UNIVERSITY OF CENTRAL FLORIDA

PROJECT ARES

NASA SL FRR 2014 – 2015

March 16, 2015

I. Summary of FRR

1.1 Team Summary

1.1.1 Team Name and Mailing Address

Project ARES
University of Central Florida 4000 Central Florida Boulevard Orlando, Florida 32817

1.1.2 Team Mentor

Gary Dahlke NAR #: 9585 TRA #: 21735 Certification level: 3

1.2 Launch Vehicle Summary

Size: Rocket length: 79.25” Diameter: 4” Mass: 11.2 lb.
Motor Choice: Cessaroni J355
Recovery System: A system using 3 black powder charges hooked up to 2 altimeters (e-bay and Payload). Drogue of 22” deployed at apogee, main of 70” deployed at 500 ft. Additional Payload chute of 30” at 1000 ft.
Rail Size: 8 ft.
Milestone Review Sheet: Please see the Project Ares website listed below with attached link. http://sedsucfstudentlaunch.weebly.com/

1. 1.2 AGSE/ Payload Summary

1.2.1 Summarize the AGSE

The task of finding, containing and displacing a payload within the rocket vessel is achieved by using an autonomous rover with a robotic arm/claw combination. The rover has six wheels: two wheels for driving and the other four for steering. A suspension system is implemented by way of the archetypal Rocker – Bogie system to help the rover maneuver about an uneven surface. Navigation of the rover is achieved by use of two high definition video web cameras interfaced with one another in a control feedback loop which also aid in navigating the robotic arm. The software control system utilizes open source computer vision libraries.

1.2.3 Summarize experiment

The rover will be experimentally tested to analyze the efficiency and reliability of the computer vision programs implemented to control the navigation processes. This testing will be completed by a series of trials where the payload is placed in different orientations on the ground and the rover is set out to collect the payload. This analysis will gauge how effectively the rover can orient itself according to its position relative to the payload so that the arm is able to collect and contain said payload. Another series of tests will be performed to judge how reliable the arm is able to displace the payload into the containment vessel. These tests will be performed in a similar manner by having the rover collect the payload in different positions relative to the rocket, thus determining the rover’s adaptive capabilities in maneuvering about the rocket in order to displace the payload within the containment vessel accurately and reliably.

II Changes made since CDR

2.1 Changes Made to Vehicle Criteria

The amount of changes made to the launch vehicle are stark in comparison to the critical design review. As many changes made in the last report were made with proper judgment and most features stuck to the final construction. Though there was one major feature that was replaced in the payload section. Previously a pressure sensor and servo was connected to the payload bay door, triggering its actuation and closing upon payload delivery. An incredibly simple idea was brought forth to add a cable that would lay across the opening of the payload bay. The ends are connected to the door edge and wall below the magnets. So when the payload is delivered by the AGSE, the cables tense and pull the door down. The momentum of the door swinging and the magnets at the edge couple to ensure a solid closure of the section. This method requires no special equipment and its robustness is highly favored over the previous design, inciting the change. Any other changes to the vehicle itself have been of a negligible importance which mainly reflect cosmetic decisions or improvements in assembly efficiency and do not change any fundamental functions or behavior of each system.

2.2 Changes Made to AGSE/ Payload Criteria

The AGSE rover follows mostly the same design laid out in the CDR. Some minor changes were made mainly to connectors as well as fabrication methods. One addition to the AGSE rover since the CDR is the coupling mechanisms that connects the wheels to the chassis as well as housing the steering servos. These couplers have been completely redesigned and 3-D printed for full customization. The claw-arm mechanism has also been rethought and fabricated using laser cut acrylic pieces instead of the original 3-D printed fabrication design. This was chosen because the speed and accuracy of the laser cutter versus the 3d printer would allow us to deal with smaller pieces more accurately. The laser cutter being a more low-priced option of prototyping and fabrication allowed the team to try different options allowing us to be confident that we had the best possible design.

2.3 Changes Made to Project Plan

The budget proposed in the CDR has been updated to have more accuracy and detail. As far as the funding plan, a portion of the funding has been secured and the rest is pending approval.

The educational plan has received several updates with more events being added as they became known. Along with these updates the timeline has been updated, with events that have already passed and completed being updated to reflect involvement.

III Vehicle Criteria

3.1 Design and Construction of Vehicle

3.1.1 Structural Elements

Design:

The main components taking the load during launch are easily identified as the Nose cone, fins, couplers, centering rings, and the body tubing. With the nose cone and fins taking the aerodynamic loads and transmitting them to the body tubing. Then the airframe, coupler, and motor centering rings have to couple supporting those stresses along with the thrust load from the motor. So the design and material selection is most critical for latter sections as they see the greatest dynamic loadings. Not discounting fins though, as they can fail just as easily as your airframe, especially in the transonic and supersonic region. Though the predicted max velocity seen keeps the vehicle well within the subsonic region and much of the focus of design analysis is spent on the airframe and how it's loaded.

The body of the airframe can be described in three parts, which are subsequently the three sections the vehicle breaks into. The lower motor tube, mid body electronics, and upper payload sections. With the body of each section housed inside of a 4 inch Blue Tube 2.0 airframe. A strong tubing that has some elasticity to it under shock loads. So there is a reduced chance of damage if a hard landing occurs in comparison to other Kraft phenolic tubing that require reinforcement. The main factor driving the design lengths of each section is the parachutes that each section contains. With the mid body section having the most empty volume of the craft when unpacked. With the payload section having the smallest parachute bay and the motor section also having a reasonably small volume. Having the small drogue chute located above the motor improves the strength of the airframe in that section. As during the design phase, considerations were made to have as much coupler interaction in this region as possible. Because it is expected to have the greatest combinations of loadings acting upon it.

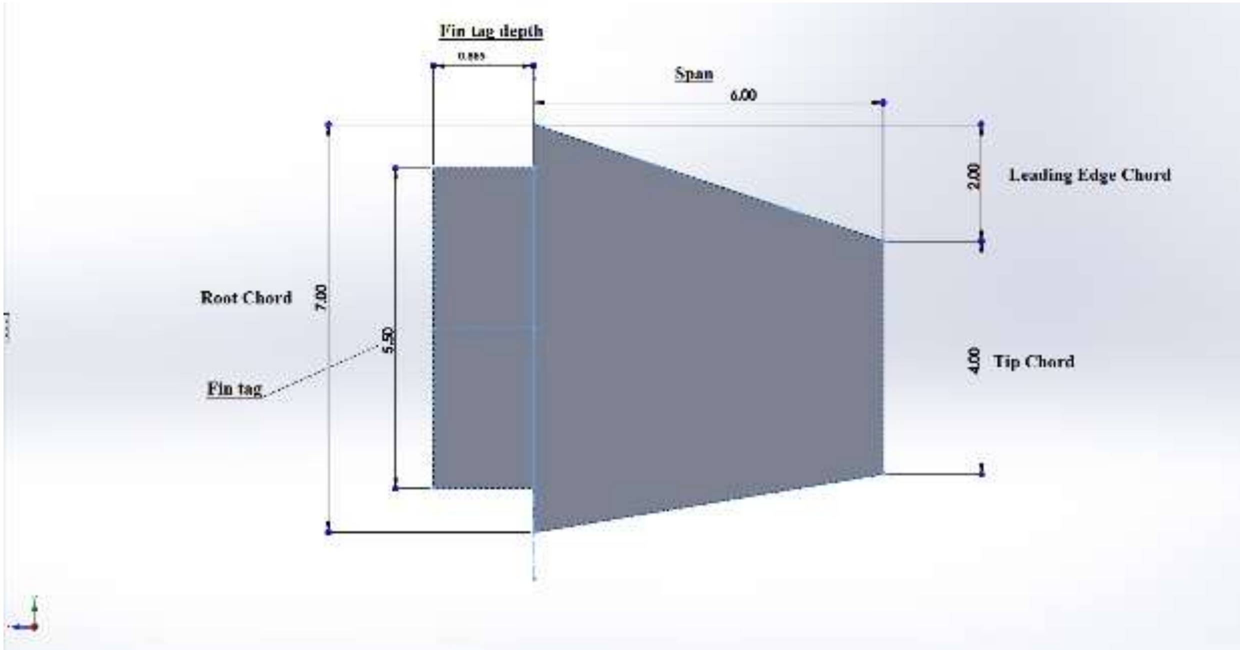


Figure 1 Fin design dimensions

To mention more on the fin design. In the above figure is the dimensions of the fins designed specifically for this launch vehicle. The fins for the full scale are custom and the estimated lengths were used to manipulate the center of pressure location when dialing in our stability margin to the desired level. Using open rocket, the fin dimensions where incremented to provide a stability margin of roughly 3 cal. According to the rocketry community and confirming via our subscale. This puts the craft in a stability region that will allow the vehicle to recover and correct itself when hitting a sudden wind gust.

Construction of structural elements:

To overview the construction. Most components were ordered pre-cut to our dimensions to allow quick assembly of the entire full scale launch vehicle with an exception to the body tube lengths. To note, all cutting and sanding of fiberglass and epoxy components were done with proper protection equipment such as safety goggles, respirators, and gloves. Sanding of wood and paper composites was completed with normal cloth masks instead of respirators.

Lower section:

Construction for this area of the launch vehicle was relatively straight forward. The components that went into this portion included:

- 22.75’’ of 98mm (4’’) blue tube airframe
- 2x birch wood 98mm (4’’) to 54mm (2.56’’) centering rings
- 12.5’’ of 54mm blue tube (to act as the motor mount)
- 3x custom G10 fiberglass fins
- Aero Pack 54mm retainer
- 1 & ½ tube of 2 part epoxy putty for filleting

- 1 tube of 2 part steel stick epoxy putty for filleting
- 2 part slow and fast cure epoxy (Loctite 5minute 2 part epoxy, and West Systems 105/106 resin and hardener)

Using the measure twice and cut once principle of construction. The dimensions of the precut fin slots along with fin dimensions were confirmed. Then placement of the centering rings were planned before any sanding and gluing began. The rear ring would be placed at the end of the fin slot closest to the end of the rocket. As then the fins, when epoxied, could be resting on the motor tube, body tube, and also resting on the rear ring. This placement also happened to be the perfect length for the retainer to fit on the motor tube and sit flush on the ring. Providing maximum adhesion as the fins and retainer were attached to the rear ring while also attached to the motor tube. As a side bonus, the rear retainer in this position came flush with the bottom of the main airframe. Allowing the vehicle to remain standing up without assistance. Afterwards, two pieces of blue tubing required initial cutting via a band saw to their desired dimensions listed above.

Figure 2: **test fitting positioning of rings, fins, and retainer**

Once cut, the edges and interior of the blue tubing were sanded at 1.25'' and 10'' from the rear where epoxy would be placed. Sanding of the centering rings edges, bottom fin edges, and the motor mounting tube was also completed in this step. With a special step to file a notch into the forward ring so that shock chord could be threaded between the ring and motor tube. So when in place, the shock chord would be tide in a knot inside the space between both rings. As when a recovery event occurs, the chord would pull on the ring which would then distribute the shock around the airframe. When completed, the centering rings were epoxied into place on the motor tube with quick hardening epoxy. With special care taken in adhering the rear ring and retainer with heat resistant JB weld to ensure that heating would not cause the retainer to fail as it did in a previous subscale test. Then the motor tube assembly was inserted into the pre-epoxied airframe, using fins to ensure the rear ring stopped in its proper position. Following this, epoxy was applied to the fins and fin slots then inserted into the airframe. A second coat of slow curing epoxy was used afterwards to re-enforce the quick hardened areas around the edges of the centering rings.

For the final finishing steps. 2 part epoxy putty was used to fillet the contact edges of the fins to the airframe. Smoothing out the transition from the body to the fin surface. The two part steel putty was used to fillet the retainer to the centering ring and the centering ring to the airframe at the aft end of the rocket. All that was needed after these steps were a final sanding to smooth out the putty and then the lower section was ready for painting.

Figure 3: Finished lower motor section

Mid-section:

Construction for this section required the least amount of work as 80% of its volume would house a parachute and a simple cut and epoxy finished it off. Like the lower section previously covered. The Blue tube airframe was cut to 22'' using a band saw and the resulting edge was sanded. When completed, the interior of the airframe was sanded down 5.25'' from the top of the tube and a 8'' coupler was epoxied inside. Covered earlier in previous reports. This coupler acts as a shoulder for a temporary bulkhead that would rest on it to separate the payload parachute from the main parachute. So when the payload chute ejection event occurred. This would prevent the payload chute from entering the main chute bay and also protect the main chute from being compressed further into its bay causing the main to become stuck upon its ejection.

Avionics bay:

The components that went into the avionics bay shown below:

- Entacore AIM usb Xtra GPS flight computer
- 2x Perfectflight stratologger CF altimeters
- 3x 9v batteries
- 1x 800mah Li-polymer
- 2x 98mm (4'') plywood bulkheads
- 2x 10'' x ¼'' threaded rods
- 4x ejection caps

- 8’’ x 3.7’’ plywood sled w/ guide
- 4x wire terminals
- 2x eyebolts w/hardware
- Zip ties and fast cure epoxy
- 12x electronic standoffs
- Velcro stripping
- JST connectors

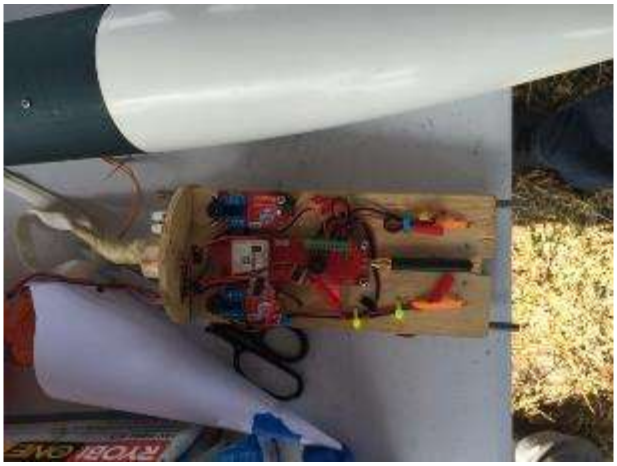


Figure 4: Finished Avionics Bay Front

Figure 5: Finished Avionics Bay Back

The avionics section was a relatively tedious portion to complete. The bulkheads, sled, and sled guides were drawn on a plywood board, cut out, and then sanded. Small holes were drilled into the sled in pre-planned positions so standoffs could be inserted. Still drilling, the bulkheads had 3 ¼’’ holes drilled into them, two for the rails, then one for the eyebolt. On the back, Velcro strips were adhered the sled with the opposite Velcro side on the batteries. Using fast cure epoxy, the sled guides and the switch block along with the switch were adhered to the sled.

The remaining assembly that remained was screwing in and wiring the flight computers to their terminals. Then placing the Velcro batteries on the opposite side and securing them further with zip ties. Inserting the rail guides through the bulkheads and sled. Along with epoxying the caps and terminals to their bulkheads.

Payload section:

This section proved to be the most intricate when fabricating. As the door component of the payload bay needed to be cut to the right dimensions and be able to fit flush with the airframe after magnetically sealing. The components going into this section include:

- 15’’ of 98mm (4’’) blue tube airframe
- 2x birch wood 98mm (4’’) to 38mm (1.5’’) centering rings
- 2x 98mm (4’’) plywood bulkheads
- 8’’ 98mm (4’’) blue tube coupler
- 1x 98mm G12 wound fiberglass ogive nosecone (16’’ exposed length)
- ¼’’ eyebolt and hardware
- Neodymium magnets
- Slow and fast cure epoxy (same as before)

Cutting of the airframe in this section for the payload door was completed using a dermal. After using a combination square to create the straight guide lines down the frame and blue painters tape going around the airframe to create the straight edges to follow as a visual aid. Using the newly cut opening as a guide. Dimensions of the door are 7’’ long and 2.75’’ wide. The door edges were marked on the centering rings lines were drawn inwards to the center of the ring to mark out a section to be cut off the ring. Which left a semi completed ring with slanted edges to the center that was completed with a band saw. The last cut was completed again using a band saw to remove an inch and a half off of the nose cone shoulder to give more flexibility to the payload bay size while staying within our designed height of the craft.

Epoxying of the bulkheads and centering rings began when all cuts were completed. The final position of the bulkheads were on the top and bottom of the payload bay door edges shown in the figure below initially with fast cure epoxy (later coated with slow cure epoxy). With the centering rings measuring 1.5’’ from each bulkhead. The door was constructed from the removed pieces of the airframe and centering rings and were epoxied at the same locations as the inner rings. Hinges were attached between the rings and bulkheads using metric 4 screws and the neodymium magnets were attached via JB weld on the door edge. Finally, slow cure epoxy was used to adhere the 8’’ blue tube coupler 3.25’’ into the airframe, butting up against the bulkhead. The finished payload section is shown below.

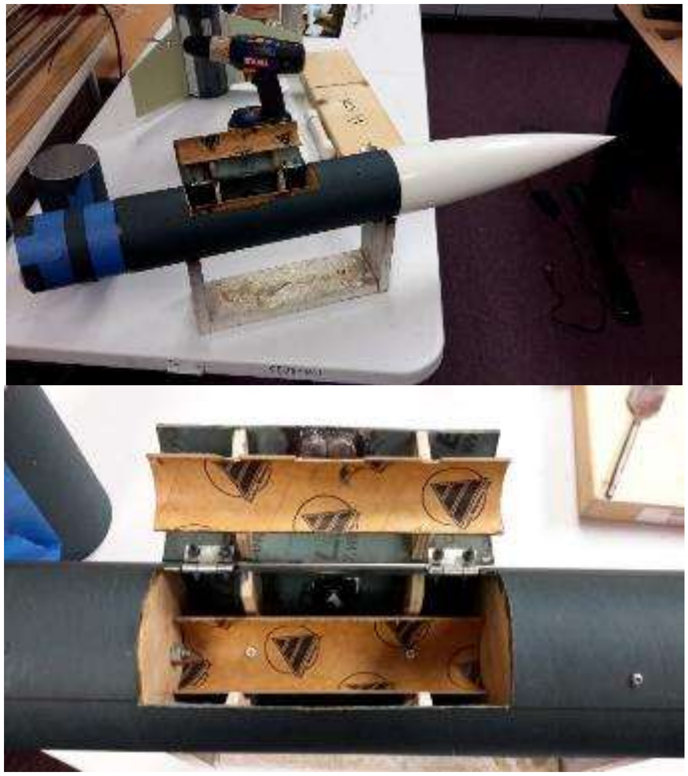


Figure 6: Finished payload section

Finishing touches:

With all three sections completed. Holes were measured on each section for screws to be inserted to hold in the nose cone to the airframe and to hold in the avionics bay to the mid-section. Afterwards, adequately sized pressure holes using Entacore's recommended sizing formula were drilled into the avionics through the airframe and coupler.

$$d_n = (0.1)d\sqrt{\frac{l}{kn}}$$

With smaller pressure holes (1/8th '') created in each parachute section to prevent the off chance of a pressure difference forcing a coupled section apart prematurely.

Remaining Construction:

As of this writing, the only remaining components to be added to the launch vehicle were not imperative to its test flight and include surface preparation for painting and the application of paint. The heated debate on the final color scheme is still ongoing and subject to delay when a new idea is presented. A factor on the choice in coloring of the rocket is restricted to the AGSE sensor color dots that the rover will be looking for. So the launch vehicle team must be careful not to color it in a way that would interfere with the performance of payload delivery.

3.1.2 Electrical Elements

Hardware

Flight Computers and Altimeters:

One AIM XTRA GPS flight computers, and two StratologgerCF, will be used in ensuring deployment of drogue parachute at 3,000 feet apogee, Payload parachute and payload deployment at 1,000 feet and Main parachute at 500 feet. The redundant flight computer in this case the AIM XTRA, will ensures system redundancy in case of StratologgerCF altimeter malfunction.

Table 1: Hardware Specifications

Hardware	Operating voltage	Minimum operating Voltage	Dimensions	Mass	Altitude Accuracy	Operating Temperature	Max Altitude
1 x AIM XTRA 2.0	3.5- 10 Volts	3.4 V	6”L, 1.185”W, 0.6”T	34g	+/- 3 feet	N/A	100,000 feet
2 x StratologgerCF	4-16 Volts	3.4 V	0.90”W, 2.75”L,0.5”T	11g	+/- 1%	-40C to 85C	100,000 feet

AIM XTRA GPS flight computer:

The AIM XTRA measures the rockets altitude by a pressure sensor and GPS to accurately give vertical altitude and resolution of vehicle. It also includes a 105g linear accelerometer for motor characterisation, flight analysis and a triple axis 16g accelerometer that adds resolution and accuracy vertically. The flight computer is also equipped with a 3 axis gyroscope, and 3 axis magnetometer to offer both rotation and magnetic field data. Furthermore, 4 high current (40 amps continuous) output channels available for multiple parachute deployment and firing mechanism. All data is relayed in real time to PC via AIM BASE receiver. Furthermore, GPS positioning will allow for payload location and extraction

Figure 7: AIM XTRA GPS flight Computer (http://entacore.com/electronics/aimxtra)

StratologgerCF(perfectflite):

The StratologgerCF "Compact Footprint" altimeter measures the vehicles peak altitude and maximum velocity by sampling surrounding air pressure relative to ground level pressure. The Stratologger collects flight data (altitude, temperature, and battery voltage) at 20 samples per second. Data can then be downloaded from the flight computer by a DT3U USB interface. Furthermore, two outputs are provided for deploying charges of drogue, main, and payload. However if any of the altimeters fail to deploy, for redundancy factors to maintain mission success the AIM XTRA flight computer will also fire its charges 2 seconds after.

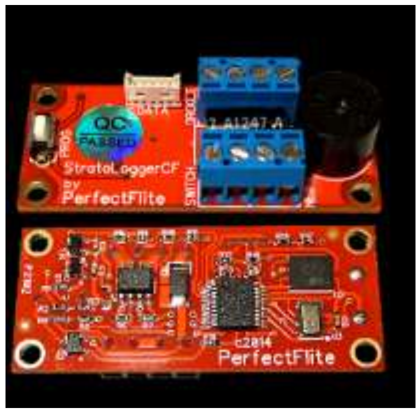


Figure 8: StratologgerCF Altimeter (http://www.perfectflite.com/sl100.html)

Power and Arming Switches:

The AIM XTRA flight computer will be equipped with a 9V battery to arm the pyro's and a 7.4V 800mah lithium polymer battery that will run the flight computer. Also each Stratologger will be power by a 9V battery. A toggle switch placed within the airframe will provide an on and off capability for arming each altimeter safely. Furthermore by incorporating this mechanism one could prevent premature firing of ejection charges and usage of power while the rocket is at launch pad. It is important to note in Figure 7 that all electronics will be arm by one switch.

Software:

Configuration of both the AIM XTRA flight computer and Stratologger Altimeter settings for deployed altitude, delay, launch detection, telemetry and other settings will be configured via their respective downloadable software. First the AIM XTRA will be programmed via its software were all ports will be set properly, continuity will be checked via the AIM XTRA Base radio transmission once the flight computer is armed and launch vehicle is on the pad. Moreover, the stratologgerCF will be programmed via the Perfectflite DataCap software.

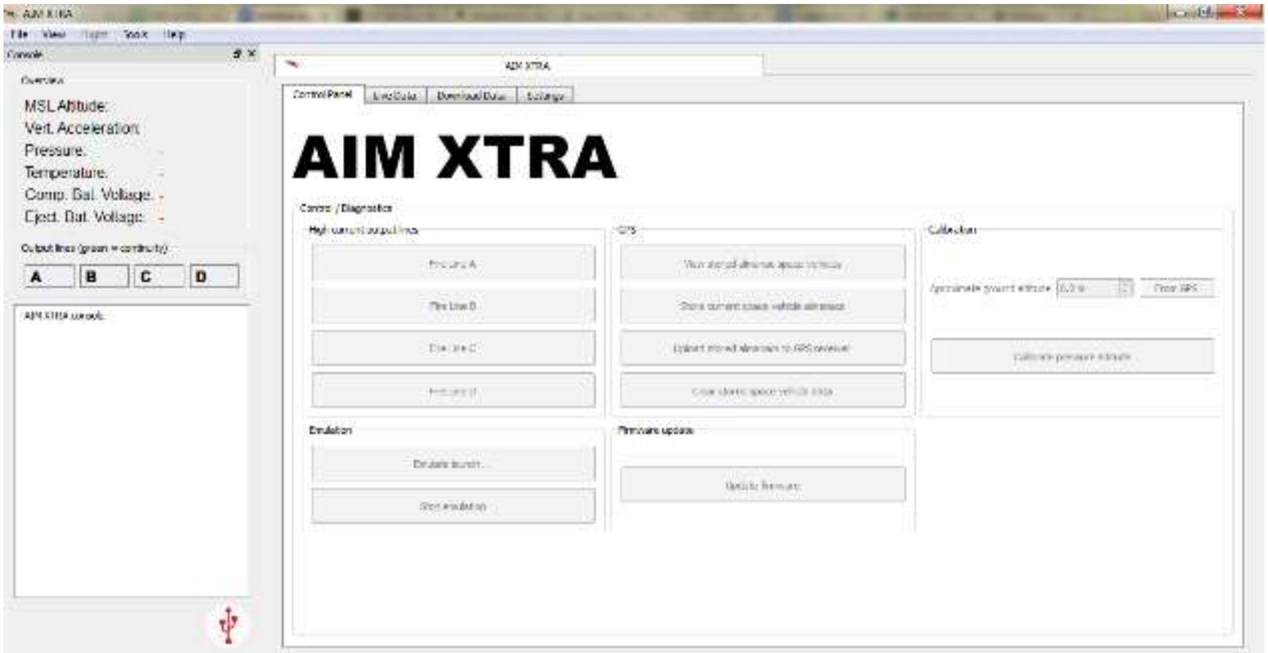


Figure 9: AIM XTRA

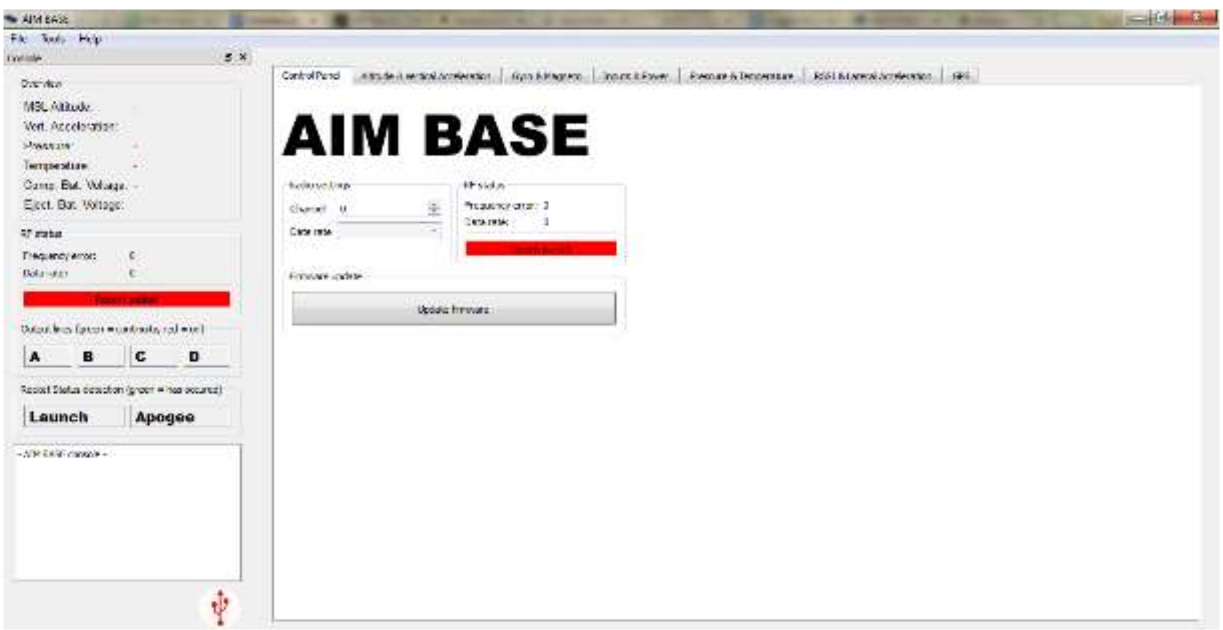


Figure 10: AIM BASE

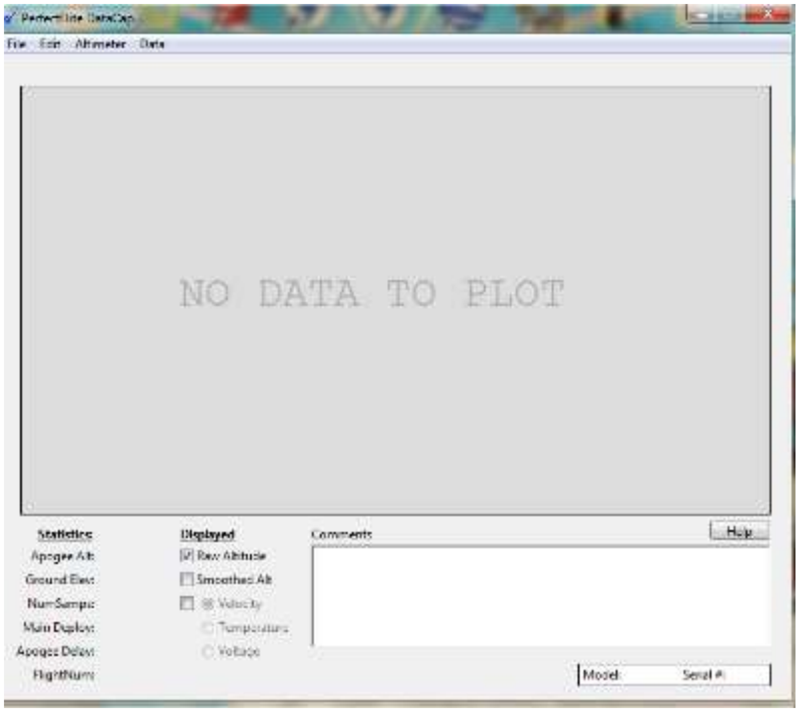


Figure 11 Figure XXX: Perfectflite DataCap

Mounting Configuration of Electronics:

The Main Electronics bay of the rocket will be placed between the main and drogue compartments. Furthermore, a vertical configuration parallel to the rocket structure placed at the center of the electronics bay which will be placed within a compartment in between the main parachute and drogue parachute will ensures proper accelerometers values and readings during flight. To ensure accessibility a removable bulkhead attached to the guide rails has been design to easily remove the electronics from the E-bay. Furthermore the flight computer and altimeter along with power supply are attached to a center plate by screws to ensure safety of electronics. In addition the flight computer battery and all three 9V batteries will be secured by Velcro and fastened by zip ties. Moreover, an LED was placed on the switch side of the E-Bay sled in order to provide visibility of the arming switch while the rocket is being assembled. The lighting of the e-bay was then increased by placing a reflective coating in the inside of the buckler.

3.11.3 Drawing, Sketches, Block Diagrams and Electrical Schematics

The following electrical schematics depict the wiring of electronics to their corresponding detonation caps. Furthermore redundancies factors will be taken into account in order ensure mission success.

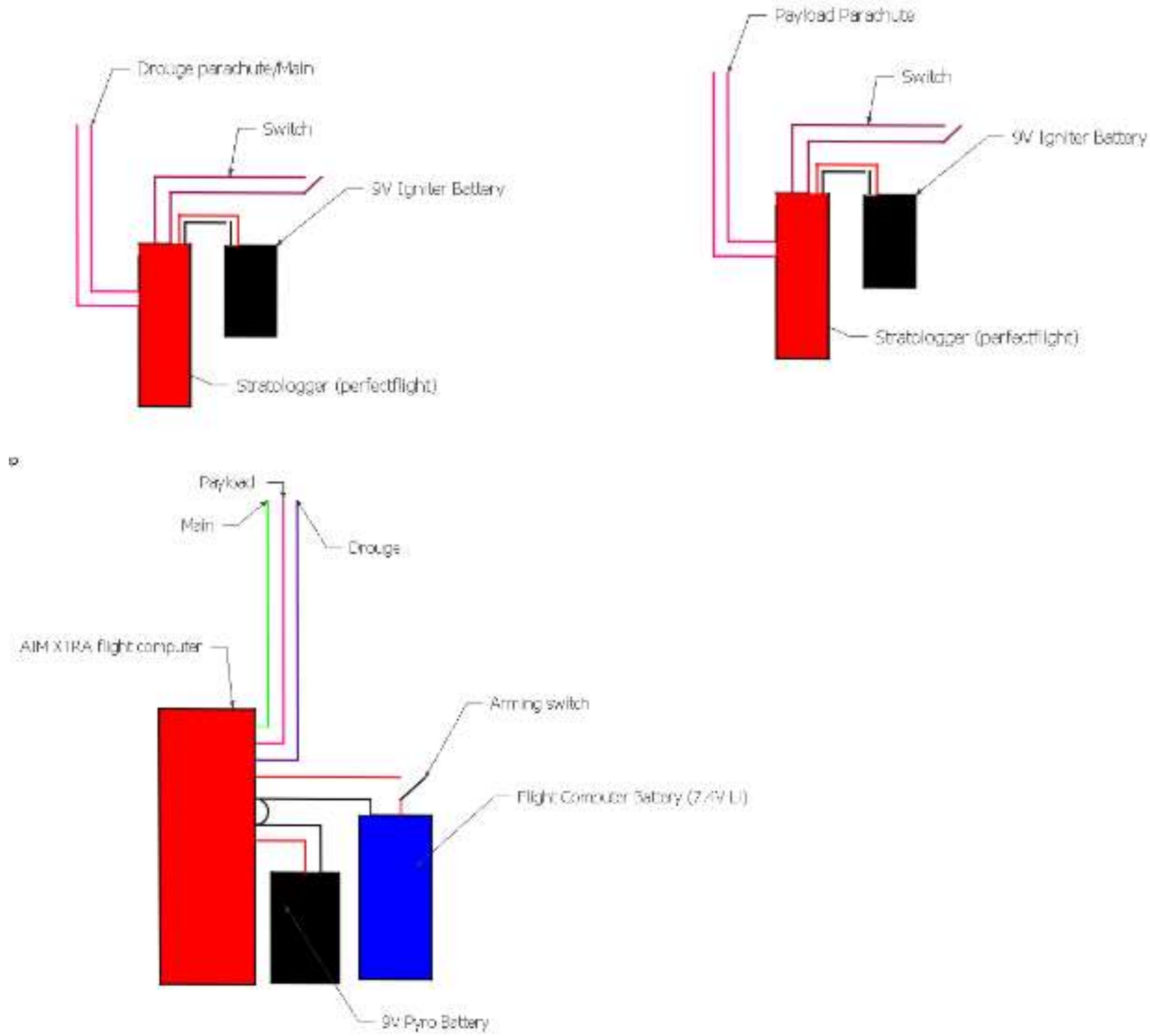


Figure 12: displays the avionics wiring diagram.

The following flowchart will depict a detailed sequence analysis of the firing of each detonation cap alongside redundancy factors taken into consideration.

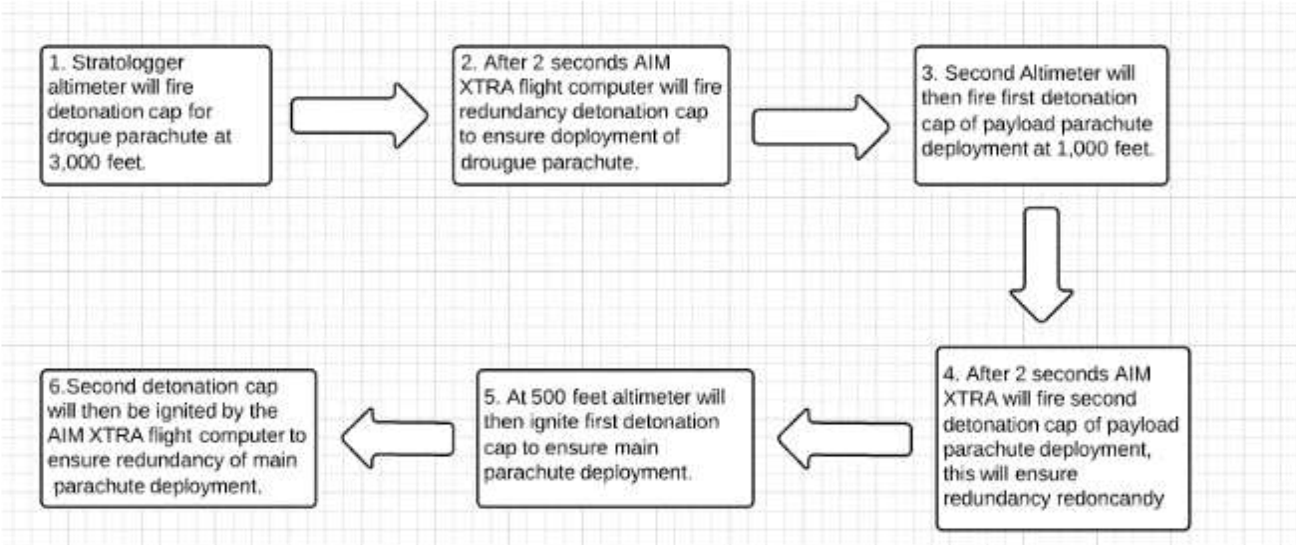


Figure 13: Flow Chart

3.1.3 Drawings and Schematics

Referencing CAD drawings of the launch vehicle and using the subscale assembly as a guide. The assembly is expected to unfold in a similar manner. The packing process will generally proceed from the bottom of the vehicle towards the top when assembling parachutes and electronics into their respective bays. Shown below is an exploded model illustrating the components and their respective steps in assembly.

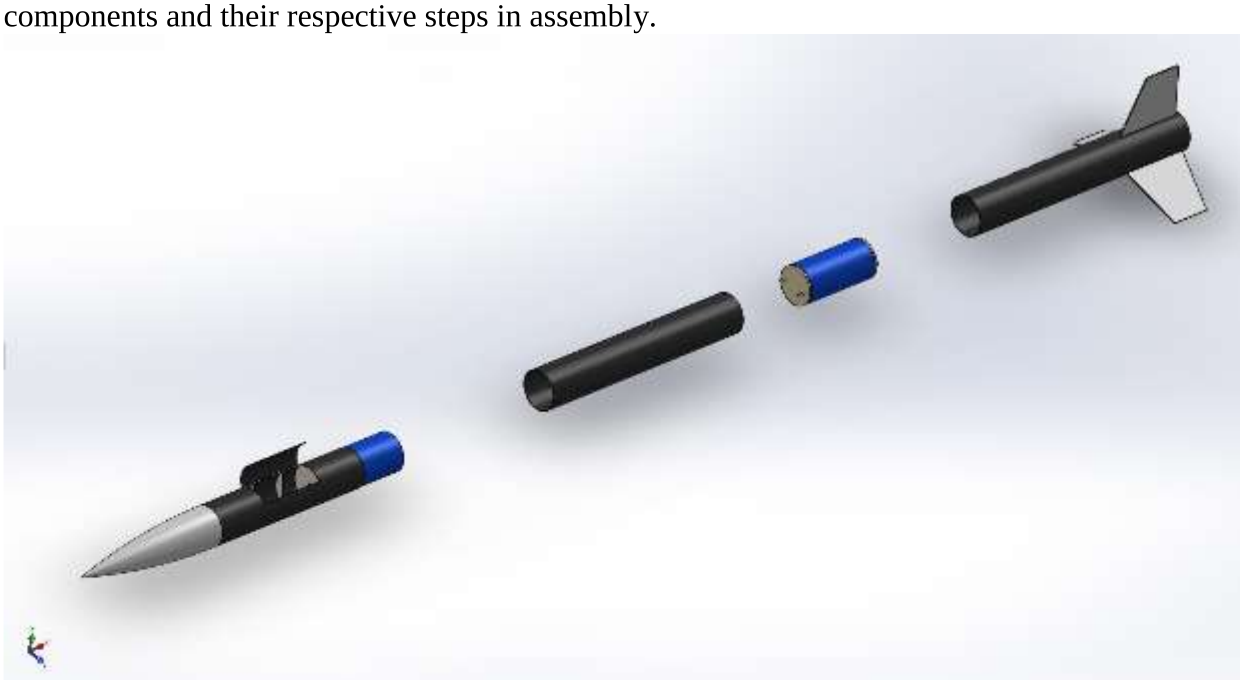


Figure 14: Exploded view of separate sections

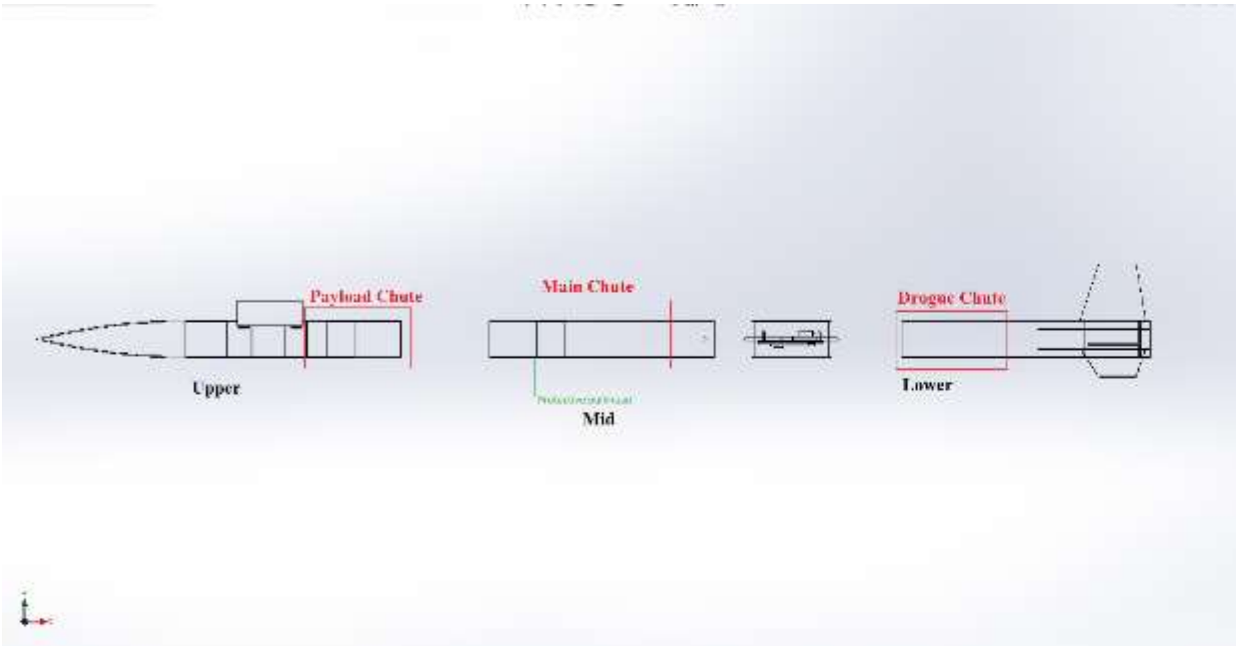


Figure 15: Wireframe view for parachute positions

Assembly Steps:

2. Parachutes are folded for packing
3. Shock cord is coiled around two fingers till sufficiently wound. Applying a rubber band to keep shape.
4. With no charges attached to FCs (Flight Computers), the batteries are connected and FCs are inserted into the Avionics bay.
5. The electronics shutoff pin is slid through the pressure vent to deactivate electronics
6. Ejection charges are loaded
7. Charge lines are then connected to their FC's via the bulkhead terminals
8. The bulkhead ends of the Avionics bay are then capped and slid into the mid body tube. Taking careful attention to pull out the shut off pin and re-inserting when avionics bay is fully inserted
9. 3 screws are then inserted to keep the avionics bay position while the drogue and shock cord are packed into the lower bay
10. Once packed, the mid tube/avionics bay coupler is slid into the lower bay
11. Paying attention to the connection wire (not shown) for the upper payload charge. The main parachute is inserted into the mid bay.
12. Confirming wire is through protective bulkhead. The upper charge is positioned behind the payload chute when inserting into its bay.
13. Connecting the charge wire to the wire extending from the protective bulkhead above the main parachute. The assembled payload section is slid into the mid body tube/main chute bay. Using this section to push protective bulkhead to the bracing coupler.
14. Shear screws are inserted above the protective bulkhead to hold it in place.
15. Open payload door and assembly is complete

3.1.4 Flight Reliability Confidence

Recovery System Reliability

The recovery system is one of the most important systems onboard the rocket to ensure safety, reusability, and mission success. There will be a total of three fight computers for redundancy; one Aim Extra and two Perfect Flight StratoLoggers. The StratoLoggers have only two ports whereas the Aim Extra has Four. One StratoLogger will power the drogue and main ejection charges. The other StratoLogger will power only the payload ejection charge. The Aim Extra will serve as a backup for all three events.

To safeguard against the batteries draining before flight only new, never used, 9V batteries will be used. The lithium polymer battery used to power the Aim Extra flight computer must be fully charged and checked that it is charged using the flight checklist. Also, all electronics have been wired through a single switch that is turned on or off using a pull pin with a “Remove before flight” tag attached. The switch is to remain off with pull pin in place until the launch vehicle is on the launch pad and ready for flight conserving all battery life. Even if all batteries are fully charged they will still be rendered useless if they shift and lose continuity during flight. To prevent the batteries from moving all batteries have been secured with both

Velcro and zip ties for redundancy. Likewise, if the flight computers are not wired properly there may never be continuity to begin with and the recovery system will not function. To be confident all flight computers are operational and have continuity the Aim Extra flight computer will be checked for continuity from a ground station on all ports via Aim Extra computer software. The Perfect Flight StratoLogger flight computers will be checked for continuity by listening for three beeps from one of the StratoLoggers indicating continuity on all ports and by listening for two beeps from the other StratoLogger indicating continuity on one of the ports. To ensure all flight computers ignite the ejection charges at the intended altitudes pressure holes were drilled into the electronics bay according to manufacturer specifications. Barrel swivels were used to attach all parachute shroud lines to the shock cords to prevent the shroud lines from twisting and tangling when the parachutes do deploy.

Ground ejection charge testing was conducted and two grams of black powder per chute was found to be the optimal amount needed to safely deploy all parachutes. The redundant ejection charges are set to go off at slightly different times to make sure that both ejection charges are not fired at the same time. Even so, the launch vehicle was ground tested with four grams of black powder in case both charges do fire at once. The airframe, shock cords, and parachutes were all able to withstand the force.

All parachutes must be protected from the black powder explosions used to push apart the airframe and deploy the parachutes. To do this every parachute will be folded with shroud lines wrapped around and covered with a flame retardant parachute protector.

During ascent the launch vehicle undergoes pressure changes as the vehicle increases in altitude. Atmospheric pressure decreases as altitude increases while the pressure inside the rocket remains at one ATM. This may cause the launch vehicle to separate prematurely on the way up which may lead to structural failure. To mitigate this problem small pressure holes were drilled into each parachute compartment to regulate pressure during flight.

During drogue descent the upper half of the rocket will be pointing downward and may cause the payload and/or main parachute(s) to deploy early from premature separation due to gravity. To mitigate this problem plastic shear screws will hold the vehicle together under the force of gravity, but will shear apart when the ejection charges fire. Metal screws are used at all other airframe coupler connection points that do not need to separate at any point during flight.

Launch Vehicle Reliability

To be confident that the fins remain attached to the airframe upon landing and do not flutter during flight the fins were inserted through fin slots in the airframe and mounted to the motor tube. The fins were also secured to the fin slots using epoxy and then filleted to the exterior of the airframe using epoxy clay.

To ensure all nuts and bolts remain in place and don't shake lose during the vibrations of flight all nuts will be secured with Loctite with the exception of the electronics bay. The nuts holding the electronics bay together must remain removable to access the electronics inside. The wooden sled holding the electronics is held together by threaded rods. To make sure the nuts don't shake loose extra length of threaded rod will protrude from the electronics bay to make that the nuts have a long way to go to completely come off.

To secure the motor retainer to the motor tube JB Weld was used. The motor retainer experiences a large increase in temperature during the motor burn. JB Weld was selected because it is rated for temperatures up to 500°F.

Payload insertion ground testing was performed by dropping the payload into the payload bay from various heights to test the probability of the payload settling into position. The centering rings used to hold the payload bay in place were cut at an angle to create and inclined plane that would allow the payload to slide down into the proper position. The results showed that when the payload was dropped from 1 ft up or lower and hit somewhere in the payload door opening that the payload settled into the correct position 10 times out of 10. At 1.5 ft up the payload settled into the correct position 9 times out of 10. At 2 ft up the payload settled into the correct position 7 times out of 10. With these results the team is confident that if the robot can simply drop the payload somewhere close to the payload opening that the payload will settle into the correct position for flight.

Above all else the things that provide the most reliability confidence are the subscale and full scale test flights. Both flights used these same components, testing, building techniques, and checks and both performed flawlessly.

3.1.5 Present Test Data and Discuss Analysis

During revision of the data previously discussed in section 3 of vehicle criteria, and among inspection of sub scale and full scale test flight it was concluded that all risks are at acceptable levels. This is contingent of following all risk mitigation steps given in the mission assurance analysis of the launch vehicle.

3.1.6 Workmanship

From previous competition experience, UCF SL team has realized that the amount of application of engineering principles to any element is critical to ensure overall success to any mission. This roughly translates to paying attention to detail and planning well in advance to evaluate and assemble an effective system of working parts.

Aside from acquiring this knowledge and applying it; it is crucial that assembly techniques and component testing understanding is properly distributed amongst the members of UCF SL team. In order to ensure this is done appropriately the more senior members will offer tutorials and answer questions from the more inexperienced members in order to pass on knowledge from present and previous SL team members to members that are interested in learning hands-on skills and who may one the pass the torch to future SL teams by participating again in future NASA SL competitions.

Due to the limited number of experienced members a blend of pre-manufactured parts and custom constructed parts will be implemented to both save time and guarantee safety for the high performance designs necessary for mission success, with machining and epoxy application being restricted to senior members.

3.1.7 Safety and Failure Analysis

Identification of Safety Officer

Diego Ospina will be Project Ares safety officer, currently pursuing L1 NAR certification, and NAR membership license #99116 SR. Additionally, Garry Dahlke will be our primary safety mentor during the project at hand. Furthermore, Anthony Laiuppa will also oversee the safety officer elected for the project in which all safety procedures will be followed with exact precision, both with experience in their field.

Risk Reduction Plan

Table 2: Risk Reduction Plan

RISK	TEST TO REDUCE RISK
Catastrophe at Ignition	Detailed checklist of launch procedure will be followed accordingly to both regulations of NAR, and safety protocol established. Thus a low level risk of failure was given.
Structural Failure	Structural stress analysis was conducted on solidworks to ensure structural composition of vehicle during flight, as well as a subscale and full scale test flight. Thus among revision of analysis, a likelihood of structural failure is given to be low.
Bird Strike	Before launch, establishing a clear flight path is essential in avoiding an accidental bird strike, though highly unlikely still very possible thus a low risk level is assigned.
Shear Pin Failure	Testing of placement for shear pin optimum stress was conducted to ensure pins break properly. Also among subscale test flight, and full scale test flight all shear pins tested to work properly allowing the bulkhead on the upper section of the main parachute compartment to deploy properly. Thus a low level of failure is given.
Failure For Payload to Detach From Main Rocket	Subscale testing of payload detaching, and full scale of payload detachment functionality tested successful on both launches, thus a low risk failure was assigned.
Drogue Parachute Not	Extensive calculations have been conducted to accurately estimate the

Deploying	velocity of the vehicle as its free falling to properly allow for low drift. Optimal packing of the parachute will be looked after to ensure tangling issues to be minimal during deployment. These procedures proved successful during both the subscale and full scale launches, thus a low risk of failure was given.
Main Parachute Entanglement	Main parachute will be carefully packed, and due to previous launches will be configured in a way to lessen the danger of entanglement, these steps proved successful in both the subscale and full scale main parachute deployment. Thought, very unlikely it’s still a very possible scenario thus a medium risk was established in order to prioritize that if entanglement was to occur main vehicle catastrophe could be imminent.
Failure of Recovery System Attachment Point	All recovery system attachment points were tested for their optimal max tensile stress to ensure they maintain their integrity during stress being applied by the recovery parachutes. Furthermore, after recovery of both the subscale and full scale test flights all attachment points were inspected and due to successful launches a low risk was established.
Motor Fails to Ignite	One random igniter was selected from the packet and tested at random to ensure low probability of the others to malfunction. However if an igniter were to not go off, extra igniters will be available to ensure mission success. Additionally with both motors igniting in both the subscale and full scale launches a low risk likelihood was established.
Payload Bay Door Properly Opening/Closing	The payload bay door were put through testing to ensure opening and closing mechanism work properly during flight of vehicle, thus during revision of functionality after subscale and full scale test flights, a low risk likelihood was given.
Electronics powered	All electronic batteries will be checked, and charged before placing them in the electronics bay to ensure all electronics are functioning properly. Furthermore, once electronics are armed they will be checked for continuity. Do to following the above steps successful pyrotechnic deployments were seen in subscale and full scale launch. Thus A low risk failure was given

Table 3: Risk Assessment

RISK	LIKELIHOOD	EFFECT OF PROJECT	RISK REDUCTION PLAN
Catastrophe at Ignition	Low	Complete mission failure.	To mitigate this risk we have detailed setup launch procedure and safety checks at every stage before launch.
Structural Failure	Low	Complete mission failure.	Structural analysis and bulkheads added to make the rocket structural sound.

Bird Strike	Low	Flight path hindered.	Cautious to launch if any wildlife is present overhead.
Shear pins failure	Low	No Main parachute deployment; catastrophic failure.	Extensive testing will be done to ensure enough force to break shear pins.
Electronics fail to power	Low	All pyrotechnics will fail to deploy.	All batteries will be checked for their voltage before flight to ensure appropriate voltage required to ignite all pyrotechnics. Flight computer and altimeters will also be checked for continuity.
Failure for Payload to Detach From Main Rocket	Low	Payload not deployed; main parachute not deployed.	Extensive testing has been done to ensure detonation caps are loaded with enough black powder to appropriately deploy payload from launch vehicle.
Drogue Parachute Not Deploying	Low	Slow down rocket to appropriate speed so that main shoot deploys at calculated altitude without major drift.	Extensive deployment testing will be conducted to find optimal packing method for drogue parachute.
Main Parachute Entanglement	Medium	Partial mission failure. payload deployment still viable, however recovery of main rocket is very unlikely.	Guidelines to properly pack the parachute will be followed.
Failure of Recovery System Attachment Point	Low	Partial mission failure. Payload deployment still viable, however recovery of rocket is very unlikely.	Ensure extensive testing of recovery system attachment points.
Motor Fails to ignite	Low	Unable to launch; mission failure.	Have a replacement igniter
Payload bay door properly opening/closing	Low	Enables Rover to properly place payload inside payload bay. Mission failure.	Extensive testing of door mechanism will be performed before mission to ensure all functions work properly

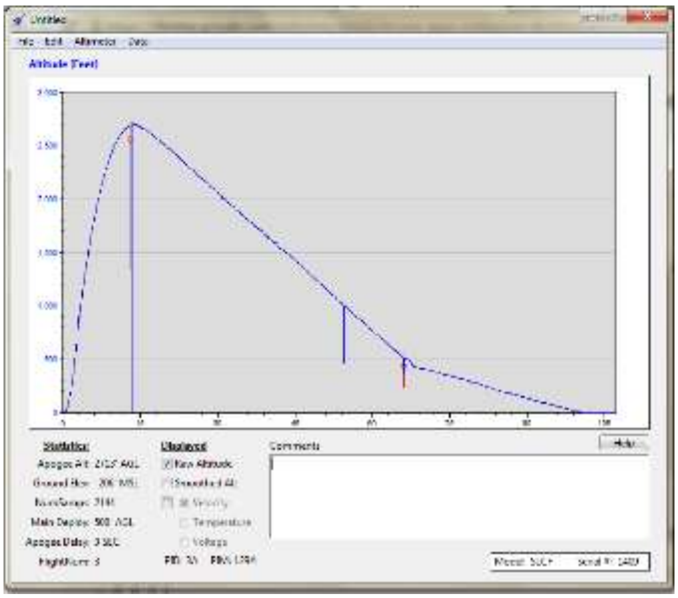
Table 4 Rocket Risk

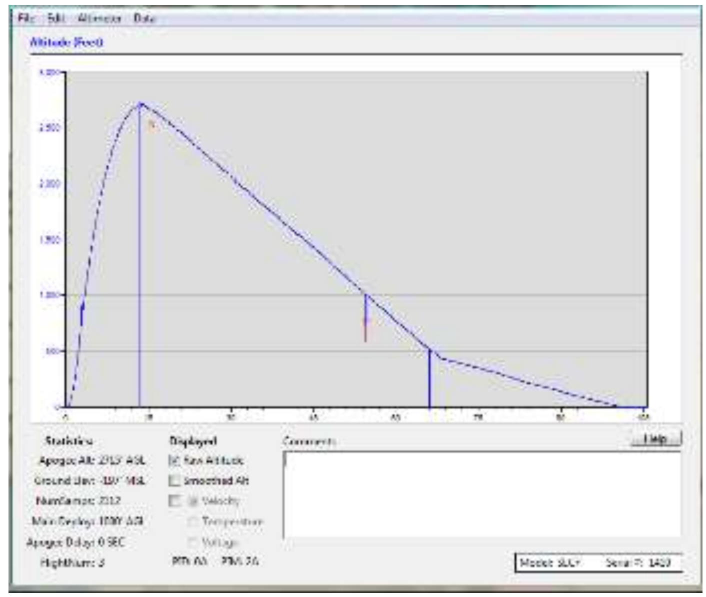
FAILURE MODE	EFFECTS	Precautions to prevent effect	Precautions to prevent event

Motor Failure	Property damage, injury to persona	Follow path of rocket and keep sight off at all times, move or take cover if needed. Proper safety distances should be followed.	Properly store and assemble motor in accordance to manufacturer's recommended instructions
Recovery System Entanglement	Property Damage, Injury to personal	Keep sight of rocket descent path, move or take cover if needed.	Extensive testing of recovery system in accordance to HPR standards
Recovery System Structural Failure(shock cord/ bulkheads)	Property Damage, injury to personal	Keep sight of rocket descent path, move or take cover if needed.	Perform extensive static testing on unrated components to ensure strength
Failure to Deploy Recovery System	Property Damage, injury to personal	Keep sight of rocket descent path, move or take cover if needed.	Extensive testing of black powder ignition caps, pyro bolts, deployment altimeters, and battery charge. Make sure to arm altimeters
Deployment of Recovery Device on Ground	Property Damage, injury to personal	Be aware of black powder ignition caps in rocket, If accidental electronics are armed stand clear of debris, wear safety glasses to avoid eye injury.	Shunt charges until they are attached to recovery electronics. Batteries should be unplugged until rocket is ready for ignition.
Mid-Flight Vehicle destruction	Loss of vehicle, injury, property damage	Keep sight of rocket, stand clear of debris.	Design and structure of vehicle must be tested to ensure mission success
Failure to successfully integrate payload in allotted 10 min time period	Launch opportunity failure	N/A	Practice integration technique of payload into payload bay within 10 min time frame to ensure mission success within time frame.

3.1.8 Discuss Full-scale test Launch

During the full scale launch test a large variety of data was recorded onto the main flight computer, and both altimeters which were retrieved and analyzed for max altitude, velocity, temperature, and Battery voltage. Moreover, a GPS flight path was also plotted to illustrate the flight of the launch vehicle. Amongst inspection of the data, and forth most the max altitude achieved by the rocket was shown to be approximately 2,700 feet. This altitude was derived from inspecting AGL Graph 1, Graph 2, and Graph 3 which ultimately in comparison to open rocket simulation felt short of its predicted 3,500 feet. However, this could have been due to the fact that there was a one pound increase in weight of launch vehicle and as well as effects due to high winds.



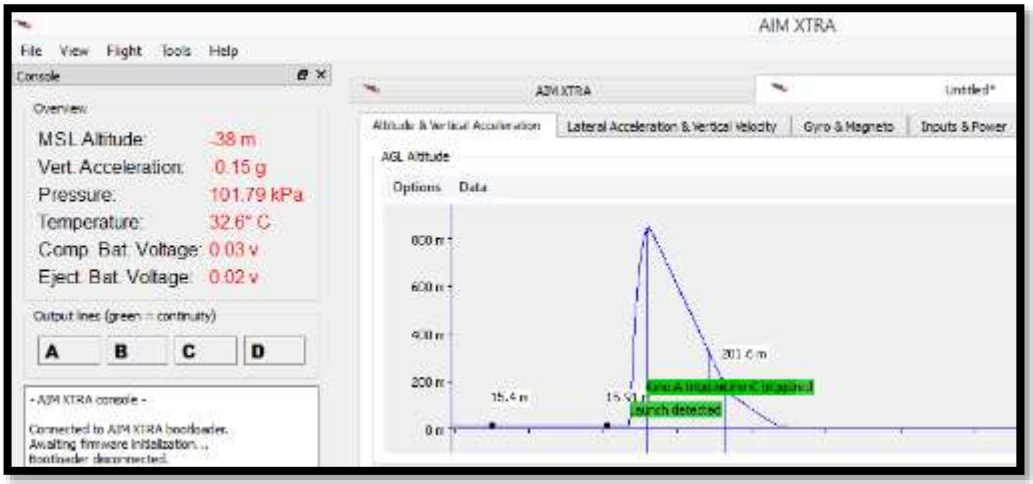


Graph 1: 2,713 feet AGL

StratologgerCF 1: Primary Main/Drouge Pyrotechnic

Graph 2: 2,715 feet AGL

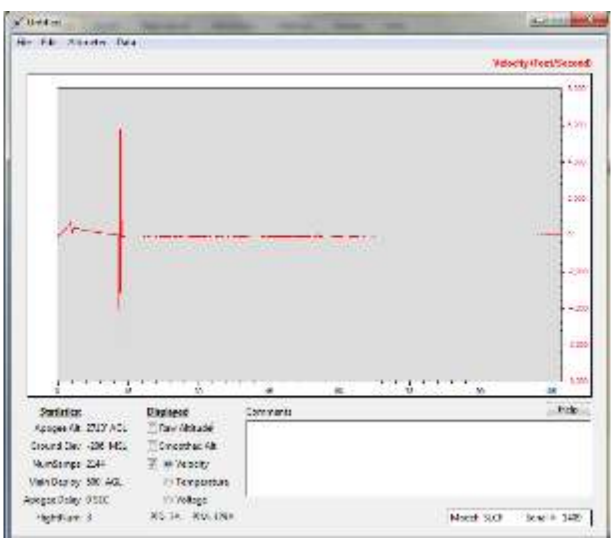
StratologgerCF 2: Primary Payload Pyrotechnic



Graph 3: 2,703 feet AGL

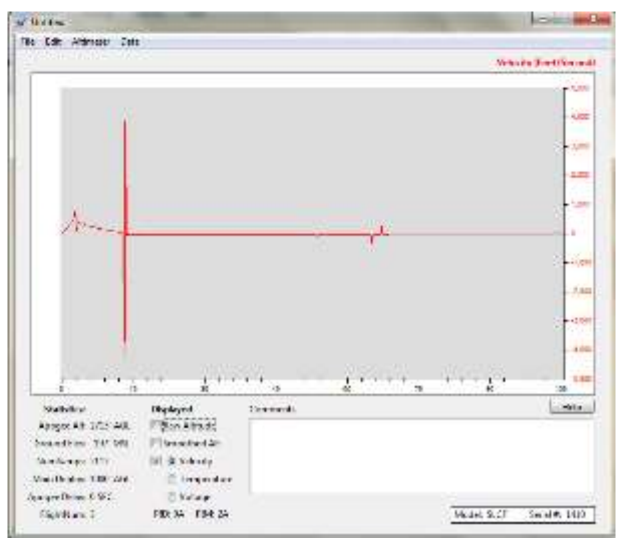
AIM XTRA 2.0: Redundant Drouge, Main, Payload Pyrotechnics

Furthermore, velocity profiles were also recorded, and compared to one another to estimate max velocity profile of the launch vehicle during ascend. Besides, these velocity profiles were compared in Graph 4, Graph 5, and Graph 6. It could be noted that in Graphs 4, 5 and 6 there is an instantaneous jump in velocity that originally did not make sense, but in the midst of inspection of the data and launch video recording it was noted that those huge jumps in velocity could have been accounted by the pyrotechnics going off close to the electronics bay. Concluding a rough estimate of around 460 ft/s max velocity.



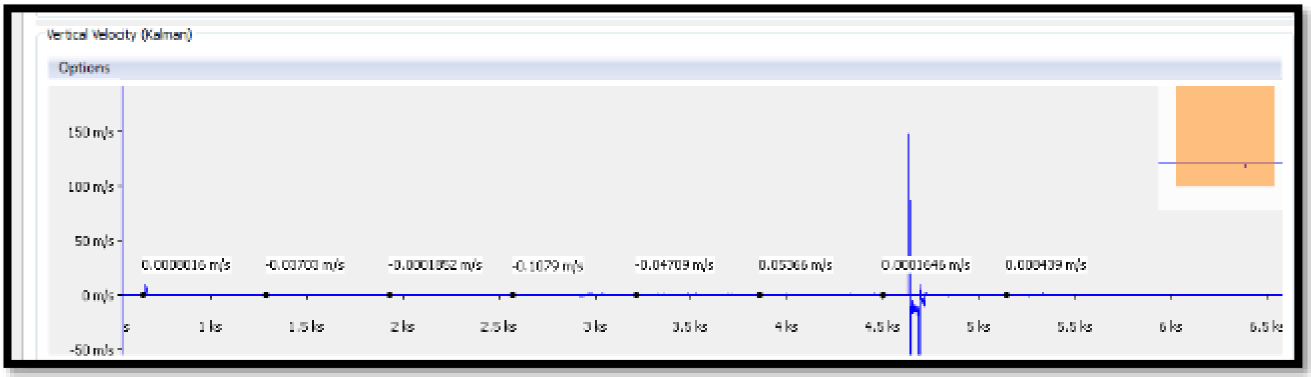
Graph 4: 550 ft/s

StratologgerCF 1: Primary Main/Drouge Pyrotechnic



Graph 5: 600 ft/s

StratologgerCF 2: Primary Payload Pyrotechnic



Graph 6: 462 ft/s

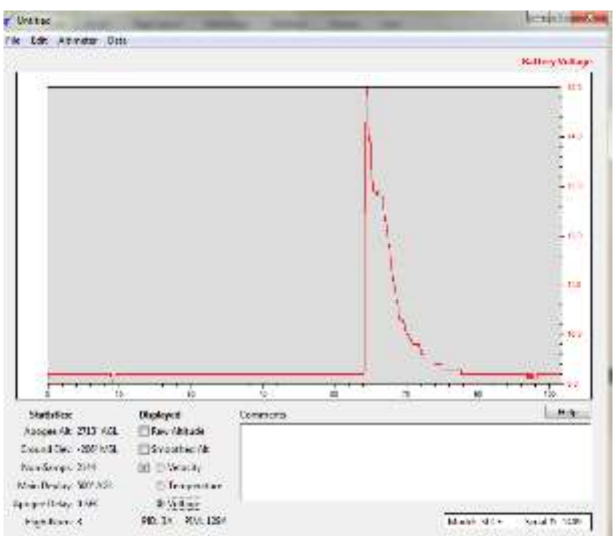
AIM XTRA 2.0: Redundant Drouge, Main, Payload

Likewise, it was decided that the temperature would also be recorded, in order to analyze an increases in temperature that could potentially damage any of the electronics. It was noted that during certain times of the flight of the vehicle a spike in temperature was recorded followed by a decrease in temperature then again followed by another spike increase of temperature in the electronics bay. At first the data seemed random, but during the retrieval of the launch vehicle and remov

The last but most important recorded data was the voltage drop of the electronics power sources, including the AIM XTRA flight computer 7.4V lithium battery and 9Vpyrotechnic battery, as well as both 9V pyrotechnic batteries powering the stratologgersCF altimeters. This was important in the regards that in order to maintain integrity of the mission at hand all ejection charges needed to deploy accordingly and in order to do so all systems must be powered at all times. Furthermore, in order to compare the reaming charge of all the batteries after launch, it was made sure that they were checked with an ohm meter before flight. The following recorded voltages were given. The flight computer main battery was tested to have a voltage of 8.2V and the igniter battery with a voltage of 9.1V. However, upon revision of the data shown on Graph 10 it was noted that a voltage drop of .131V for the flight computer battery and a .08V for the igniter battery were recorded. In addition both of the altimeters batteries which prior to launch had 9.1V showed a drop of power of only approximately .1v which can be shown in Graphs 11 and12. Though, the batteries were being drained while the launch vehicle was on the pad as well as the flight time of the vehicle it can be assumed that the overall voltage drops were minimal and a low risk failure was given.

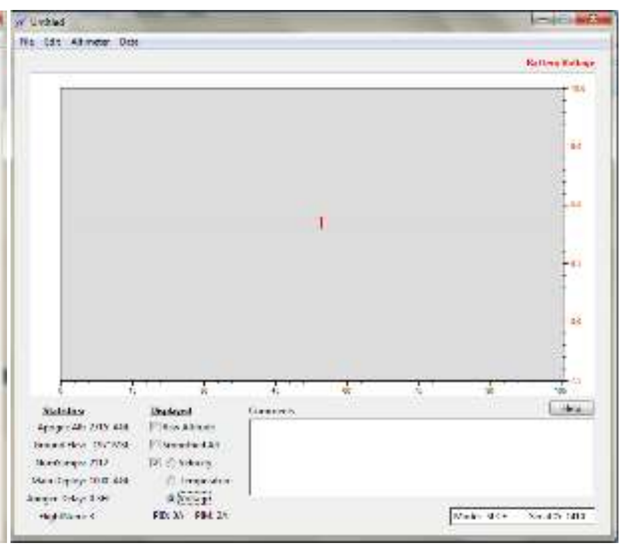
Graph 10: Voltage drops

AIM XTRA 2.0: Redundant Drouge, Main, Payload



Graph 11: Voltage drop

StratologgerCF 1: Primary Main/Drouge Pyrotechnic



Graph 12: Voltage drop

StratologgerCF 2: Primary Payload Pyrotechnic

A final illustration will also be included with the recorded data to briefly depict the GPS positioning of the vehicle throughout the flight. This holds very accurate in the fact that by checking the coordinate system of latitude and longitude of the rocket with what was given from the flight computer it can be concluded that the system was functioning properly. This path can be seen in Figure 1.

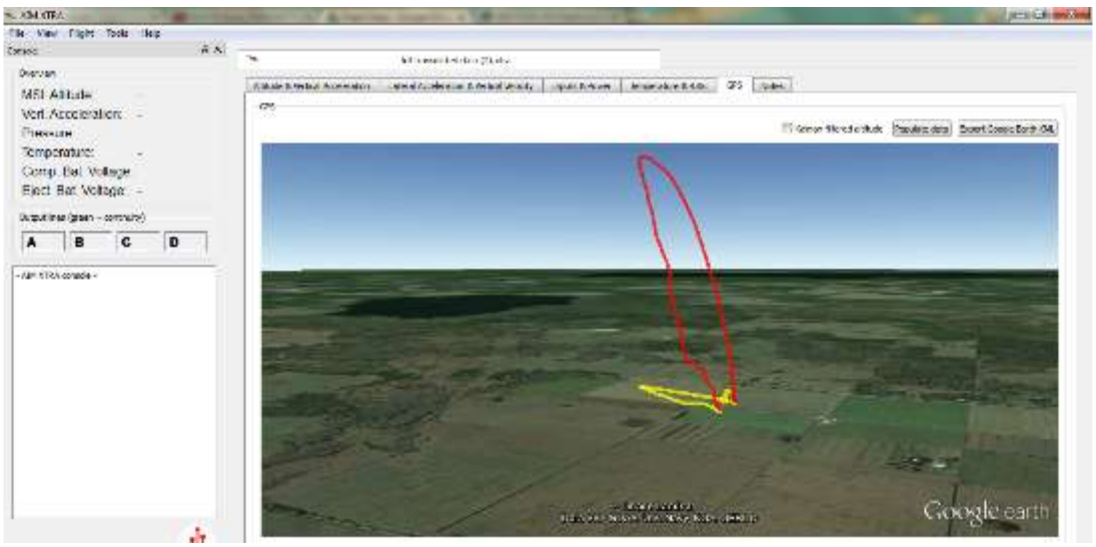


Fig. 1 Flight path of Launch Vehicle.

3.1.9 Mass Report

The simulated model of the subscale rocket was created using Open Rocket software. The simulated model predicted the total mass of the completed subscale rocket including the payload, the motor grains and motor casing to be 75oz. The team then built the subscale launch vehicle according to the dimensions designed in Open Rocket. Once assembly was completed the launch vehicle was weighed and found to have a mass of 101oz which translates to an overall mass increase of 26oz. Contributing factors to the increase in mass included epoxy, and various small hardware components such as ejection canisters, terminal blocks, wires, door hinges, magnets, and screws which were all not considered in the simulated design.

The full scale model was designed in a similar manner using Open Rocket software which predicted the full scale launch vehicle to weigh 139oz. The hardware needed to assemble the full-scale rocket consisted of the same items used to assemble the subscale model except for 3 additional ejection cups that are used for redundancy in the recovery system. The full scale model was also expected to use more epoxy resin and hardener due to larger components and more surface area needing to be secured in place. The team estimated using approximately an additional 4oz of epoxy resin and hardener. The total mass increase for the full-scale model was expected to be roughly 30oz more than the Open Rocket prediction for a total expected mass of 169oz. However, after completion, the full scale launch vehicle weighed a total of 176oz (11lbs) which translates to a 37oz mass increase compared to Open Rocket prediction and is 7oz more than the team's 30oz mass increase prediction. This 7oz increase can be attributed to using longer shock cords for all three parachutes than were used for the subscale rocket which was not taken into account when estimating the total mass increase for the full scale. Simulations in Open Rocket also predicted that the launch vehicle would reach an apogee of 3,341ft using a J360SM-6 Cesaroni motor. Inputting the actual mass of the completed launch vehicle into Open Rocket lowered the apogee to 2,913ft. The mass increase brought the thrust-to-weight ratio down to 7.35:1 which is still above the minimum 5:1 thrust-to-weight limit and has a predicted rail exit velocity of 63 ft/s.

3.2 Recovery Subsystem

3.2.1 Structural Elements

The base of our rocket will be two interconnected blue tube airframes consisting of 4 inch diameter. The blue tube material is made from a paper fiber and is abrasive resistant to restrict any form of cracking during launch. We will be utilizing trapezoidal fiber-glass fins that are to be inserted from the bottom half of the blue tube airframes, approximately 0.125 inches from the bottom, with the help of our manufacturer "Always Ready Rocketry" who will provide this service for us.

Our motor retention system will be composed of aluminum since its strength and lightweight properties have proven effective in previous flight missions such as our sub-scale launch. The bulkheads connecting the parachutes to the main deployment compartments will be stabilized with epoxy adhesive as this material has proven suitable in past launches. The motor retainer will be withheld with JB Weld adhesive to secure the retainer and mitigate any resistance during flight.

3.2.2 Electrical Elements

The Discussion of the electrical elements can be found in section 3.1.2.

3.2.3 Redundancy Features

Redundancy features is implemented by including two StratoLoggers.

3.2.4 Parachute Sizes and Decent Rates

When the drogue parachute is deployed, it is required to slow the system to a descent rate of 48.88 ft/s prior to the payload ejection and 43.96 ft/s after the payload ejection. To accomplish this, the drogue chute will have a diameter of 22 inches. When the main parachute is deployed, it is required to slow the system to 13.82 ft/s to safely land on the ground. To accomplish this, the main chute will be 70 inches in diameter. To safely land the ejected payload the parachute will have a diameter of 30 inches and will slow the payload to 18.80 ft/s.

3.2.5 Drawings and Schematics of the Electrical and Structural Assemblies

Please reference section 3.11.3

3.2.6 Rocket-Locating Transmitters

Our rocket will be monitored during recovery with the TrackR 1 device pack to secure the payload. The main launch vehicle will be detected using a GPS transmitter that will correspond to our flight computer software AIM XTRA Base which will be connected to a laptop at ground control. To ensure maximum GPS connectivity, the RF receiver should remain 9 feet off the ground projecting straight into the air.

For the wattage of the software the inputs are protected against over-voltage up to 12 volts, but only display values from 0 up to ≈3.3 volts.

3.2.7 Discuss the Sensitivity of the Recovery System

3.2.8 Suitable Parachute Size for Mass

A 36 inch drogue parachute will deploy at apogee, allowing the 9.26 rocket to have a descent rate of 41 ft/s. A 28 inch diameter payload chute will be attached to the jettisoned payload containment section which will yield a descent rate of 24 ft/s. A 76 inch diameter parachute will deploy from the main vehicle at 500 ft leading to a descent rate of 17 ft/s. The AIM XTRA, will provide system redundancy in the effect of a Stratologger altimeter malfunction. A toggle on/off switch will ensure reliable arming capability for the altimeters being held within the airframe.

The main electronics bay will be stationed between the main and drogue portions of the vehicle. The flight computer, altimeter and power supply will be attached to a center plate by screws in order to provide stability and safety.

3.2.9 Safety and Failure Analysis

Please reference section 3.1.7

3.3 Mission Performance Predictions

3.3.1 Mission Performance Criteria

To consider this mission to be successful, four criteria need to be met. These criteria involve payload transportation and integration, altitude, an independent jettison, and recovery.

- The vehicle shall deliver the payload to, but not exceeding, an apogee altitude of 3,000 feet above ground level (AGL)
- The drogue parachute will deploy at apogee

- The payload section must be jettisoned off at 1000 ft
- The main parachute must deploy at 500 ft
- The kinetic energy at landing must not exceed 72 lb*ft
- The drift of any section must not exceed guideline requirements
- The rocket must be reusable after use

3.3.2 Flight Profile Simulations

Throughout the entire project as well as this FRR, the flight simulation software selected was OpenRocket. A comprehensive and accurate model of the rocket was constructed within the software; which was then run through numerous simulations with different motor configurations in order to find the optimal setting. International Standard Atmosphere (ISA) conditions were used to simulate atmospheric conditions. The simulations using the motor used in the full scale launch, Cesaroni J360, yielded an altitude of 4201 ft and a weight of 10.2 lb. Due to the J360 being a skidmark which is prohibited by competition rules a Cesaroni J355 red lightning was selected as an acceptable alternative. After launch it was determined that more thrust was needed in order to compensate for software uncertainty and mass increase, the rocket was resimulated with a more accurate weight that will reflect the configuration planned to be used at competition launch. More detail for each simulation mentioned along with plots and graphs will be further discussed.

Test Flight Simulation

Figure 16: Unfinished View of Rocket with Cesaroni J360

Ignition occurs at t=0. The burnout time of the motor is 2.8 s with the time to reach apogee being 14.3 s. The max velocity is simulated as Mach 0.56 at 598 ft/s with an apogee of 3517 ft and max acceleration of 332 ft/s^2 A simulated rail exit velocity of 65.5 ft/s is well over the minimum rail exit velocity of 42 ft/s. The weight of the rocket and stability margin is 10.1 lb and 3.16 cal respectively. A 22" drogue is deployed at apogee, a payload chute is deployed at 1000 feet, and a main chute is deployed at 500 feet.

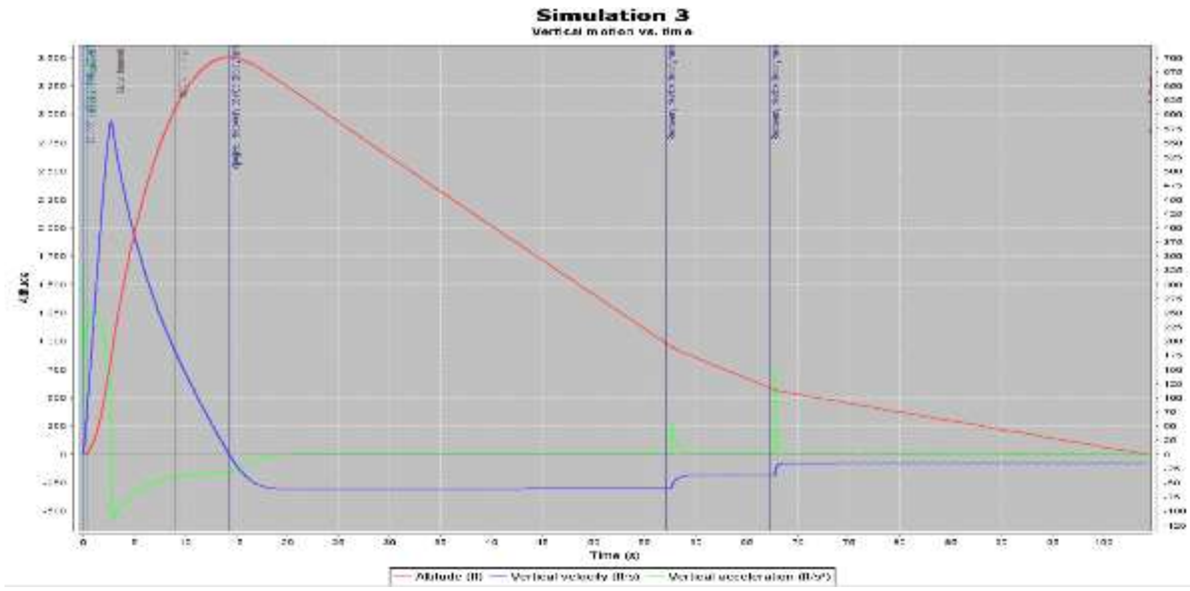


Figure 17: Altitude, Velocity, and Acceleration Plot for J355

Figure XXX shows the altitude, velocity, and acceleration plot superimposed on each other; The altitude is represented by the red line, the vertical velocity is represented by the blue line, and the acceleration is represented by the green line. The apogee is visible near the 15 second mark, with the payload event and main event occurring at 57 s and 67 s respectively. The drift time is inaccurate due to parachutes being used are not correctly modeled in simulation.

Competition Flight Simulation

Figure 18: Unfinished View of Rocket with Cesaroni J355

The fully assembled full scale rocket was weighed on a scale and yielded a measured weight of 11 pounds which meant there was a mass increase, as expected. In order to better simulate the projected flight at launch in Huntsville, mass components were attached to the rocket in the e-bay and motor sections in order to increase the total weight by 1 lb. The model was then re-simulated with a Cesaroni J355 which can be used at competition since it does not use a titanium sponge. Ignition occurs at t=0. The burnout time of the motor is 3.4s with the time to reach apogee being 15.3 s. The max velocity is simulated as Mach 0.54 at 596 ft/s with an apogee of 3973 ft and max acceleration of 249 ft/s^2 A simulated rail exit velocity of 60.9 ft/s is well over the minimum rail exit velocity of 42 ft/s. The weight of the rocket and stability margin is 11.2 lb and 2.87 cal respectively. A 22" drogue is deployed at apogee, a payload chute is deployed at 1000 feet, and a main chute is deployed at 500 feet.

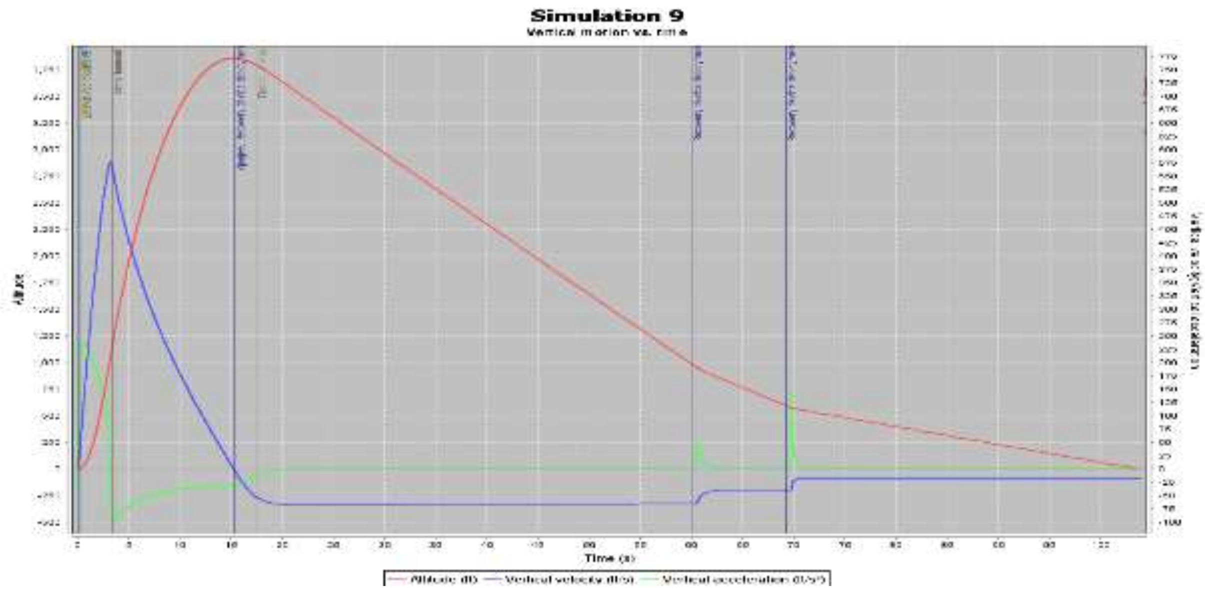


Figure 19: Altitude, Velocity, and Acceleration Plot for J355

Figure XXX shows the altitude, velocity, and acceleration plot superimposed on each other; The altitude is represented by the red line, the vertical velocity is represented by the blue line, and the acceleration is represented by the green line. The apogee is visible near the 15 second mark, with the payload event and main event occurring at 57 s and 67 s respectively. The drift time is inaccurate due to parachutes being used are not correctly modeled in simulation.

3.3.3 Thoroughness and Validity of Analysis

3.3.4 Stability Margin

The following parameters were simulated with OpenRocket to be as follows: stability margin of 2.87 Caliber, center of pressure of 65.66” from nose, and center of gravity of 54.194” from nose.

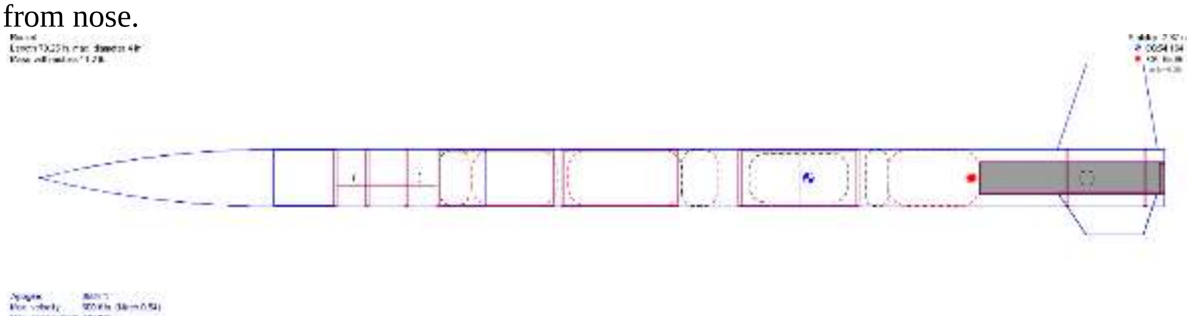


Figure 20: Side View Showing CP and CG

3.3.5 Discussion of Management of Kinetic Energy

To solve for kinetic energy first velocity needed to be found at each point where kinetic energy was to be calculated. Using a parachute calculator from rockethead.net the velocity of the drogue chute during descent was calculated both before and after payload ejection and was determined to be 41ft/s and 36ft/s respectively. The velocity of the main chute descent was calculated to be 17ft/s. The separate payload parachute descent rate was determined to be 24ft/s. The velocity off the rail was simulated to be 60.9 ft/s using Open Rocket From these velocities the kinetic energy was found at each of these points in flight. The kinetic energy during drogue descent before payload ejection was calculated to be 830.98 ft-lb. The kinetic energy during drogue descent after payload ejection was calculated to be 543.607 ft-lb. Main parachute descent energy was determined to be 53.726 ft-lb. The separate payload descent kinetic energy was calculated to be 23.503 ft-lb. Kinetic energy off the launch rail was calculated to be 1289.924 ft-lb.

Table 5: Kinetic Analysis

	Mass: slugs	Decent Rate: ft/s	Total Energy: ft*lb	Parachute Size: in.
Drogue Decent 1	0.3478	48.88	830.98	22
Drogue Decent 2	0.2813	43.96	543.607	22
Payload Decent	0.0665	18.80	23.503	30
Main Decent	0.2813	13.82	53.726	70

3.3.6 Drift Analysis

The table below shows the estimated drift calculations for the launch vehicle and payload based on a 5 degree inclination. Several wind speeds were chosen as arbitrary variables to form a linear relationship between wind speed and drift distance. Using the derivative of the line, the drift distance can be determined for any given wind speed the launch vehicle may encounter.

Table 6: Drift Data

wind speed (mph)	drift main (ft)	drift payload (ft)
0	262.466	262.466
5	255.4390053	-5.1202497
10	895.8398262	395.202315
15	1536.236247	785.2814469
20	2176.626801	1184.160779

3.4 Verification (Vehicle)

Table 7: Verification

Requirement	Satisfying Design Feature	Verification Statement
1.1.) The vehicle shall deliver the payload to an apogee altitude not exceeding that of the 3000 ft. (AGL) target altitude.	The vehicle will be propelled by a Cesaroni J-355 solid rocket grain.	The Full scale test launch (FTL) electronics recorded an estimated apogee of 2700 ft.
1.2.) The vehicle shall launch with a minimum of one officially placed altimeter to record altitude achieved during competition.	The electronics bay design includes an AIM XTRA GPS flight computer capable of recording barometric pressure. Two secondary altimeters will record altitude.	The GPS plot depicted the flight pattern of the launch vehicle, and all 3 altimeters recorded an altitude within a close proximity of each other.
1.3.) The launch vehicle shall be designed to be recoverable and reusable	All materials used in the design are made of strong composites, metal, or fiberglass to withstand any forces experienced during launch. Separate components of the vehicle are fixed together using epoxy.	The full scale launch vehicle was recovered, showing no signs of damage or fatigue. All components were considered flight worthy through close inspection.
1.4.) The launch vehicle shall have a maximum of (4) independent sections.	The vehicle design uses (3) independent sections.	An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute. By inspection, the vehicle design utilizes (3) sections to complete the mission. One section for drogue deployment, One for main chute deployment, and another for the payload.
1.5.) The vehicle shall have one stage.	The vehicle design uses only one grain for propulsion.	The propellant is a single J-355 motor.
1.6.) The launch vehicle	The design of the rocket	Full scale assembly required only 54

shall be capable of being prepared for flight at the launch site within 2 hours.	requires minimal assembly prior to launch. only requires motor insertion, charge placement, and initialize flight computer.	minute to be flight ready.
1.7.) The launch vehicle shall be able to remain on the pad in launch configuration for a minimum of 1 hour without losing functionality.	A 9V battery cell is used to power the onboard computer.	During testing the vehicle showed minimal power losses.
1.8.) The launch vehicle shall be capable of being launched by a standard 12V direct current firing system.	The J-355 motor is a commercially available motor designed to start with a standard 12V firing system.	The full scale test vehicle successfully ignited the propellant on the first attempt.
1.9.) The propulsion system used must be commercially available and use ammonium perchlorate composite propellant.	The launch vehicle is designed to use a Cesaroni J-355 motor.	The Cesaroni J-355 is commercially available.
1.10.) The total impulse shall not exceed 5120 Newton-seconds (L-class).	The J-355 has a lower impulse than an L class motor	1189.5 Ns(J-355) is less than 5120 Ns
1.12.) Pressure vessels on the vehicle must be approved by the RSO.		
1.13) All teams will launch and recover a subscale model.	A subscale test was completed and successful	An altitude of 996.4ft was achieved by the subscale launch on 2/14/2015
1.14) All teams shall successfully launch and recover their full scale rocket prior to launch.	A Full scale launch test was conducted using the assigned payload.	The full scale launch took place on 3/14/2015, reaching an estimated 2700 feet.
1.14.3) A full scale motor does not have to be used	The full scale test did not use the full scale motor.	The Cesaroni J-360 was used for the full scale test

during testing.		
1.14.4) The vehicle shall be flown in its fully ballasted configuration. (i.e the ballast that will be flown in the competition.	The full scale test was conducted using the vehicle design intended for competition.	The full scale test included all components being used in competition, including the sample payload.
1.14.5) The launch vehicle and its components may not be modified following the recovery of the test flight.	The launch vehicle design is in no need of modification.	The results of the test met the mission requirements within an acceptable range or error.
1.15.) The allowable spending budget of the rocket and Autonomous Ground Support Equipment is $5,000.		
1.16.) the launch vehicle shall not utilize the following *1.* forward canards *2.* forward firing motors *3.* Motors that expel titanium sponges. *4.* hybrid motors *5.* cluster motors	The J-355 motor does not utilize forward canards, forward firing motors, motors that expel titanium sponges, hybrid motors, or cluster motors.	Despite using the J-360 motor for testing, the J-355 meets competition requirements.
2.1) The vehicle shall stage the deployment of its recovery devices with a drogue parachute deployed at apogee and a main chute deployed at a much lower altitude.	Design of the launch vehicle implements drogue deployment at apogee, and main parachute much closer to the ground level.	design specificates drogue deployment at apogee and main parachute deployment at 500 feet AGL
2.2) Teams must perform a successful ground ejection test for both the drogue and the main chute.	A ground test was performed to check ejection for the drogue and main parachute.	The successful ground test showed successful separation and deployment.
2.3) At Landing each		

independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.		
2.4) The recovery system electronics shall be separate from that of the payload circuits.	The system electronics are independent of the payload circuits.	The system electronics are located in the electronics bay of the launch vehicle. The payload uses its own mechanism.
2.5) The recovery system shall contain redundant, commercially available altimeters.	The electronics bay contains a redundant altimeter system.	Three independent altimeters are in installed in the electronics bay. Two StratoLoggers and one AIM XTRA
2.6) A dedicated arming switch shall arm each altimeter.	A safety pin must be removed to arm the altimeters.	Testing showed no altimeter functionality when safety pin installed.
2.7)Each altimeter shall have a dedicated power supply.	4 batteries power the 3 altimeters.	The StratoLoggers are only connected to one battery each. The flight computer uses one 9V and the Li-Po battery.
2.8) Each arming switch shall be capable of being locked in the on position for launch.	Once the safety pin is removed, the arming switch remains locked till the switch is reinserted.	Testing shows the switch remains locked when the safety pin is removed.
2.9) Shear pins shall be used for the main and drogue chutes.	The main parachute uses shear pins	The design uses shear pins for main parachute deployment.
2.10) An electronic tracking device shall be installed in the launch vehicle.	The launch vehicle uses a GPS enabled flight computer. The payload uses a GPS locator device.	Testing of the flight computer shows GPS tracking data.
2.11)The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight.	Manufactures ensure the recovery system will not be affected by any onboard electronics.	Ground testing, subscale testing, and full scale testing show no signs of electrical interference.
2.11.1) The recovery system altimeters shall be	The electronics bay is located in its own	By design, the electronics bay with altimeters is located in a separate

physically located in a separate compartment within the vehicle away from radio frequency.	compartment.	compartment.
2.11.2) The recovery system electronics shall be shielded from all onboard transmitting devices.	The electronics bay housing is lined with metal ducting tape for shielding.	there is no resulting interference between devices as shown by the successful test flights.
2.11.3) The recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves.	choice of components does not present magnetic waves or interference.	testing shows compatibility between components on the launch system
2.11.4) The recovery system electronics shall be shielded from any other devices that may adversely affect the proper operation of the recovery electronics.	The electronics bay housing is lined with metal ducting tape for shielding.	testing shows compatibility between components on the launch system.
3.1.1.1 Teams will position their launch vehicle horizontally or vertically on the launch pad.	Launch vehicle will be placed horizontally on the launch pad for payload insertion.	System design and AGSE integration uses a horizontal launch vehicle for payload insertion.
3.1.1.2) A master switch will be activated to power on all autonomous procedures and subroutines.	The launch vehicle uses a safety switch to arm all systems. The AGSE utilizes a master button to initialize loading sequence.	Testing of the safety switch and master switch activate all autonomous procedures.

3.1.1.3. After the master switch is turned on and all systems are booted, a pause switch will be activated, temporarily halting all AGSE procedure and subroutines. This will	A button will be added to the rover that will begin the automation sequence upon button press.	Software is written to pause program on load. When button is pressed, the program continues.

allow the other teams at the pads to set up, and do the same.		
3.1.1.4. After setup, one judge, one launch services official, and the team will remain at the pad. During autonomous procedures, the team is not permitted to interact with their AGSE.	All features of the AGSE will not require user input.	A button press is all that is required to start program. All team members, the services official, and judge will remain on the pad once the button has been pressed.
3.1.1.5. After all nonessential personnel have evacuated, the pause switch will be deactivated.	Once setup is complete, only one person will remain at the AGSE for the button press. That member will evacuate after press.	Only one person will be needed at the AGSE after setup to press the button. Everyone else will evacuate.
3.1.1.6. Once the pause switch is deactivated, the AGSE will capture and contain the payload within the launch vehicle. If the launch vehicle is in a horizontal position, the launch platform will then be manually erected by the team to an angle of 5 degrees off vertical, pointed away from the spectators. The launch services official may re-enable the pause switch at any time at his/her discretion for safety concerns.	On button press, the rover will use computer vision to capture and contain the payload.	Once the button has been pressed, the rover captures the payload using a mechanical arm.
3.1.1.7. After the erection of the launch vehicle, a team member will arm recovery electronics.	The launch vehicle will only require one person to arm recovery electronics.	Before launching the rocket, the recovery system only requires one person to switch the electronics on.
3.1.1.8. The igniter is manually installed and the area is evacuated.	The igniter will be installed manually, with the evacuation of the area following after	Verified by launch procedures

3.1.1.9. Once the launch services official has inspected the launch vehicle and declares that the system is eligible for launch, he/she will activate a master arming switch to enable ignition procedures.		Verified by launch procedures
3.1.1.10. The Launch Control Officer (LCO) will activate a hard switch, and then provide a 5-second countdown.		Verified by launch procedures
3.1.1.11. At the end of the countdown, the LCO will push the final launch button, initiating launch.		verified by launch procedures
3.1.1.12. The rocket will launch as designed and jettison the payload at 1,000 feet AGL during descent.	design of the rocket and launch system provides a payload jettison at 1000 feet AGL during descent.	Full scale test jettisoned payload at 1000 feet AGL.
3.1.2.The Autonomous Ground Support Equipment (AGSE)		
3.1.2.1. For the purpose of this challenge, ASGE is defined as all mechanical and electrical components not part of the launch vehicle, and is provided by the teams. Components may include the payload containment device, computers, batteries, etc.	The only external parts to the rocket are contained on the rover as the payload retrieval vehicle.	The rover is used for obtaining and depositing the payload into the rocket. Because the rover is the only external component to the launch vehicle, it is the AGSE.
3.1.2.2. The payload containment system shall be fully autonomous with no human intervention.	No human interaction will be needed for the rover to complete the payload containment task.	All software was written to ensure that no human intervention was necessary.

3.1.2.3. Any pressure vessel used in the AGSE will follow all regulations set by requirement 1.12 in the	No pressure vessels will be used in the AGSE.	No pressure vessels were necessary in the creation of the AGSE.
3.1.3.1. As one of the goals of this competition is to develop equipment, processes, and technologies that could be implemented in a Martian environment, the AGSE and any related technology cannot employ processes that would not work in such environments. Therefore, prohibited technologies include: Sensors that rely on Earth's magnetic field, Ultrasonic or other sound-based sensors, Earth-based or Earth orbit-based radio aids (e.g. GPS, VOR, cell phone), Open circuit pneumatics, Air breathing systems	No sensors that rely on earth specific properties will be used on the rover.	Computer vision and pressure switches help guide the AGSE.
3.1.4.1. Each launch vehicle must have the space to contain a cylindrical payload approximately 3/4 inch in diameter and 4.75 inches in length. The payload will be made of ¾ x 3 inch PVC tubing filled with sand and weighing approximately 4 oz., and capped with domed PVC end caps. Each launch vehicle must be able to seal the payload containment area autonomously prior to	The launch vehicle will contain a door on the side that will later eject as the containment vessel with appropriate dimensions for the payload compartment.	The payload containment area is just the right size to house the payload. It closes when an object is placed on a string between the door and the side of the launch vehicle, which closes the door and locks using a magnet.

launch.		
3.1.4.2. Teams may construct their own payload according to the above specifications, however, each team will be required to use a regulation payload provided to them on launch day.	The AGSE will be capable of obtaining an object of the regulated properties, while the containment vessel will have a compartment with the appropriate shape and size.	The AGSE is built to rely on the white color of the PVC payload with the specified dimensions. The containment vessel has exactly the correct dimensions to be able to collect the payload and seal itself.
3.1.4.3. The payload will not contain any hooks or other means to grab it. A diagram of the payload and a sample payload will be provided to each team at time of acceptance into the competition.	The payload will be a PVC pipe filled with sand and of the dimensions: 3/4 inch in diameter and 4.75 inches in length	The payload is of the specified dimensions with no hooks or other means of grabbing it..
3.1.4.4. The payload may be placed anywhere in the launch area for insertion, as long as it is outside the mold line of the launch vehicle when placed in the horizontal or vertical position on the AGSE.	The AGSE will not rely on the payload being placed in any particular location, especially not within the mold line of the rover.	Using computer vision software, the rover locates the payload without the expectation for it to be placed nearby.
3.1.4.5. The payload container must utilize a parachute for recovery and contain a GPS or radio locator.	There will be a parachute and a GPS installed in the payload container.	A parachute has been rigged to deploy after ejection from the launch vehicle. A GPS is installed to help with recovery.
3.1.5.1. Each team must provide the following switches and indicators for their AGSE to be used by the LCO/RSO.		
3.1.5.1.1. A master switch to power all parts of the AGSE. The switch must be easily accessible and hardwired to the AGSE.	An easily visible and accessible power switch will be added to kill power at any time.	A large power switch has been added for quick power cutoff.

3.1.5.1.2. A pause switch to temporarily terminate all actions performed by AGSE. The switch must be easily accessible and hardwired to the AGSE.	A power kill switch will be added to temporarily terminate all actions.	The power kill switch was added to stop all actions of the AGSE. To restart actions, the rover must be restarted.
3.1.5.1.3. A safety light that indicates that the AGSE power is turned on. The light must be amber/orange in color. It will flash at a frequency of 1 Hz when the AGSE is powered on, and will be solid in color when the AGSE is paused while power is still supplied.	An Orange LED will be added within the rover circuitry to specify power and/or paused.	An LED was added to ensure that we are aware when power is supplied to the rover and when the program is in a paused state.
4.1. Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and launch day operations.		
4.2. For all academic institution teams, a student safety officer shall be identified, and shall be responsible for all items in section 4.3.	A safety office has been appointed by the team.	Diego Ospina is the safety officer
4.3.1.Monitor team activities with an emphasis on Safety during:		
4.3.1.1. Design of vehicle and launcher	Safety officer present during design.	Diego Ospina was present for design
4.3.1.2. Construction of vehicle and launcher	Safety officer present during construction.	Diego Ospina was present for construction
4.3.1.3. Assembly of vehicle and launcher	Safety officer present during assembly	Diego Ospina was present for assembly

4.3.1.4. Ground testing of vehicle and launcher	Safety officer present during ground testing	Diego Ospina was present for ground testing
4.3.1.5. Sub-scale launch test(s)	Safety officer present during subscale test	Diego Ospina was present for subscale test
4.3.1.6. Full-scale launch test(s)	Safety officer present during full scale test	Diego Ospina was present for full scale test
4.3.1.7. Competition launch	Safety officer will be present during competition launch	Diego Ospina will be present for competition launch
4.3.1.8. Recovery activities	Safety officer will be present during recovery	Diego Ospina will be present for recovery
4.3.1.9. Educational Engagement activities	the team engaged in educational activities	participated in STEM day
4.3.2.Implement procedures developed by the team for construction, assembly, launch, and recovery activities.		
4.3.3.Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.		
4.3.4.Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.		
4.4. Each team shall identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the	Gary Dahlke was identified as the team mentor for this project.	Gary Dahlke has agreed to be the team mentor. He carries both TRA and NAR level 3 certification.

school, institution, or organization. The mentor shall be certified by the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to the launch at the competition launch site. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.		
4.5. During test flights, teams shall abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch and/or Centennial Challenges competition launch does not give explicit or implicit authority for teams to fly those certain	All test flights abided by the rules and regulations of the local rocketry club launch site.	The RSO at the local rocketry launch site approved our vehicle for range launch for both subscale and full scale test launches.

vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.		
4.6. Teams shall abide by all rules and regulations set forth by the FAA.	All rules set by the FAA have been followed by the team	By complying with the launch site rules, the FAA rules were met jointly.
5.1. Team members (students if the team is from an academic institution) shall do 100% of the project, including design, construction, written reports, presentations, and flight preparation. The one exception deals with the handling of black powder, ejection charges, and installing electric matches. These tasks shall be performed by the team's mentor, regardless if the team is from an academic institution or not.	Team mentor has been present for handling of black powder ejection charges and installation of electric matches.	
5.2. The team shall provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations.		
5.3. Each team shall successfully complete		

and pass a review in order to move onto the next phase of the competition.		
5.4. Foreign National (FN) team members shall be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities. If participating in the Maxi-MAV, less than 50% of the team make-up may be foreign nationals.	Foreign National team members will not attend restricted activities during launch week.	No Foreign Nationals are on the competition team or attending launch week.
5.5. The team shall identify all team members attending launch week activities by the Critical Design Review (CDR). Team members shall include:		
5.5.1.For academic institutions, students actively engaged in the project throughout the entirety of the project lifespan and currently enrolled in the proposing institution.	All members are currently enrolled at the University of Central Florida.	This club sponsored project requires team members to be club members. the club is only available to actively enrolled students.
5.5.2.For non-academic teams, participants actively engaged in the project who will remain affiliated with the team for the entirety of the project lifespan. The Team Lead, Team Mentor, and team Safety Officer shall be noted on the team roster. Team members may hold multiple positions.	Does not apply	Does not apply

5.5.3.One mentor (see requirement 4.4).	one mentor for the team	Gary Dahlke will be the mentor
5.5.4.No more than two adult educators per academic team.	one educator for the team	Dr. Justin Karl will be the adult educator
5.6. The team shall engage a minimum of 200 participants (at least 100 of those shall be middle school students or educators) in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement form, by FRR. An educational engagement form shall be completed and submitted within two weeks after completion of each event. A sample of the educational engagement form can be found on page 45 of the handbook.	At least 200 students will be engaged during a STEM related workshop and an educational engagement form will be submitted.	An educational engagement form was submitted after participating in a STEM day hosted by the University of Central Florida. Nearly 2,000 students attended the event.
5.7. The team shall develop and host a Website for project documentation.	the team acquired and maintained a website.	http://sedsucfstudentlaunch.weebly.com/team-members.html
5.8. Teams shall post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.	website contains all required deliverables, available for download.	direct link: http://sedsucfstudentlaunch.weebly.com/competition-reports.html
5.9. All deliverables must be in PDF format.	all deliverables are available in PDF format.	download link http://sedsucfstudentlaunch.weebly.com/competition-reports.html
5.10. In every report, teams shall provide a	Each report adhered to the report guidelines	Each report contains a table of contents with major sections and respective sub

table of contents including major sections and their respective sub-sections.		sections.
5.11. In every report, the team shall include the page number at the bottom of the page.	Each report adhered to the report guidelines	Each report contains the page number at the bottom of the page.
5.12. The team shall provide any computer equipment necessary to perform a video teleconference with the review board. This includes, but not limited to, computer system, video camera, speaker telephone, and a broadband Internet connection. If possible, the team shall refrain from use of cellular phones as a means of speakerphone capability.	Each report has provided the necessary equipment for a video teleconference with the review board members.	The PDR and CDR presentation had working sound and video for the review board members,
5.13. Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (http://www.section508.gov): 1194.21 Software applications and operating systems. 1194.22 Web-based intranet and Internet information and applications.	All standards will be met	Based on all standards listed, all were implemented successfully.

3.5 Safety and Environment (Vehicle)

3.5.1 Safety and Mission Assurance Analysis

Please reference section 3.1.7

SAFETY CHECKLIST

In order to assure a safe and successful launch, a checklist was composed to ensure the preparation and launch was followed accordingly in congruence with the safety guidelines. The following safety procedures must be followed during preparation before moving the vehicle to its final destination in order to reduce personal hazards.

- Safety glasses must be worn at all times when dealing with rocket parts containing small hardware and pyrotechnic charges.
- Never look down the rocket tube with live pyrotechnic charges in place.
- Point rocket and pyrotechnic charges away from people and body.
- Avoid live electrical contacts that could accidently set off charges this include: radios, cell phones, etc.)
- If humid make sure to ground yourself before touching any metal or live rocket pyrotechnics.
- Never arm electronics unless vehicle is at pad and a clear area has been cleared. Furthermore, make sure everyone knows pyrotechnic continuity checks are being done.
- Always follow NAR/TRA safety codes.
- Follow all applicable local, state, and national laws as well as regulations applicable to the previous mentioned.
- No smoking or open flames are allowed within 25 feet of proximity of rocket motor and pyrotechnics.
- If any outstanding technical issues arrive, do not proceed with launch without consulting both the safety officer and NASA officials if needed.
- Verify that ignition leads are not live before connecting igniter to ground control (simple check is to touch leads and check for spark, sound or place against tongue)
- Verify rocket will exit launch pad with no obstruction on rail.
- Verify rocket launch pad surrounding ground area is clear of any flammable materials.
- Make sure the guidelines within the checklist are followed thoroughly to assure a safe working environment and mission success.

3.9.4 SAFETY CODES

Tripoli Rocketry Association and the National Association of Rocketry have adopted NFPA 1127 as their safety code guidelines for all high power rocket operations. All members involved in the project should have general knowledge of codes and guidelines. The codes will be available in the Appendix of document.

3.5.2 Personnel Hazards

Before as well as during the manufacturing of each component of the rocket, safety guidelines covering all aspects of accidental avoidance and hazardous material handling will be briefed and discussed among everyone involved.

- General
  - Always ensure to ask the safety instructor if unsure of the following:
    - Tools
    - Equipment
    - Materials
    - Chemicals
    - Procedures
    - Any other concerns
  - Be aware and cognitive of your surroundings and equipment handling.
    - Make sure to point out safety concerns
    - Review safety guidelines and procedures before beginning any manufacturing of rocket
  - Safety attire/equipment
    - Closed toe shoes will be worn at all times during manufacturing
    - Safety glasses will be worn when directed
    - Long hair should be tied back and away from any open flames, or safety concerns
    - Proper clothing should be worn
- Equipment and Tools.
  - Risks of operation
    - Cuts
    - Personal injury
    - Burns
  - Risk mitigation
    - Proper clothing should be worn accordingly to procedure.
    - Appropriate safety equipment should be used accordingly
    - Understanding of task and procedure before beginning
    - Long hair should be tied back and away from open flames.
- Chemicals
  - Risks of Chemical handling
    - Irritation to skin, eyes, and respiratory system from contact and/ or accidental inhalation of hazardous fumes
    - Secondary exposure
    - Lab Contamination
  - Risk mitigation
    - Identify chemical to be used and circumstances of use.
    - Consult an up to-date MSDS for chemicals being used
    - Evaluate type of toxicity of chemicals
    - Consider possible routes of entry
    - Select appropriate procedure to minimize exposure by wearing appropriate safety equipment
    - Prepare for contingencies
- Composites Safety
  - Epoxy, carbon fiber, fiberglass, and other composite materials used during building of the rocket
  - All team members will be briefed in usage of composite materials

- Safety concerns
    - Splinters
    - Respiratory irritation
    - Eye irritation
    - Secondary exposure
- Risk mitigation
    - Gloves should be worn at all times during handling of pre-cured composites
    - Goggles/safety glasses should be worn when working with composites
    - Facemask should be worn during sanding, cutting and grinding
    - Lab has been assure to meet with required guidelines when using
    - Puncture-resistant gloves must be worn when handling post-cured composites

- Chemicals
    - Risks of Chemical handling
        - Irritation to skin, eyes, and respiratory system from contact and/ or accidental inhalation of hazardous fumes
        - Secondary exposure
        - Lab Contamination
    - Risk mitigation
        - Identify chemical to be used and circumstances of use
        - Consult an up to-date MSDS for chemicals being used
        - Evaluate type of toxicity of chemicals
        - Consider possible routes of entry
        - Select appropriate procedure to minimize exposure by wearing appropriate safety equipment
        - Prepare for contingencies
- Composites Safety
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    - All team members will be briefed in usage of composite materials
    - Safety concerns
        - Splinters
        - Respiratory irritation
        - Eye irritation
        - Secondary exposure
    - Risk mitigation
        - Gloves should be worn at all times during handling of pre-cured composites
        - Goggles/safety glasses should be worn when working with composites
        - Facemask should be worn during sanding, cutting and grinding
        - Lab has been assure to meet with required guidelines when using
        - Puncture-resistant gloves must be worn when handling post-cured composites

3.5.3 Environmental Concerns

- All waste materials will be disposed of using proper trash receptacles.
- Solid Rocket motor will be disposed accordingly in coherence with the manufacturers guidelines.
- Biodegradable and flame resistant recovery wadding will be used.
- Waste receptacles will be available for quick disposing of waste around prep area to encourage a clean environment.
- A checklist of prep materials will ensure no waste is left behind after mission launch.
- Hazardous materials that could possibly be introduced into the environment.
    - Carbon Fiber composite
    - Aeropoxy 2032 Epoxy Resin
    - Aeropoxy 3660 Hardener
    - Ammonium Perchlorate Composite Propellant
    - Black Powder

3.6 AGSE Integration

3.6.1 Describe the Integration of the AGSE into the Launch Vehicle

The AGSE mission plan consist of three basic stage for integration into the launch vehicle. The first stage utilizes the navigation camera to identify the payload. If necessary the AGSE will adjust its position depending on where the camera determines the location of the payload. The second stage of the integration process is the retrieval of the payload with the rover arm. The claw arm mechanism will grab the payload after determining it is in position to do so. If there is not a successful retrieval, the arm and rover may adjust. The final stage of the integration process is the insertion of the payload into the payload compartment of the launch vehicle. The claw arm will drop the payload into the payload compartment and allow it to fall into place. Upon completion of the integration process, the payload door will shut and the launch vehicle will be ready for the launch sequence.

3.6.2 Compatibility

1. **AGSE Rover and AGSE Rover Arm**

    The rover arm will be placed on top of the main body of the rover. It will be mounted directly in the center of the rover body, which would be half of the distance between the wheels. The reason for locating the arm directly in the center is because of the view from the camera. It makes the programming simpler if we don't need to off-set for the position of the arm relative to the camera, because the camera will be aligned with the arm. The rover arm will be mounted near the edge and there will be a little grove for the arm to be able to go down farther than the normal edge of the rover body if necessary. The communication of the arm is done from the main motherboard of the rover through the wiring. The computer controls the arm movements, using servos.

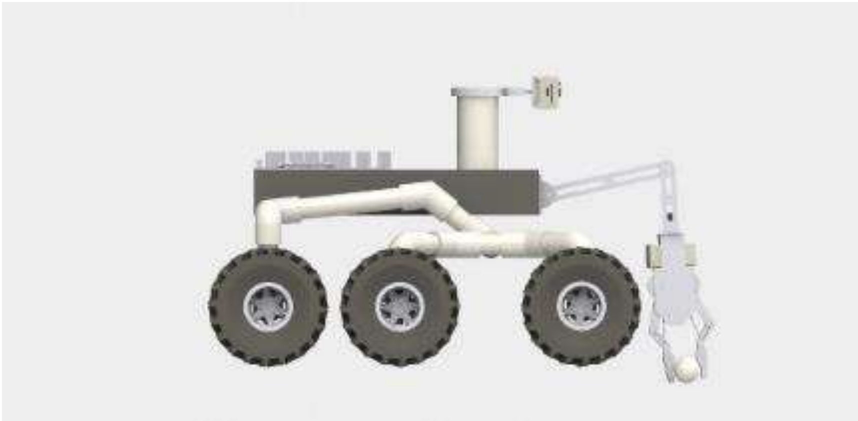

Figure 21: AGSE Side View

2. AGSE Rover Arm and Payload

The rover arm picks up the payload with its claw. The claw will have a supplemental cushion surrounding the inside of both claws so that when picking up the payload it will be squeezed tightly and won't be able to slide out one end or the other if the claw is at an angle.

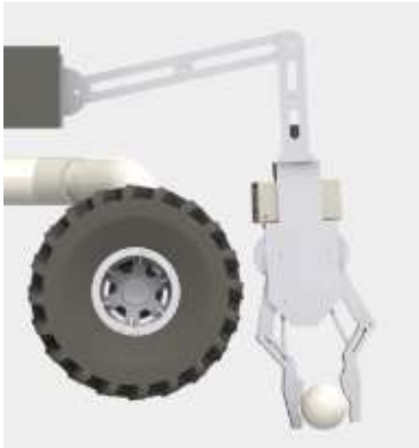

Figure 22: AGSE Robotic Arm

3. AGSE Rover and the Launch Vehicle

The rover will be detecting the side of the rocket using the camera mounted on the center of the front of the body of the rover. The program will detect two pink dots on the side of the rocket and move according to the location and distance between them. As the rover gets closer to the rocket the distance between the two pink dots will get bigger, therefore at a certain point the program will have a set width that it will read as a stopping point. The rover will pick up the payload with its claws and then move closer to the payload door, with the two pink dots on each side, centering itself in between the dots as it goes. Once the rover is at its set distance it will stop and start lowering the arm to a certain point and then drop the payload into the payload bay.

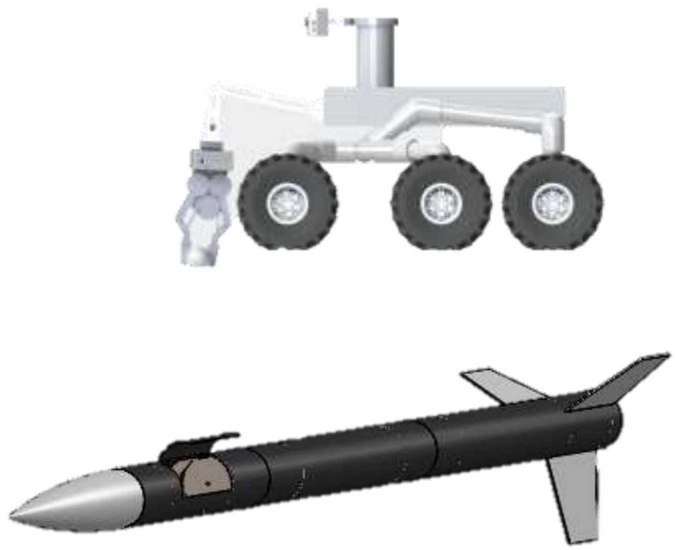

Figure 23: Rover and Lunch Vehicle

4. Rover arm and the payload compartment

After retrieving the payload from outside the mold line, the AGSE Rover will deliver it to the payload compartment of the rocket. The payload compartment door will have a pink colored spot on the inside of the door, exposing it to the outside when opened. The AGSE will use its cameras and software protocols to find the pink color on the payload compartment door. When no color is detected, a secondary protocol allows for AGSE adjustment to reanalyze a different field of vision until the color has been detected.

Upon detection, the AGSE rover will move into position so the rover arm is above the payload compartment door. When the rover determines the arm is in position over the payload compartment, the rover will release the payload and allow it to fall into place.

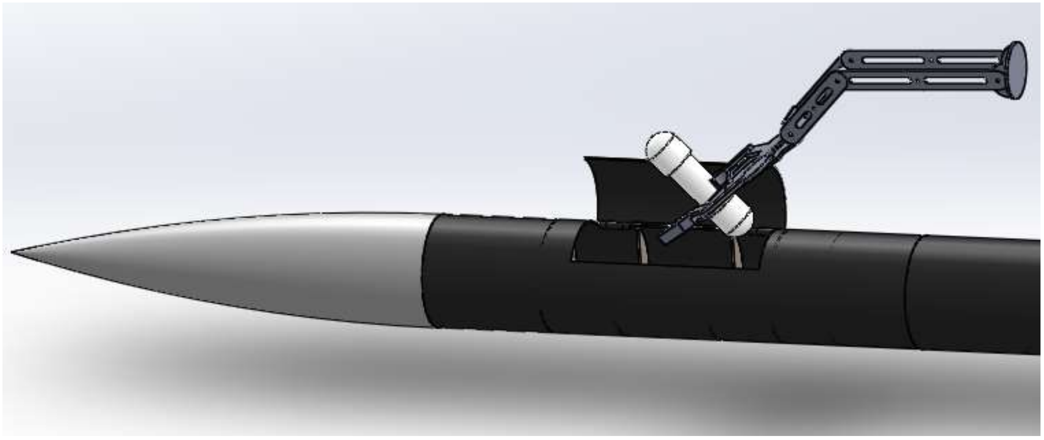

Figure 24: Payload Compartment and Robotic Arm

5. Payload Compartment and Payload Door

The payload compartment is designed to have a platform to help secure the payload during the launch and descent sequence. Centering rings support the internal platform as well as provide structural support for the section of body tubing that was cut. This design allows a degree of control as to where the payload will be placed after AGSE insertion. The payload will rest parallel to the launch vehicle.

The payload compartment door will contain multiple strings as the method of closing. The strings will be secured to the inside of the door and run loosely over the platform that houses the payload. When the payload falls into place, the force of the payload puts the strings into tension thus pulling the hinged door down. The strings are only required to pull the door 45 degrees, where gravity takes over and allows the door to fall into place. At 170 degrees the door experiences a magnetic attraction due to the magnetic door latch. The magnets on the compartment door will connect to the magnets on the inside of the payload compartment to secure the door closed.

Figure 25: Payload Compartment and Door

Figure 26: Actual View of Compartment Door

6. Payload Section and Launch Vehicle

The payload compartment will be housed in the upmost stage of the rocket. The elements included in the payload section will be the: nosecone, payload compartment, payload door, payload, parachute, and locator. During the mission, the entire payload section will be responsible for protecting the payload during the launch sequence and delivering the payload back to the surface. Upon re-entry at 1000 feet, the payload section will be jettisoned from the launch vehicle.

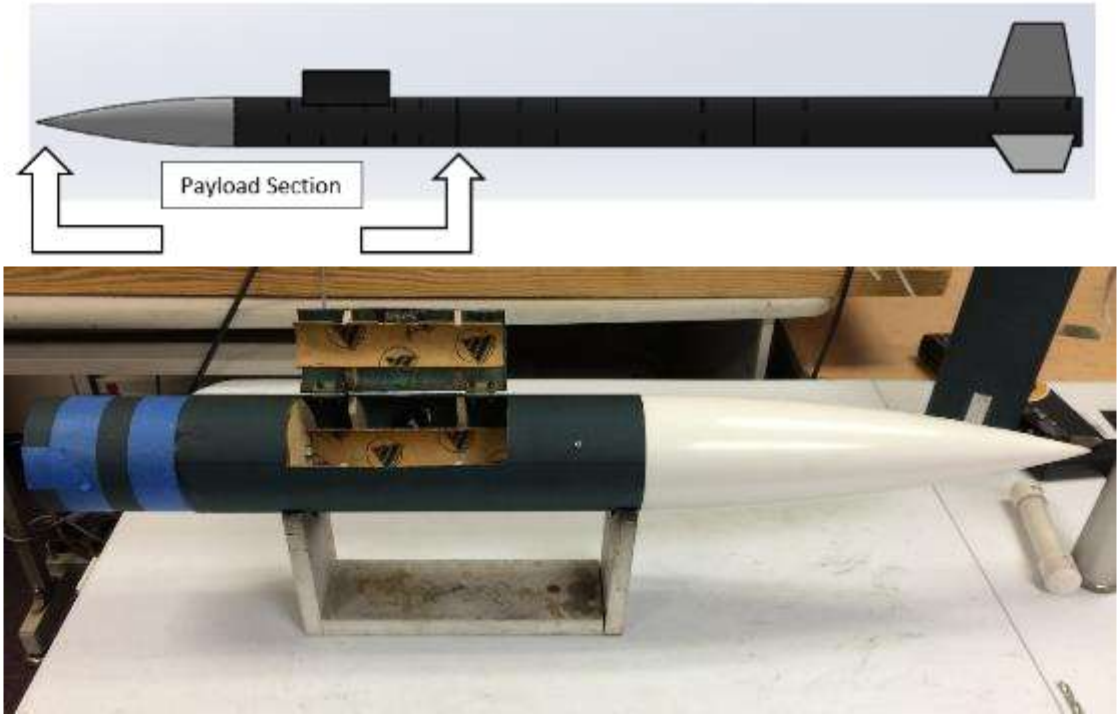

Figure 27: Payload Section

3.6.3 Describe and justify the payload housing integrity.

The design of the payload compartment has an access door cut into the side of the body tube of the launch vehicle. To ensure minimal structural losses, only one fourth of the diameter was cut out for the door. Centering rings are incorporated into this compartment to provide extra structural support to this section as well as support the payload platform. The successful launch of the subscale and full scale launch vehicle shows the payload section did not suffer from losses in structural integrity and could support all forces experienced during the launch and descent sequence. The magnetic latch on the compartment door uses Neodymium Magnets with a 4lb rating. Both the subscale and full scale test launch proved the latch and door does not exceed this force and the payload door remained closed with the payload inside.

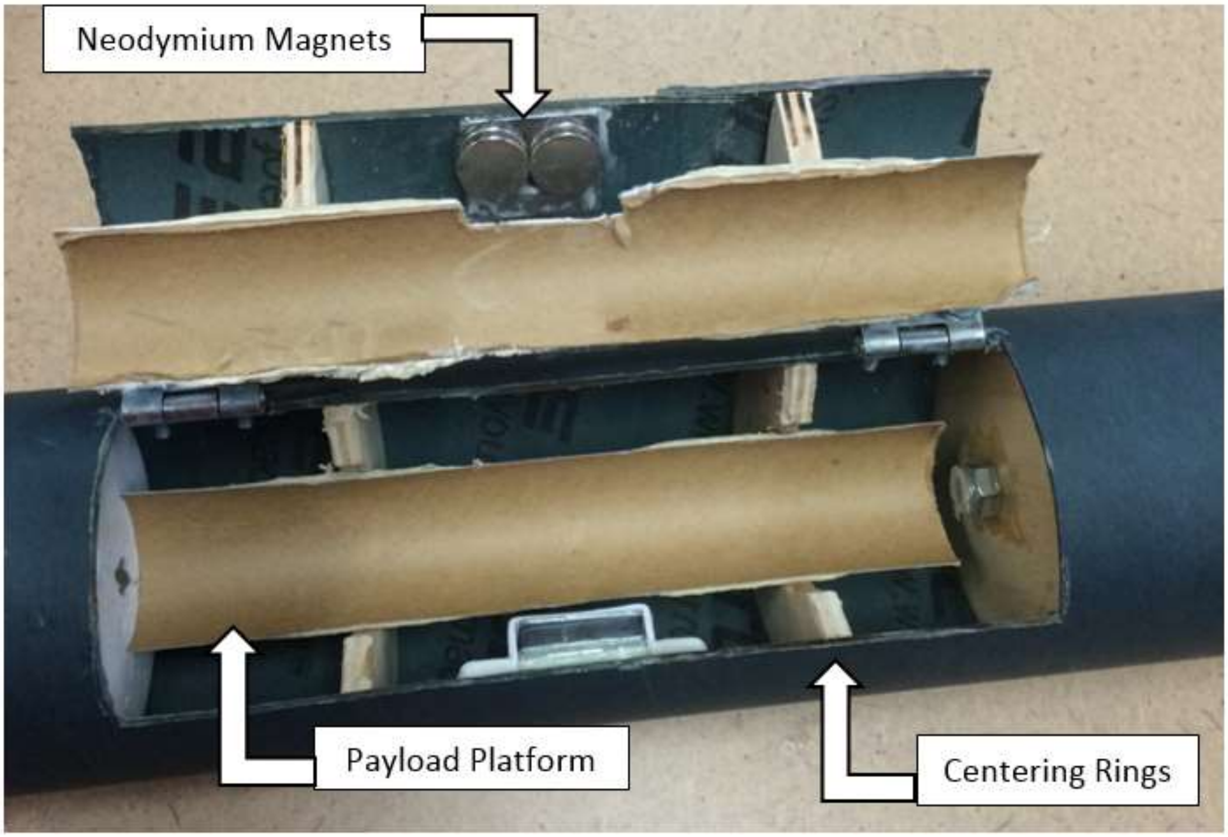

Figure 28: Payload Housing

3.6.4 Demonstrate Integration

Launch Vehicle:

The launch vehicle will consist of 3 main sections; the payload section, electronics bay, and motor tube. The payload section will have a shoulder on the rear, allowing for insertion into the top of the electronics bay. A coupler will separate the rear of the electronics bay from the motor tube to prevent any damage to the vital electronics by the motor. This couple will allow for the electronics bay to conjoin with the motor tube. The stages of separation will follow: drogue parachute at apogee, payload and payload parachute at 1000 feet, and main parachute at 500 feet.

Payload Section:

The Payload Section is broken down into 3 components: the Nosecone, the Payload Compartmnet, and the Parachute Compartmnet. The Nosecone will house the electronics for flight/ post flight location. The shoulder of the nosecone will be secured with screws to the body tube of the payload compartment.

The payload compartment will house the required payload for the flight mission. The paylaod will rest ontop a cardboard platform, which will be epoxied to a set of centering rings. The platform will provide extra support to the payload during the flight and descent sequence. The centering rings will be epoxied to the body tube of the compartment. Aluminum hinges will hold the payload door to the structure of the launch payload section using bolts and nuts. Neodyminum magnets will be epoxied to the inside of the payload door and will connect to the magnet which is expoxied inside the payload compartment.

Figure 29: Rocket Compartments

The parachute compartment will be separated from the payload compartment with a wooden bulkhead. The bulkhead will be epoxied to the body tube of the payload section to ensure it withstands any forces. At the center of the bulkhead, an attachment bolt will be utilized to connect the shock cord and shroud lines of the parachute.

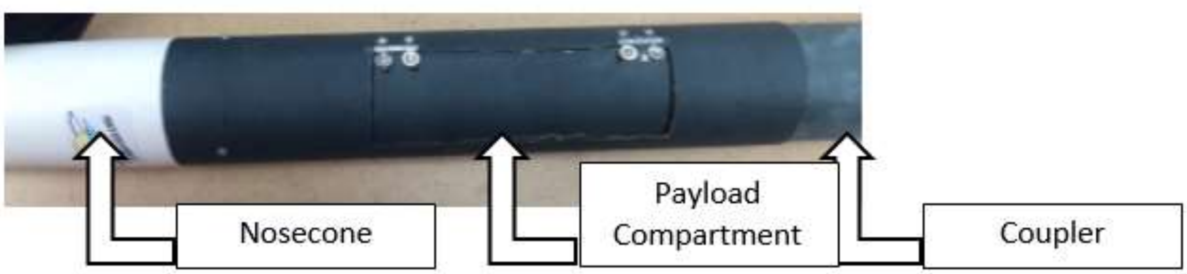

Figure 30: Rocket Sections

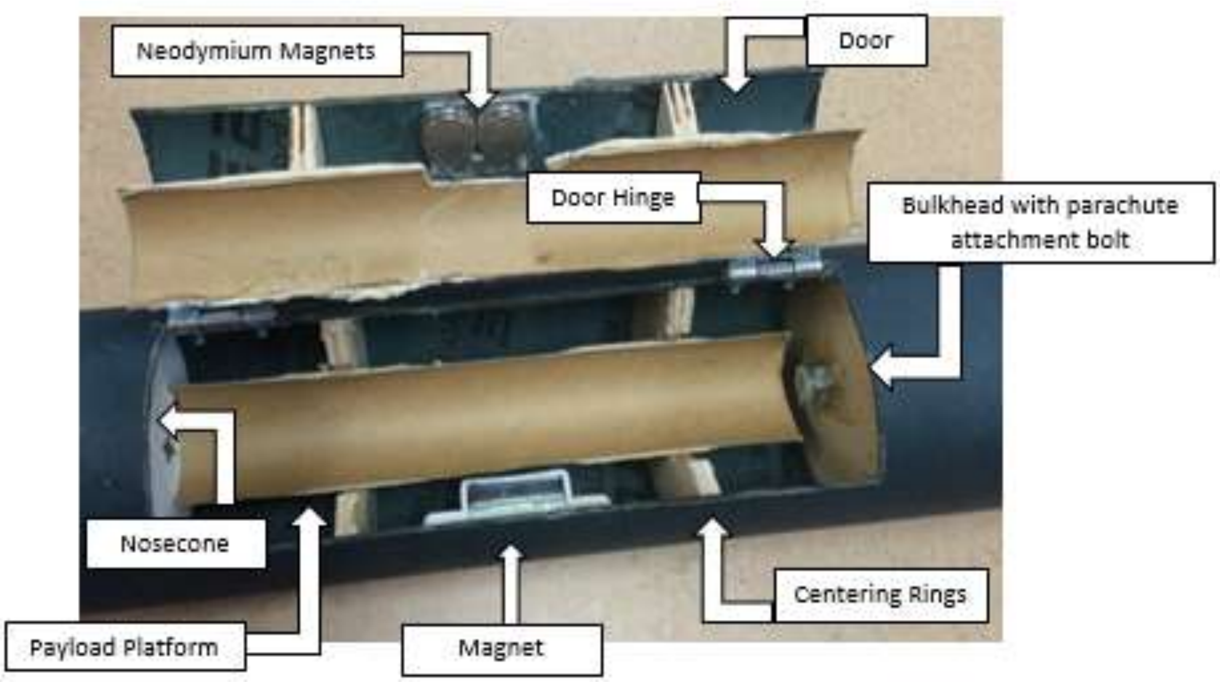

Figure 31: Payload containment vessel

Electronics Bay:

One Aim XTRA GPS flight comptuter will be used in conjunction with two Stratologgers to ensure the deployment of all parachutes and have redundency in the event of malfunction. The electronics bay will have a toggle switch which will be used to arm and disarm the flight computers to prevent any misfires before launch and conserve the battery packs. The electronics will all be mounted to a centering sled structure to allow for ease of access to the components.

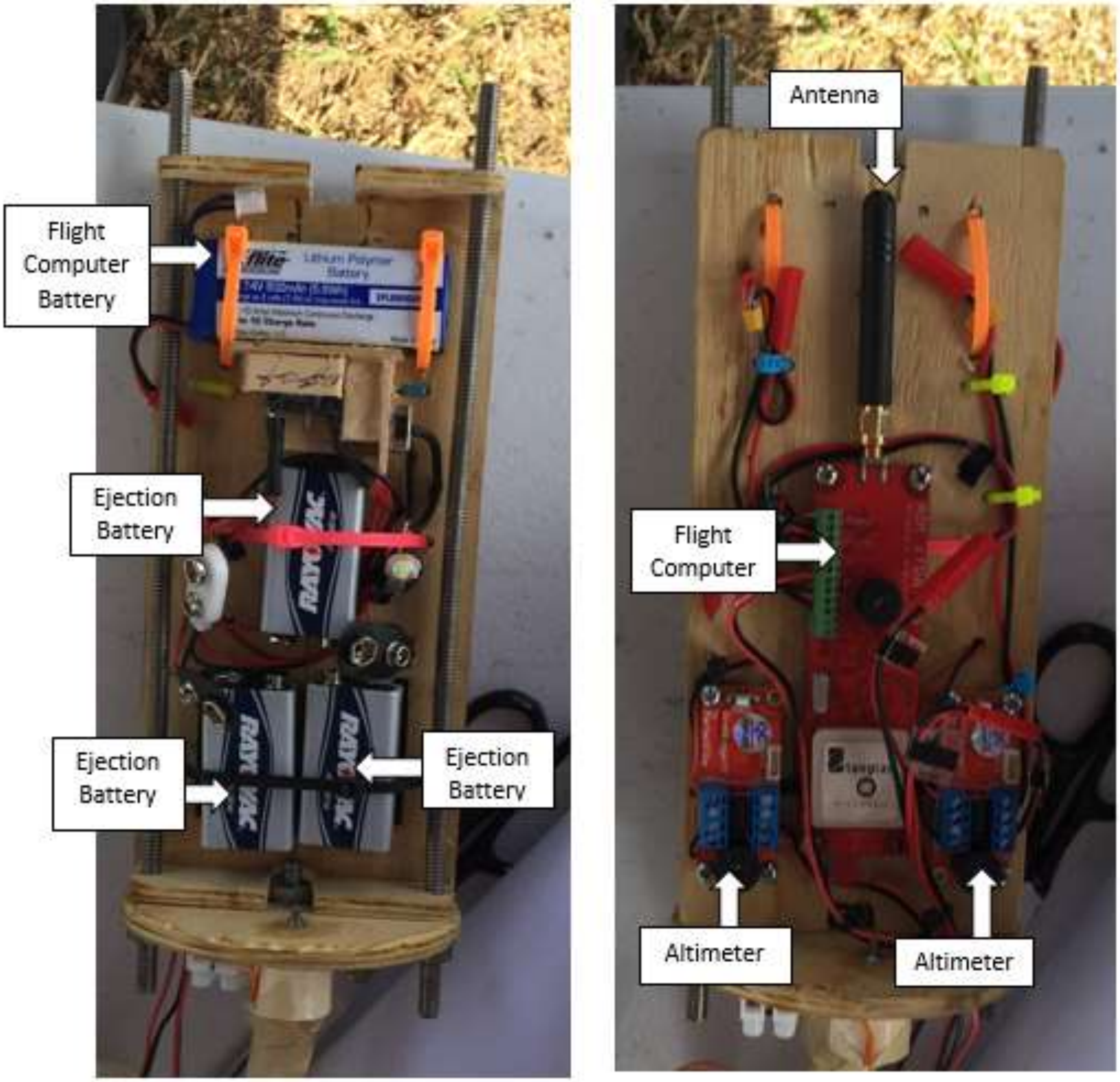

Figure 32: Rocket Electronics Bay

Motor Tube:

The motor tube of the launch vehicle will contain the: motor case, centering rings, and the fins. The fins will be attached with epoxy and epoxy putty. These will provide stabilization to the launch vehicle during flight. The centering rings will be accached with epoxy and JB weld. These centering rings will ensure the motor case is installed as close to the center of the launch vehicle as possible, providing an even thurst distribution.

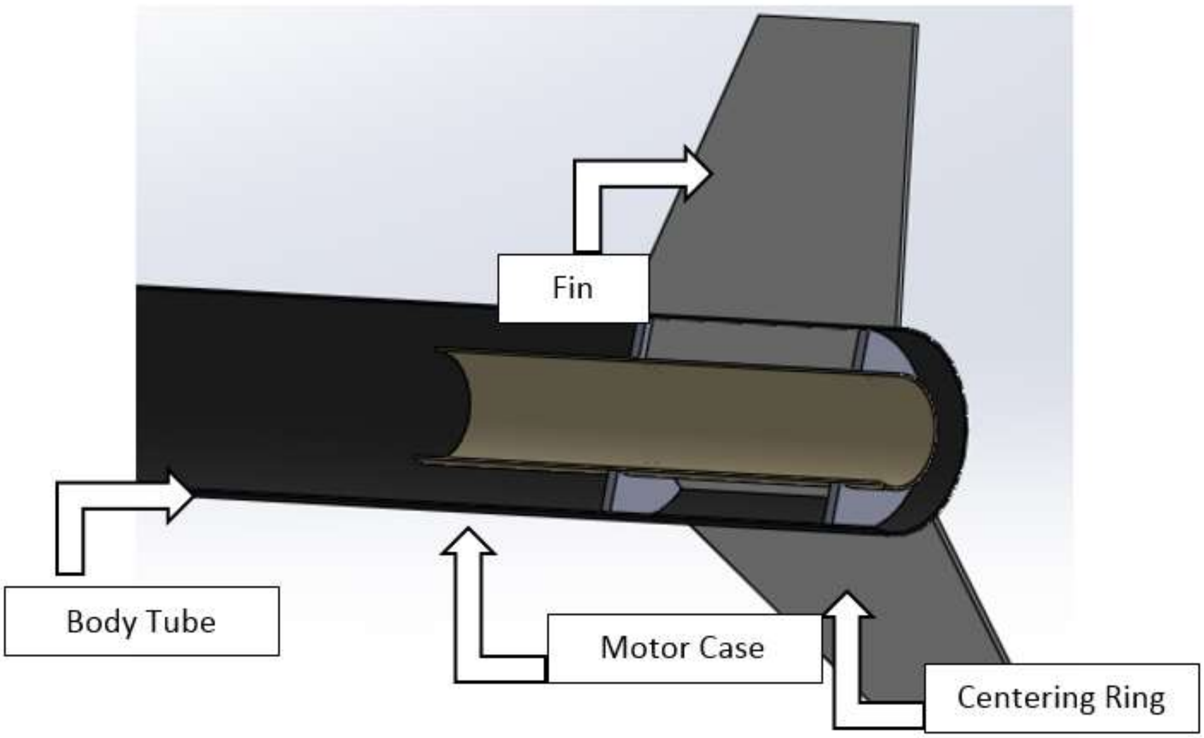

Figure 33: Rocket Parts

IV AGSE/ Payload Criteria

4.1 EXPERIMENT CONCEPT

Our rover will be testing the viability of using computer vision to guide a vehicle with no human interaction. By understanding the environment of the rover ahead of time, we can use that knowledge to achieve a goal. In this particular scenario, we know the color of the surroundings, as well as our payload. Using this information, we can guide a rover to steer toward the color of the payload, and then toward predefined color markers on the rocket.

Computer vision is extremely useful for guiding rovers. Without having some functionality based on sensors and computer vision, it can be nearly impossible to achieve specific tasks as it can take minutes or hours to send individual instructions from Earth to the remote location of a rover or probe.

4.1.1 Creativity and Originality

The AGSE was created based on the wide variety of perspectives within our team. Having members with various backgrounds including computer science, electrical, mechanical, and aerospace engineering allowed us to approach the challenge with fewer limitations than a team with focus on only one field of engineering.

The rover itself is constructed using materials that were readily available to our team. Using resources available at the University of Central Florida, we were able to laser cut acrylic and print 3D models into the ideal forms to suit the needs of each individual part. This enabled us to be creative with the structure of the rover.

The suspension system is entirely made using standard PVC pipes, keeping the structure inexpensive, strong, and lightweight. Our design is for the suspension is loosely based on the Rocker-Bogie system developed by NASA engineers. It is a simplistic system that can easily be manufactured without the need for extra springs, mechanical parts that require electronic control systems.

4.1.2 Uniqueness and Significance

The AGSE's significance lies in its versatility. The Successful deployment of the AGSE will prove the viability of the Rover's design in actual NASA Missions. The claw-arm Mechanism is a versatile tool that could be implemented in numerous varied missions. The Success of this mission is just the first step toward a multipurpose rover for interplanetary exploration.

The method of navigation is unique as it does not rely on knowing exactly where the payload is ahead of time. Using color tracking, the rover is guided toward colors that it recognizes as the payload as well as markers on the rocket.

4.2 SCIENCE VALUE

4.2.1 AGSE / Payload Objective

The Autonomous Ground Support Equipment (AGSE) is an autonomous rover to be constructed with the objective of designing it to simulate a scenario that could be used by NASA on a foreign planet. This AGSE is designed to be scaled up and modified to be used for multiple scenarios.

The University of Central Florida's AGSE is a rover that will autonomously find, collect and displace a payload. The mission is to develop equipment, processes, and technologies for the rover that could be implemented in a Martian environment. The rover will employ two webcams that will serve as the major sensors for collecting digital imagery information and aiding in rover navigation.

4.2.2 State the Mission Success Criteria

- AGSE: defined as all mechanical and electrical components not part of the launch vehicle, is provided by the student launch teams.
- Payload containment system is fully autonomous with no human intervention.
- Payload capture system is fully autonomous.
- Rover navigation is completely autonomous.
- Any AGSE component will not employ any process that would not function properly in a Martian environment.

The Success of this rover is dependent on the successful utilization of all of its components. The rover will utilize two separate cameras. One of the cameras will be mounted on the claw for payload detection and navigation, while the other will be mounted on the body of the chassis for navigation once the payload has been collected. The cameras will detect the payload by searching for color. When the claw camera detects the payload it will then initiate our collection protocol to retrieve the payload. After retrieving the payload, the rover will use its chassis navigation camera to locate the rockets loading bay with the aid of bright colored markers on the side of the rocket. Alternate colored markers will also be used on the reverse side of the rocket in the case that the rover is on the wrong side of the rocket when attempting navigation to the loading bay.

4.2.3 Experimental Logic, Scientific Approach, and Method of Investigation

The rover has been undergoing multiple tests, starting with modeling the rover using SolidWorks and using the finite element analysis (FEA) simulation software included with SolidWorks, as well as extensive prototyping. We are currently problem solving every scenario. As mentioned earlier, the suspension system we have designed is a simplified rocker bogie system similar to the ones used on current NASA rovers. We have built a simplified prototype without the use of a differential gear box. While this will give us more limited movement of the rover, it will still be an effective configuration, which could easily be upgraded if used on further missions. Tests are currently being applied to verify that our modifications will successfully traverse the desired terrain. The arm and claw mechanism was tested to ensure that material strengths are strong enough for our intended use, the final outcome proved that acrylic, over ABS 3D printed plastic, was the smarter choice, due to material strength, cheapness of material, as well as ease of production. There has also been extensive software tests, simulating different scenarios to ensure that the claw and arm can successfully retrieve the payload every time, in all possible scenarios.

The logic used in our approach was pretty straight forward, starting with the design phase the team started with a few design ideas and discussed all possible problems that might occur, creating an analysis of the different designs the team had come up with. The design that was chosen was discussed in length and was decided on for its versatility, and ease of manufacturing.

The next steps were to create a thorough 3D model to analyze the aspects of the design that we originally missed in our original discussions. Finally the manufacturing of the individual components and the assembly of the rover to uncover anything that might have been missed in the earlier two phases.

4.2.4 Test, Measurements, Variables, and Controls

For autonomous motor control tests, the rover will be instructed to move to a certain location, recover the payload, lift the payload to optimal position for maneuvering, then find its way to the payload bay on the rocket, and place the payload into the payload bay.

The Controls of this experiment include the positioning of the rover at the start of the sequence, payload location, and rocket location. Moreover, the Variables of the test consists of the path the rover takes to complete the mission, the recovery position of the claw relative to the payload, positioning of the recovered payload for optimal (center of gravity) maneuvering, and the arm and claw positioning/detaching the payload into the payload bay of the rocket.

Time will play an important role in testing the rover's navigation capabilities given that each team is only allotted ten minutes to complete the task of collecting the payload and displacing it within the containment vessel built into the rocket. Variables to consider during testing are time management, power supply, navigational precision and efficiency as well as adapting the programming algorithm to account for problems that may be encountered which were not previously addressed. Controlling the rover autonomously will be the most difficult task to accomplish. Observing the open source computer vision libraries on the internet, there is an ample supply of computer vision source code that can be used to successfully control the rover. Rover arm controls include operating each of the joints and opening and closing the claw. Feedback will come from the camera on the end of the rover arm utilizing the docking algorithm to collect and contain the payload. Pressure sensors placed on the inner portion of the claw will dictate when the payload is actually within the confines of the rover claw. Once the payload is collected, each of the cameras will work in conjunction to determine the necessary distance needed to travel and the appropriate relative position of the arm with respect to the rocket to accurately dispense the payload within the containment vessel.

4.2.5 Discuss the Relevance of Expected Data

The success of this mission is the first step toward setting up a method of transferring physical scientific specimens from an extraterrestrial planet. Current technology of this transfer only allows data analyzed by the current rovers to be sent, not physical specimens. The concept behind our rover is to create a universally viable way of transferring physical specimens. The versatility of the rover makes it valuable to a number of scientific fields, as well as future missions, it is possible that the rover could be re-programmed to be used to upgrade hardware of current rovers like the Mars Science Laboratory, or even to be for the assembly of a prefabricated base on a planet or moon prior to the arrival of a manned missions. To expand the use of the rover's abilities, a depth camera could be used along with a RGB camera to more accurately detect objects for retrieval.

The AGSE rover team is currently troubleshooting all bugs that were discovered through our first series of tests. These fixes will have a significant effect on the accuracy and overall efficiency of the rover. An error analysis will be used to address any problems that are likely to arrive once full-scale development begins. The analysis will provide a means to document each of the potential problems. It will also serve as an analytical approach to break down each malfunction and allow the team to determine the root cause of the problem. In understanding the core of each potential bug, the team will be able to efficiently manipulate the algorithm and adapt the feedback control system codes accordingly.

4.2.6 Experimental Process

The entire rover was designed using SolidWorks 3D CAD software. Each part of the rover is modeled with specific dimensions. The appropriate material was then applied to each of the parts. This allowed the team to do extensive static simulation before moving on. The next step involved each of the parts to be assembled virtually giving a 3d model of the full rover to run a series of analysis tests on the entire rover. Through this analysis the team was able to assess the points of highest stress by applying loads and constraints upon the assembly. A series of motion simulation were then applied to see how the rover would move in real time. All of this was able to be done before ever building a physical prototype solving overlooked design issues before any manufacturing was completed. After these test the team moved on to the next stage and started the manufacturing of the rover to solve any issues that might have been missed in the simulation process.

AGSE/PAYLOAD DESIGN

4.3.1 Structural Elements

In order to meet the success criteria, certain parameters were met while designing the AGSE. The body of the Rover was designed to be large enough to hold all electronic units that was necessary for the rover to be fully capable of functioning autonomously while completing the mission at hand. With the structure of the body being made from acrylic and a rectangular geometry, the body was designed to be robust while inexpensive. The suspension that was designed for the rover was inspired by the suspension used on Mars rovers such as Curiosity and Pathfinder. The Rocker Bogie suspension was designed to be able to conquer rough and uneven terrain all the while provide an efficient and simplistic way for the body of the rover to maintain stability. This allows for a larger probability of success for completion of not only the mission at hand but other possible missions in a Martian environment.

SolidWorks 3D CAD software was used for the entire design of the rover. This allowed for all design criteria to be met while being able to easily and accurately measure and adjust for changes along the way. After the final product was reached, production of the body and arm was done very accurately with respect to the 3D CAD by a laser cutter with low tolerance. The suspension was put together using PVC pipes and a caliper using measurements assigned from the 3D CAD model.

4.3.2 Electrical elements

The electrical system of the AGSE involves a mini-ITX motherboard interfaced to an Arduino microcontroller through an Ethernet module. Using this interface, the computer can control the 8 servos and 2 motors involved in the control of the rover.

Connected to the Arduino is an Adafruit servo controller, and a dual H-Bridge motor controller. The servo controller is capable of controlling up to 16 servos. Because we have 4 wheels to turn and 4 joints in the arm to control, there is a total of 8 servos that are plugged into the module. The Dual H-Bridge motor controller is capable of controlling 2 motors in either direction. Because we are driving the rover with only two motors (located in the center of each side of the rover), we only needed one of these modules.
The image below shows our constructed electrical system on the AGSE.

Figure 34: Constructed Electrical System

The figure below visualizes the connections between all essential parts of the electrical system

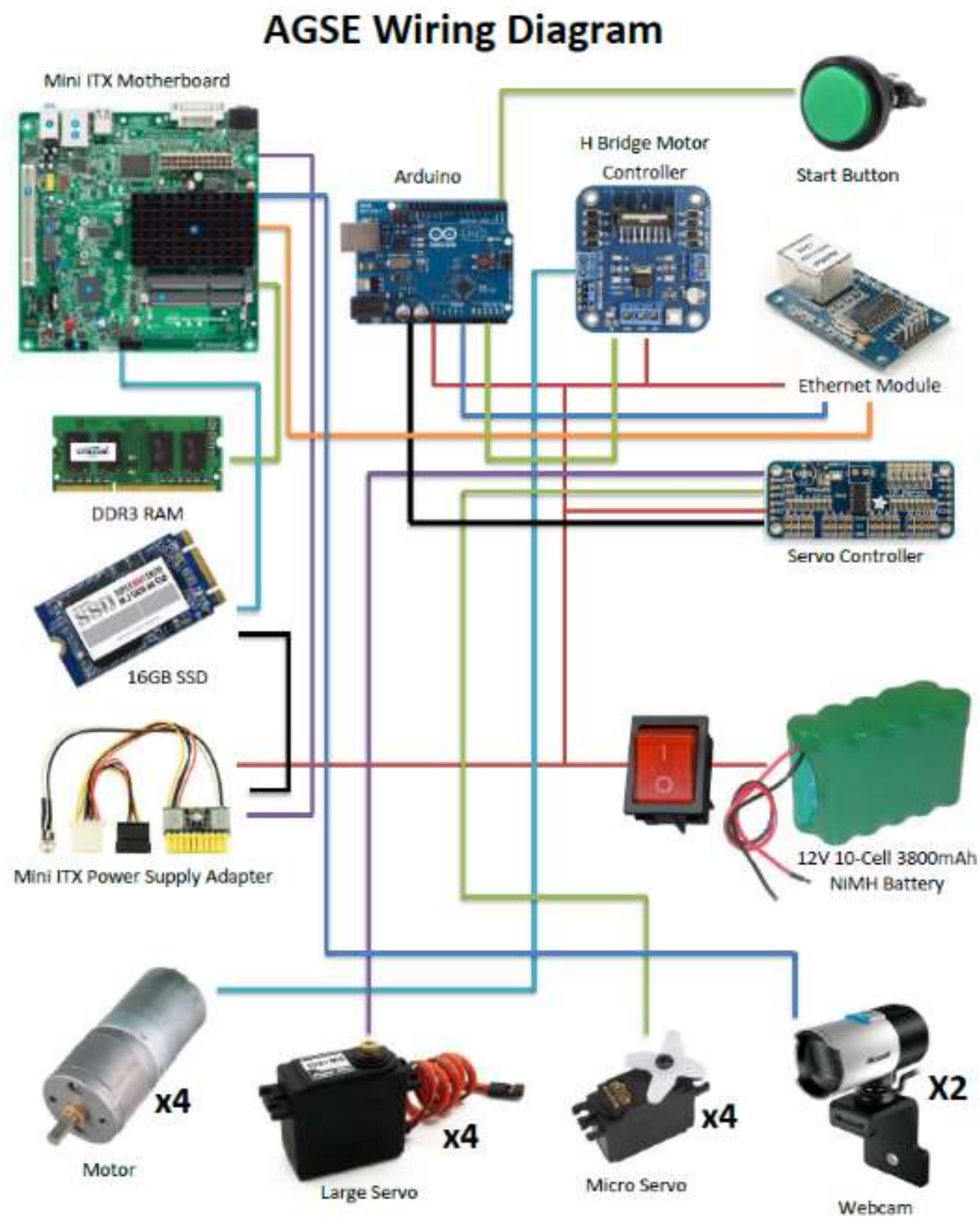

Figure 35: Electrical System Schematic

Table 8: Battery Retention

Device	Voltage (V)	Max Power (W)	Max Current (A)
Mini ITX Motherboard	12V	~80W	~6.6A
Arduino	5V	5W (Typically ~0.25)	1A (Typically ~50mA)
Motor Controller (+ motors)	5V Logic/12V Motors	~14.4W	~300mA each * 4 =~1.2A Max
Servo Controller (+ Servos)	5V Logic/5-6V Servos	~10W	~250mA each * 8 =~2A Max
Ethernet Module	3.3V	~0.165W	~50mA
Totals	12V battery	~110W	10.85A

Because we need the battery to last at least 10 minutes, plus some additional time (+5 minutes), we need a battery with a capacity to give 10.85A for at least 15 minutes.

10.85A * 15 minutes (0.25) = 2712.5 mAh

We have chosen a 3800mAh 12V battery that should surpass our expectations for battery life.

All switches and indicator lights have been mounted on the inside of the electronics box on the Rover. Because the main power switch is connected directly to the battery, and there could potentially be a large amount of current being drawn from it at any given time, the switch will be fairly large and capable of handling at least 10-15 Amps. The start button will be of minimal tolerance as it will be completing a low current 3.3V circuit with the Arduino. All indicator LEDs will be of minimal current as well because of the low required power.

4.3.3 Drawings and schematics to describe the design and assembly of the AGSE/payload

Figure 36: the Rocker-Bogie suspension system used to support maneuvering the AGSE.

Figure 37: shows a CAD version of the 4 servo housing that will be put on the 2 front and 2 back tires for maneuvering abilities.

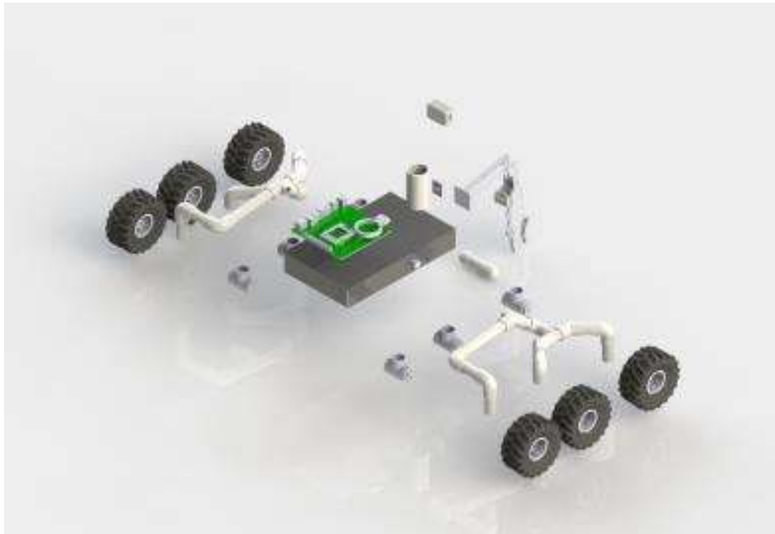

Figure 38: shows an exploded view of the whole AGSE CAD.

4.3.4 Precision of Instrumentation

The AGSE has been assigned a primary goal to locate, retrieve, and drop off a given payload. This primary goal has to be completed autonomously. In order to accomplish this, the instrumentation on board of the AGSE to be used must be able to accurately and precisely contribute in a repeated process if need be.

Using webcams onboard the AGSE along with code using implementations of the OpenCV library and an interface with an Arduino microcontroller, it will be contributing to the accomplishment of the autonomous process. Locating the payload and rocket will be done using color recognition software running on the main computer motherboard and the acknowledgement of payload color, and color markers around the payload bay of the rocket.

The precision of instrumentation and repeatability of measurements have been broken down into four categories listed below.

Ensuring ability to operate within confined workspace:

- Autonomous servo control for orientation throughout mission workspace; this shows the capability of the AGSE to maneuver through obstacles in order to recover and drop off the payload.
- Controlled trajectory programming of the Servos; this confirms the ability for the AGSE to perform a programmed predestined trajectory in order to recover and drop off the payload and account for obstacles along the way.

Image processing search protocol and payload recognition:

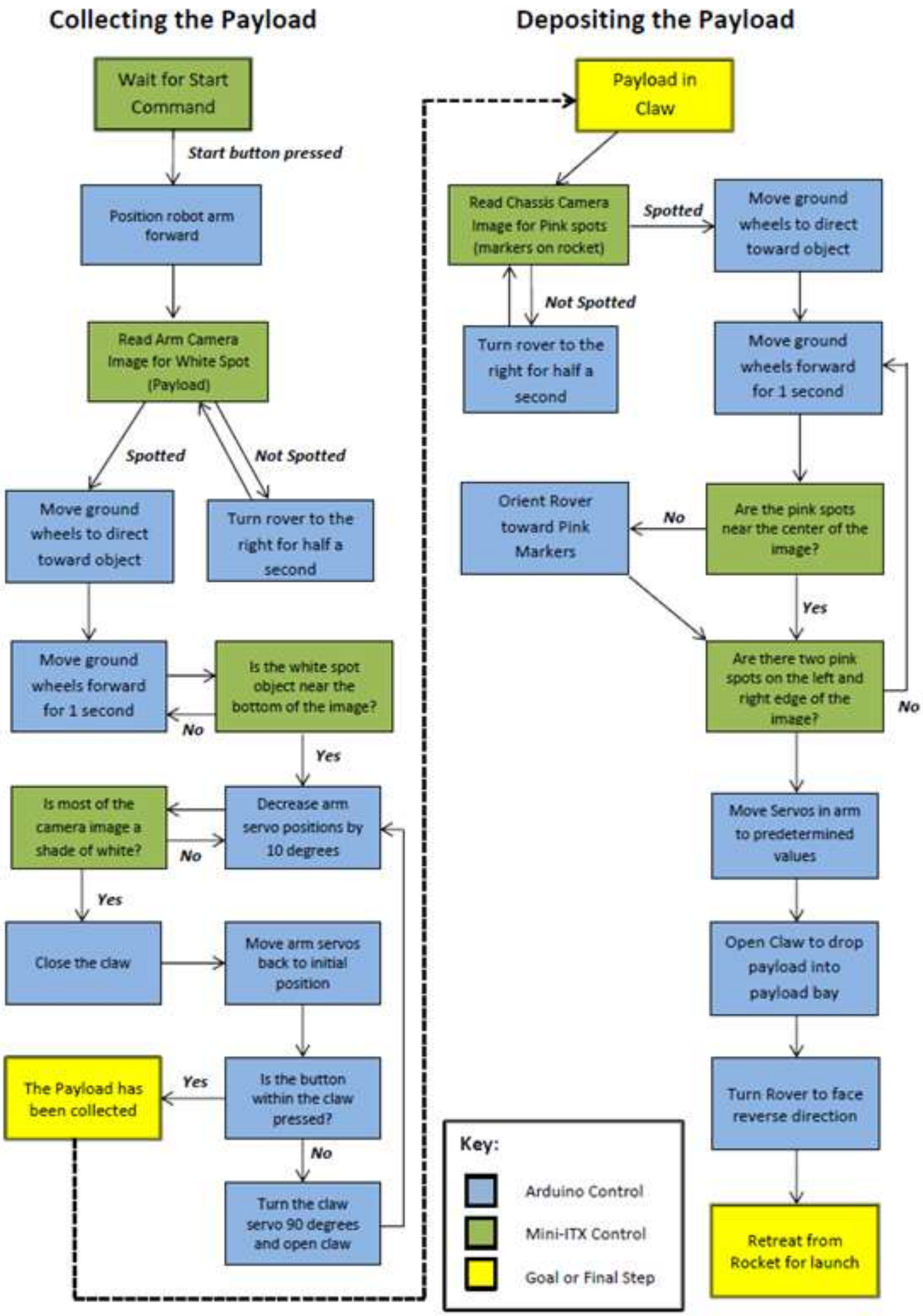

Figure 39: Search Protocol

Payload recovery:

- Use of camera visual aid systems for AGSE payload recovery; this ensures the arm to stretch out to predetermined orientation, and the claw to grasp the payload in order to properly recover payload.
- Use of camera visual aid system for AGSE payload drop off; this ensures the arm to be stretched to maximum length, and the claw servos to properly orient itself for drop off protocol.

Mission success improvements:

- Pressure sensors embedded on claw; this ensures the payload had been retrieved and gripped properly on recovery, and allows onboard motherboard to acknowledge the payload to be dropped off as well.
- Create iteration process for arm/claw system maneuvering; this allows for the arm/claw system to reiterate upon unsuccessful retrieval/drop off.
- Create iteration process for AGSE maneuvering; this ensures the ability for the AGSE to reiterate its maneuvering capabilities upon unsuccessful location of the payload, as well as the rocket.

4.3.5 Approach To Workmanship

When manufacturing the AGSE, elaborate measurements and CAD software allowed for accurate production. Hand calculations were also done in order to incorporate proper geometry to simplify programming for the arm/claw system. Furthermore, all manufacturing took place at UCF using precision tools such as the 3D printer and laser cutter for a better quality AGSE.

4.4 Verification

Table 9: AGSE Verification

SUBSYSTEM	FUNCTIONALITY	EVALUATION & VERIFICATION	STATUS
Claw	Pick up and contain the payload sample	Evaluate efficiency of claw by containing payload from various angles	Incomplete: Claw was accidently demolished during final rover assembly
Arm	Move the claw from its initial resting place down to the payload operating within 4 degrees of freedom	Displace the arm to each of its full extended positions in each degree of freedom	Incomplete: Claw arm was accidently demolished during final rover assembly.
Control System	Microprocessor controls feedback from cameras to output signals to motor controllers	Various programs are written to check efficiency of electronic hardware	Verification in progress. Programs written and implemented to control steering servos and driving wheels
Electronics Housing	Houses and contains all	All hardware is safely	Complete: All

	of the electronic hardware controllers and processors	contained within the Lexan box	hardware is placed and contained within the housing box
Suspension System/ Chassis	Allows the rover to traverse over uneven ground and keeps the Electronics housing sturdy in place	Test the suspension outside and its ability to maneuver over uneven ground and	Partially Complete: Suspension system is fully functional and supports the Electronics housing
Driving Wheels	Moves the rover forwards and backwards	Program controls DC motor output	Complete: Driving wheels accelerate the rover forwards and backwards
Steering Wheels	Aides the rover in turning precisely	Program written to control Servo motors output	Complete: Wheels turn back and forth to aide in turning the rover as it is driving forwards or backwards
Navigation	Controls where the rover moves as well as where the arm moves to aid in collecting and displacing the payload	Contain and displace the payload starting at different locations away from the payload	Partially Complete: Code written to detect color and shape differences in environment but not yet tested in laboratory practice

4.5 Safety and Environment

4.5.1 Safety and Mission Assurance Plan

Risk	**Likelihood**	**Effect of project**	**Risk Reduction Plan**
Battery Fails	Low	Mission Failure.	Make sure batteries are not overcharged or drained below 1.2V
Arm Misses Payload Pickup	Low	falls in region inaccessible to pickup, time extension to recover payload. Mission failure.	Extensive testing of payload pickup and programing to assure accurate pickup of payload
Arm Misses Payload Insertion into Payload bay	Medium	Time extension due to failure for insertion within required 10 min time. Mission failure	Extensive testing of payload insertion on rocket. Ensure all programing, and accuracy is tested before mission
Rover Stuck on	Low	Time extension to complete	Extensive testing of Rover on

Terrain		mission. Mission failure	simulated terrain. ensure maneuverability of Rover to be
Rover Wheels Come Off	Low	Rover unable to maneuver. Mission failure	Ensure all bolts attaching wheels are properly secured and tighten.
Camaras do not Get Enough Voltage	Low	Rover unable to see and maneuver, Rover disorientation. Mission failure	Ensure batteries are fully charged and all connections are properly attached before mission.
Cameras Unable to Recognize Payload	Medium	Rover arm unable to pick up payload. Mission failure	Extensive testing of camera recognition of payload before mission. ensure all connections are properly connected.
Camara Unable to Recognize Payload Bay.	Medium	Rover unable to deliver payload to payload bay. Mission failure.	Extensive testing of camera recognition of payload bay. ensure all connections are properly connected
Rover Orientation Malfunction	Medium	Rover unable to orientate itself. Failure to pick up payload/payload insertion. Mission failure	Extensive testing of autonomous orientation of Rover. extensive testing of software.

As the payload collection process within the software is executed, we should expect that there will be false recognition of the payload or, unsuccessful navigation to the rocket.

In the case that an object is recognized as the payload, the software will check for consistency. If the white "spot" recognized as the payload is not in a reasonable position from the last analyzed image after a movement of servos or motors, the software will take a second sample image and look for inconsistencies and other possible "spots". If none are found, the procedure will start over.

For navigation of the rover to the rocket, the same rules will apply. Because of the unnatural color of the pink markers, we expect fewer false recognized markers.

Because there are no explosives on the rover, we aren't expecting many safety hazards. There will be a safety power switch with easy access on the top of the rover in the case that all power needs to be cut.

4.5.2 Personnel Hazards

Please Reference Section 3.5.2

4.5.3 Environmental Concerns

Environmental concerns of interest are unexpected weather conditions during the day of the competition. The top of the rover is currently open to the environment so a removable cap will be built in case there is rain, that way all of the electronics are not ruined by water. In case there is a significant amount of rain during the week of the competition, there will likely be a significant amount of mud covering the ground surface which would likely negatively affect the traction of the rover. This concern is actually of little interest because the rover utilizes off road tires that are meant to be used in dirt and off-road. Excess humidity or fog could potentially cause the electronics to malfunction due to moisture absorption. The last concern of interest would be the overall temperature in the city of Huntsville, Alabama. High temperature could potentially cause the electronic hardware to overheat and thus cause the software to malfunction and crash. These concerns are all of interest to the robotics team and have been accounted for by planning potential solutions that can be installed on to the rover if need be during the day of the competition.

V Launch Operations

5.1 Checklist

Table 10: Launch Procedure Checklist

Recovery preparation	1. Ensure that all 9V batteries are brand new and still good 2. Ensure the lithium polymer battery is fully charged and still good. 3. Check to make sure all flight computers are programmed to deploy at the desired altitudes. Be careful not to set both redundant charges to ignite at the same altitude. One at a time. Calibrate flight computers. 4. Ensure all shock cords are tightly tied to I-bolts. Tape loose ends together with masking tape 5. Secure main and drogue parachutes to shock cords at about the halfway point. Be sure to use a barrel swivel. 6. Tie payload parachute to loose end of shock cord. Be sure to use a barrel swivel. 7. Secure all batteries using Velcro and zip ties. 8. Connect all E-bay wires and turn on electronics. Be sure all wires lead to the proper ports i.e. main port to main ejection charge, drogue to drogue, payload to payload. 9. Check for continuity. Don't take too long and drain batteries. 10. Insert sled into E-bay coupler. 11. Insert push pin through coupler and into switch to turn off all electronics. 12. Attach forward and aft E-bay bulkheads. Secure tightly with washers and nuts. 13. Fill all ejection cups with 2 grams of black powder. Use dog barf as necessary. Cover each ejection cup with blue painter's tape. Make sure E-matches are inserted in the bottom of the ejection cups. 14. Pull out pin, insert forward end of E-bay into airframe, reinsert pin. Screw E-bay into place. 15. Fold all parachutes correctly with shroud lines wrapped around. Cover parachutes with flame retardant parachute protector. Tuck shock cords and parachutes neatly into their designated compartments. Be sure not to cover pressure holes with parachutes. 16. Check that all coupler connections are not too tight or too loose. If loose, use blue painter's tape on coupler. If tight, sand coupler.

	17. Screw in plastic shear screws as needed.
Motor preparation	1. Follow manufacturer's instructions when assembling motor. Do not assemble motor around a heat source. Only personnel with the proper certifications should be assembling the motor. 2. Use grease to insert motor into rocket as needed. 3. Don't forget to screw on motor retainer.
Setup on launcher	1. Check direction and velocity of upper winds. 2. Loosen launch rail and lower down rail. 3. Slide rocket onto launch rail. Be sure the launch rail is compatible with the rail guides. 4. Raise launch rail up and aim slightly into the wind as appropriate. Tighten launch rail well. 5. Pull out E-bay pin to turn on all electronics. 6. Check for continuity by listening for beeps. One should be beeping twice. The other should be beeping three times. Check the third flight computer for continuity on laptop.
Igniter installation	1. Insert igniter all the way up into the motor until it stops. 2. Tape igniter to launch rail to prevent it from falling out. 3. Clamp gator clamps onto exposed igniter ends and wrap around gator clips.
Launch procedure	1. Everyone should be at the minimum safe distance depending on what is being launched. 2. Designate people on the team to visually track certain sections of the launch vehicle during flight. Try to spot where it lands. Use binoculars as needed. Designate another person to track the rocket using GPS. 3. Check that sky is clear of aircraft, birds, or cloud cover. 4. Loudly countdown to liftoff.
Troubleshooting	1. If flight computers not showing continuity DO NOT LAUNCH! Remove from launch pad when safe. Dismantle E-bay and check that all wires are completely connected and that batteries still have power. 2. Check to see if correct launch pad is armed. 3. Disarm launch pad and check to see if ignitor fired. If not re-clamp wires with

	gator clips and wrap around again. 4. If igniter still does not fire the igniter may be bad. Use a different igniter and try again. 5. Try a different launch pad if available.
Post-flight inspection	1. Find downed rocket using GPS or sight. Be mindful of your surroundings. Be safe. 2. Do not touch rocket at fist. Take pictures as is. Motor section may still be hot. 3. Check for damage and possible missing broken pieces. Be careful of possible sharp broken pieces. 4. Check to see if all ejection charges fired. 5. Check payload condition. 6. Fold up parachutes and shock cords enough so that you do not trip over the line when walking back. 7. Dismantle E-bay and connect flight computers to laptop to check the data. Check to see if data makes logical sense compared to what you saw.

5.2 Safety and Quality Assurance

5.2.1Provide Data

During revision of the data previously discussed in section 3 of vehicle criteria, and among inspection of sub scale and full scale test flight it was concluded that all risks are at acceptable levels. This is contingent of following all risk mitigation steps given in the mission assurance analysis of the launch vehicle.

5.2.2 Risk Assessment

Please Reference Section 3.1.7

5.2.3 Environmental Concerns

Please Reference Section 3.5.3

5.2.4 Identification of individual responsible for safety

Please Reference Section 3.1.7

VI Project Plan

6.1 Budget Plan

The budget is in good shape for completing the project. Enough funding sources have been obtained to pay for the remaining parts and the majority of travel costs, including gas and hotel. Even including travel expenses in the budget, the project is still under the $5,000 maximum. Some expenses are still estimates due to uncertainty in knowing which last minute parts will be needed, calculating gas prices for travel, and finding final costs plus shipping for the Kickstarter rewards and fees. The different expenses may be seen in Table 9.

Table 11: Project Ares Expenditures

Expense	Amount
Parts	$2,000.79
Kickstarter Fees and Rewards (estimated)	$541.50
Travel (Hotel and Gas, estimated)	$2,293.50
Total	$4,835.79

The total expenses came out to be $4,835.79 with estimated travel and fees. The $164.21 remaining from the $5,000 budget will be reserved to cover any additional parts and unexpected purchases that may occur.

6.2 Funding Plan

Funding for the project has made significant progress since the CDR. Several significant individual donations have been received, and one sponsor gave above the predicted amount. A KickStarter campaign was also completed in the month since the CDR, raising well above the goal. With the stipends for the motor and travel from ATK, enough money will have been raised to cover the majority of the cost of the project including travel expenses. The breakdown of funding may be seen in Table 10.

Table 12: Project Ares Funding Sources

Funding Source	Amount
Individual Donations	$300
Sponsor	$1,235.41
Kickstarter Campaign	$2,367
ATK Stipends	$600
Total	$4,502.41

Since expenses were estimated at $4,835.79, that leaves $333.38 that was not covered by fundraising. This cost will be covered by our sponsoring campus organization, Students for the Exploration and Development of Space.

6.3 Timeline

Table 13: Competition Timeline

Design and Report Timeline	Date
Proposal Due	10/6/2014
Website Established	10/31/2014
PDR Draft Report Complete	10/27/2014
PDR Final Report and PowerPoint Due	11/5/2014
PDR Presentation	11/12/2014
CDR Draft Complete	12/20/2014
CDR Draft Presentation Complete	1/10/2014
CDR Posted	1/14/2014
CDR and CDR Presentation Due	1/16/2015
CDR Presentations	1/21/2015-1/31/2015
FRR Draft Complete	2/25/2015
FRR Draft Presentation Complete	2/25/2015
FRR Posted	3/15/2015
FRR Due	3/15/2015
FRR Presentations	3/18/2015-3/27/2015
PLAR Draft Complete	4/28/2015
PLAR Due	4/29/2015
Winner Announced	5/11/2015

Table 14: Status of Activities and Schedule

November 5th, 2014	(PDR) Preliminary Design Review reports due
November 7th, 2014	Construct completely functional rover and arm prototype

November 8th, 2014	**Write software algorithms in programmable language C**
November 15th, 2014	**Test computer vision software capabilities, resolution and efficiency**
November 22nd, 2014	**Debug the software programs**
December 1st, 2014	**Finalize Rover conceptual design**
January 7th, 2015	**Order all parts necessary**
January 16th, 2015	**(CDR) Critical Design Review reports due**
January 28th, 2015	**Complete finalized rover chassi and arm construction**
February 7th, 2015	**Complete integration of electrical components and debugged programmable software**
February 9th, 2015	**Begin ground testing for performance analysis on repeatability traits of payload capture, collection and displacement functions**
March 14th, 2015	**Finish ground testing and performance verification**
March 16th, 2015	**(FFR) Flight Readiness Review reports due**
April 10th, 2015	**Launch Day**

6.4 Educational Engagement

6.4.1 Purpose of Community Outreach

The goal of our team in our endeavors to engage in outreach with the surrounding community of the Orlando area is to generate interest in the STEM fields, especially relating to those fields of study integral to the advancement of the space industry, as well as to promote general interest in the industry in the community at large. To do this we are currently engaged in and plan to engage in multiple outreach events directed at middle school and high school students. The intention of these events is to expose these students to the basic principles of rocketry, as well as the space industry as a whole. It is critical that these events be directed at students of this age group because at this point in their lives they are discovering the things that interest them and what they plan to do with their lives and careers, and as such it is our responsibility to introduce them to STEM, and in particular rocketry, as it may be their first chance to learn about these fields of study and to gain the same level of passion that we hold for them.

6.4.2 Tentative Schedule for Outreach

Throughout the next few months as our team continues to work on the development of our rocket, we plan to also hold a number of events specifically intended to spark the interest in rocketry of middle school and high school students. We have two events currently in process and plans for other events for the later months. We are also planning on participating in multiple UCF and general community outreach events in the later months.

November 8th: The Society of Women Engineers at UCF "Outreach with SWE at UCF"
January 30th: iSTEM "STEM day"
February 14th: SECME "Regional Competition"
March 19th: High School class direct outreach
March 21st: Science Olympiad
March: Boy Scouts of America "Space Exploration merit badge workshop"
May: Boy Scouts of America "Model Design and Building merit badge workshop"
April: Engineers Without Borders at UCF "6k Run for Water"
Summer: Possible FSGC event

6.4.3 Boy Scouts of America Space Exploration merit badge workshop

This event will be targeting specifically toward many Boy Scout troops in the Orlando area, with a focus on fulfilling the requirements needed for the scouts to earn the Space Exploration merit badge. As we are a space and rocketry organization, this event is ideal for us to present a workshop on. In previous years our members have held Intro to Rocketry meetings, where in the basic principles and history of rocketry are introduced to newer members. Our intention is to hold a modified Intro to Rocketry presentation tailored to the specifics of the merit badge. This will provide a fun and exciting way for our members to introduce many aspiring young students to STEM and rocketry while allowing them to complete the requirements of the badge in a meaningful way that will benefit them in the future. The scouts will learn about the basic physics of rocketry, and will also be given a kit to assemble their own small model rockets. Our plan is to later invite the scouts to a launch day where they will all be able to launch their own rockets in a safe manner, however at this time the schedule for when this will be done is uncertain.

6.4.4 Boy Scouts of America Model Design and Building merit badge workshop

Although similar to the Space Exploration merit badge, there are distinctions with this merit badge, and as such we intend to hold another day for the Boy Scouts of America to join us for a workshop to learn about and build model rockets, and in the process fulfilling many requirements for this merit badge that they would otherwise have great difficulty doing. The plan is to hold another Intro to Rocketry presentation tailored specifically to the merit badge requirements. The plan currently stands at having the scouts build their rockets at the workshop to fulfill merit badge requirements and then inviting them to a later event where they will be able to launch their rockets in safe conditions.

6.4.5 Society of Women Engineers Outreach event

Scheduled for November 8th a small group of our membership will be going to an event being put on by a fellow STEM organization at UCF the Society of Women Engineers, were we will be featuring a simple rocketry activity to generate interest for space and rocketry. The event is targeted at female middle school students with the intention of helping expose a greater number of young women to the STEM fields. The cause of promoting women in STEM is one that our members all believe in and want to participate in. The event will be important for increasing interest of young students for the fields of STEM that we all are passionate about and that the United States has an ever increasing need of professionals in.

6.4.6 iSTEM STEM Day

The purpose of iSTEM is to seek out young students with potential for the STEM majors and promote interest in STEM at an early point in their college years. iSTEM also places focus on outreaching to young students preparing to inter college. For this reason we are planning to become involved with their bi-annual outreach event, called simply “STEM day” which is an event meant for organizations exactly like ours looking to outreach to K-12 students, utilizing activities, demonstrations and speakers to promote student involvement.

6.4.7 Other planned Outreach events

For the coming months we intend to becoming involved in a large amount of community and educational outreach events to increase our presence in the public eye as a positive force for academia and scientific initiative. One such event expected for the spring is the Engineers Without Borders 6k Run for Water, which we have participated in over previous years. Another possibility we are looking into is an outreach event that would take place in conjuncture with FSGC. This event would most likely take place in the summer. As more outreach opportunities arise over the months we will continue to be involved in the community and the education of young students with interest in rocketry. We also volunteered at a regional competition with SECMC, where we helped run a water bottle rocket competition, helping the participating students with the construction of their rockets, and then launching them. For March there are two events planned with the high school classes of a former member of our SEDS chapter, where our primary purpose will be to get the students in that class excited about STEM, college and SEDS by presenting our organization and the projects that we do.

VII Conclusion

The University of Central Florida has designed a an autonomous rover and launch vehicle which will optimize the ability to complete the task of collecting and launching a payload from the surface. The unique three section design utilizes the space of the entire rocket efficiently. This in turn reduces cost and weight without hindering performance. Testing and simulations have provided enough feedback to the initial design to establish the final design specifications required to reach the goal.