different presets and different apogee delays

1.4.3 - Altitude Sensor Test

1) Press and hold the power button to turn off the altimeter

2) Press and hold the power button to turn on the altimeter to reset and prepare for launch

3) Last flight flashes will indicate last peak height and peak velocity

4) Once LED is off, 30 second pause until it is ready to record the next flight

5) Small flashes occur when the altimeter is ready for the next reading

6) Cusp ones' hands around the altimeter and suck out the air to mimic a flight

7) Record the series of flashes to determine altitude

5. Test Results

No test results have been accumulated at this time, future results will be obtained in the next few weeks.

1. **Sub-Systems Being Tested**
Control Subsystem

   2. **Approval**
Approved by:
   Team Members – Austin Brenner and Vicki Trojanowski
   Guide – Kevin Trojanowski

3. **Test Strategy**
1. *We will be testing the all the components of the control subsystem. The accelerometer accuracy and communication with the microcontroller will be tested. The altitude and pressure for the altitude/pressure sensor will be tested through serial communication. The temperature sensor and IR receiver will be tested through a controlled environment to test functionality. All the tests will be isolated and independent. We will not be testing on flight simulation.*
2. *Equipment/Materials*
   Alkaline 9 V battery   (1)
   Battery terminal leads   (1)
   Arduino Nano microcontroller   (1)
   IR Receiver   (1)
   Red LED   (1)
   SparkFun Altitude/Pressure Sensor Breakout - MPL3115A2   (1)
   Temperature Sensor - TMP36   (1)
   330 Ohm resistor   (2)
   SparkFun Triple Axis Accelerometer Breakout - ADXL335   (1)
   Electrical Wire
   Test Configuration - Accelerometer
* *Connect the 3.3 V pin on the accelerometer to the 3.3 V on the Arduino controller*
* *Connect the ground of the accelerometer to the overall system ground*
* *Connect the X,Y,Z analog pins where applicable to the nano Arduino controller analog input (pins 19-26)*
   Pre-checks
* *Make sure the electrical wires on all connected and the microcontroller is powered on*
   Test Configuration - Microcontroller
* *Plug the board into the output power supply given to ensure the microcontroller works properly*
   Pre-checks
* *Make sure the power supply is fully connected*
   Test Configuration - IR Receiver
* *Connect the lead of the output of the IR receiver to the digital input on the microcontroller (pins 5-15) and the other to ground*
   Pre-checks
* *Make sure all electrical connections are secure and the microcontroller is powered on*
   Test Configuration - Altitude/Pressure Sensor
* *Connect the VCC of the sensor to the 3.3 V on the Arduino controller*
* *Connect the ground of the altitude/pressure sensor to the overall system ground*
* *Connect the SDA pin on the altitude/pressure sensor to the 330 Ohm resistor and connect the other end to SDA pin on the microcontroller*

- *Connect the SCL pin on the altitude/pressure sensor to the 330 Ohm resistor and connect the other end to SCL pin on the microcontroller*
        Pre-checks
- *Make sure the electrical wires on all connected and the microcontroller is powered on*
        Test Configuration - Temperature Sensor
- Connect the temperature sensor (pin 2) to the nano Arduino controller analog input (pins 19-26)
- Connect pin 1 to the 3.3 V (pin 17) or the 5 V (pin 27) reference on the microcontroller
- Connect pin 3 to ground
- Set the AREF field (pin 18) to ground
        Pre-checks
- *Make sure all electrical connections are secure and the microcontroller is powered on*
    3. Responsibilities included: Ensuring that the battery is not leaking and is fully charged for each test. Make sure that all electrical connections are connected. Perform numerous tests in order to ensure accuracy test results.
    4. Test risks include the explosion of the alkaline battery due to battery leakage, high current draw leading to explosion of the LED. Any test equipment and sensors can malfunction and explode if wired incorrectly or have incorrect power supplied to them.
    5. The purpose of the these tests is to ensure that the sensors all behave correctly. The hardware tests ensure that all the sensors work with the microcontroller. The Arduino software is being tested to ensure the hardware and software interact efficiently

4. Test Procedure

1.4.1 - Accelerometer Test

    1) Secure the accelerometer and microcontroller into one assembly
        2) Start the software program to record and save the acceleration in the x-direction
        3) Accelerate the assembly in the x-direction at a predefined acceleration
        4) Compare the data to the predefined acceleration and check for accuracy
        5) Repeat steps 2-4 with the y and z direction

1.4.2 - Arduino Microcontroller Test

        1) Connect a 9 volt battery to the external power supply (pin 30)
        2) Make sure that the microcontroller turns on and operates correctly
a. Optional, attach a decoupling capacitor (.01 uF) between power and ground of the 9 volt battery

1.4.3 - IR Receiver Test

1) Replace the output pin of the IR receiver to a LED
        2) Test ambient light sources and see if LED turns on
3) If ambient light turns on the LED, increase filter on the IR receiver
        4) Test the IR transmitter and see if the LED turns on

1.4.4 - Altitude/Pressure Sensor Test

1) Connect the I2C communication of the microcontroller with the sensor
2) Run the sample program pressure for the MPL3115A2 in the Arduino software, set the baud rate to 9600
3) Observe the pressure readings on the terminal and compare with the actual pressure readings in the room
4) Cusp hands around the sensor and suck air out to mimic a decrease in pressure
5) Observe and determine if the pressure readings are changing

1.4.5 - Temperature Sensor Test

1) Set the temperature of the room to room temperature, record the temperature with an external thermometer and record
2) Using the ADC conversion on the analog input, compare the value on the microcontroller to the external thermometer and record
3) Repeat for various temperatures (range of temperatures -50 C to 125 C translated to voltage 0 V to 1.75 V)
4) Calculate the differences between the external and internal temperatures, also record absolute error

5. Test Results
No test results have been accumulated at this time, future results will be obtained in the next few weeks.