UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

WSGC 2013 Regional Rocket Design Competition

Ad Astra II

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Within the competition guidelines, the design was based off the following dimensions of 72 in for the height and four in in diameter, while having the goal of reaching the apogee of 3000 ft and having a recoverable rocket using a duel deployment system.

I. Rocket Build

During the design process, the team decided to purchase a rocket kit from Public Missiles Ltd. with the following dimensions; 72 in. in length and four in. in diameter. The diameter was chosen for multiple reasons including easy access and maneuverability during the construction process in addition to prior experience with a similar kit. This then led to the decision to use a plastic based material; quantum airframe tubing. Components such as this were chosen because of the added durability during flight, for example, the prevention of zip chords and damage resulting from high decent velocity would be minimized. Quantum airframe tubing was chosen instead of fiberglass tubing for weight and cost restrictions. Furthermore, fiberglass did not allow for enough length to store the avionics and parachutes while staying under the seven and half lb. weight limit. Since the launch is neither high speed nor high altitude, no air pressure bleeder hole was required in the nose cone section of the rocket.

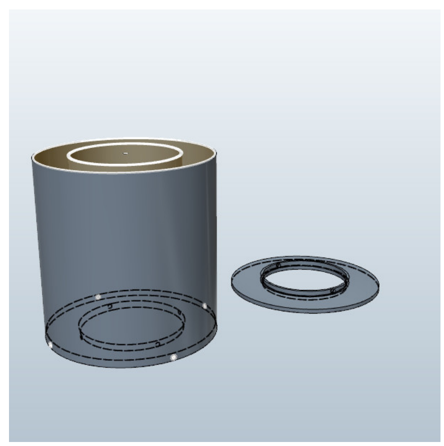
Transitioning from a single deployment rocket to a duel deployment rocket proved to be a challenging task that we overcame. By using a sliding bay and guiderails we created a unique duel deployment avionics bay. In order to create a transition ring between the two stages of the rocket, extra tubing was required therefore we had to order more tubing. This allowed for a fluid duel deployment system.

Following the instructions in the kit, one rail guide was placed half an inch from the base of the rocket, while the other is placed at the center of gravity. There was not a lot of concern given to the difference between using a rod and rail guide, and ultimately chose brass rods. The rod guides will have a negligible effect on aerodynamics and performance will not be hampered by this decision.

While considering the shape and number of fins for the rocket we considered several options that came with various kits. However, the team decided that the best option for this flight would be simplicity rather than complicated aerodynamic designs. Therefore, a system of three trapezoidal fins was chosen. This seemed both technically appealing for what we were trying to accomplish while also being simple enough for the mission. Since this flight is subsonic a trapezoidal fin is simpler while having many of the same effects as an elliptical fin. Neither aspect ratios nor swept fins were considered as part of the design.

In order to secure the nose cone to the top section containing the main chute we used three three-quarter inch screws that can be attached or detached from the nose cone. As for preventing the main chute to deploy with the drogue ejection charge three 440 nylon screws were used. This was calculated using an iPhone application recommended by Central Illinois Aerospace (CIA) representatives.

Rather than using boattails on the fins or streamers to add increased drag to reach the desired altitude of 3000 ft. a weight canister was designed to sit in between the center of pressure and gravity. The part was drawn in a CAD program and then 3-D printed in the aerospace department laboratory. Advantages include the ability to add the correct amount of mass for varying weather conditions.



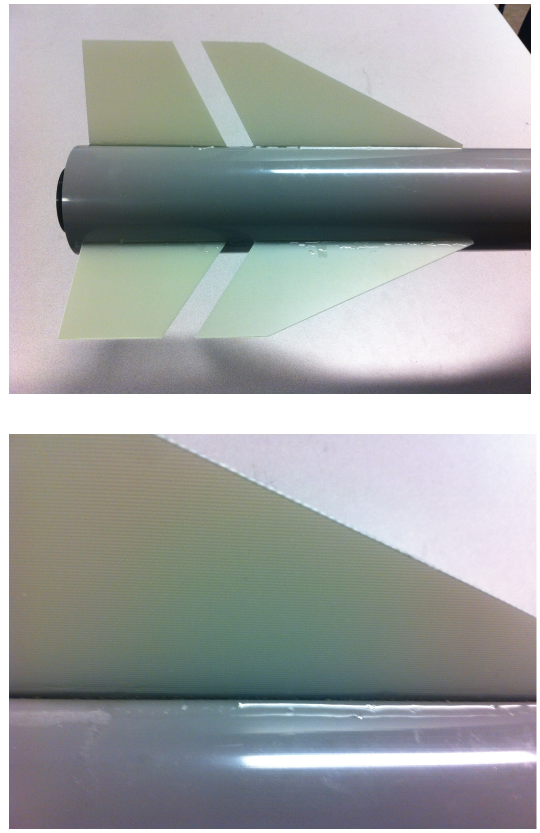
Weight Canister

II. Constraints

The three biggest limitations our team faced during the design process were weight, length and cost that would lead to a product achieving a desired altitude within our 1000 ft. window. In the appendix a chart details all expenditures. In our budget we covered construction costs, Educational outreach materials and part prices. Our group was fortunate enough to be exempt from paying taxes on all our items and even received a 20% student discount at the local hobby shop.

III. Adhesives

A thirty-minute epoxy was used to secure Non-impact components such as electronic bay, electrical wires, payload components. A three-hour epoxy was used on the Exterior (Phenolic Tube/Fin Assembly, Couplers) for higher resistance to impact during Recovery Stage. We mixed equal parts of resin and hardener in small disposable plastic containers using wooden popsicle sticks and stirring rods and applicators.



Epoxy Fillets applied to Fins

IV. Flight Characteristics

The most successful simulation we ran had these results using Open Rocket software:

Initial Conditions:

Mass w/o motor: 2946g or 6.49lbs.

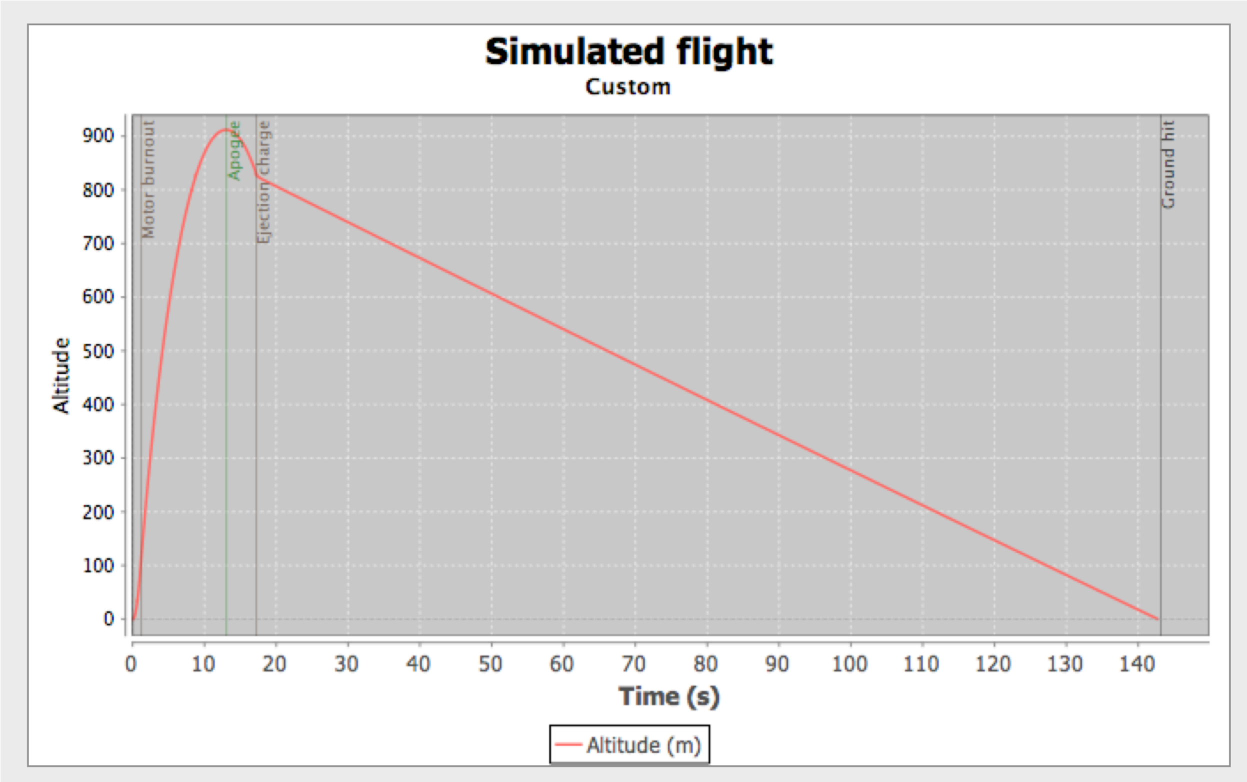
Mass w/ motor: 3545g or 7.82lbs.

Wind Speed: 10 m/s w/ 0.2 m/s variation

Temperature and Pressure: 15° C and 1013mbar

Apogee: 2985.56 ft	Launch rail Clearance: 0.13s	Maximum Velocity: 547.9 ft/s
Distance from pad: 312.2 ft.	Impact Velocity 21.29 ft/s	Max Acceleration 557.7 ft/s^2

Total Flight Time: 142 s



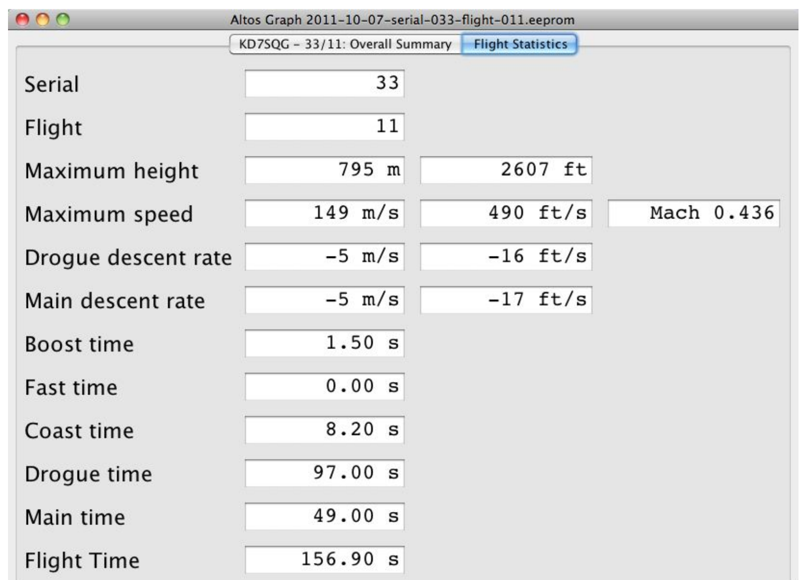
V. Educational Outreach

In order to share our experience in this competition we decided to have an education outreach component. Our focus was to teach an average University of Illinois undergraduate student the power of the engine we were using. The apparatus we used for them to actually feel this impulse is akin to the mechanism to learn how to water-ski on dry land. Funny enough, we had to postpone this project multiple times due to flooding on our campus Quad. The system works as such. Using an old ski line and handle, a pulley, 50 lbs. of deadweight dumbbells and a sturdy overhanging tree branch we created our outreach. The pulley is attached oriented parallel to the branch. The ski line is then fed through the pulley and attached to weights using no slip dry knots. The participant then takes the line 15 ft. away from the tree and sits down while we hold up the weight. After the volunteer sits down with the line taught, the weights are released and they are pulled to an upright position. This had of course varying results depending on the weight of our student. It was then described to them that our rocket has an impulse over the course of one second that is more than twice the force they recently experienced. To wrap up the presentation we explained the lettering behind the classification of the motors and using our motor retention system to provide a basis for size.

Avionics Hardware (Receiver, Altimeter, Battery, Charger)

VI. Avionics

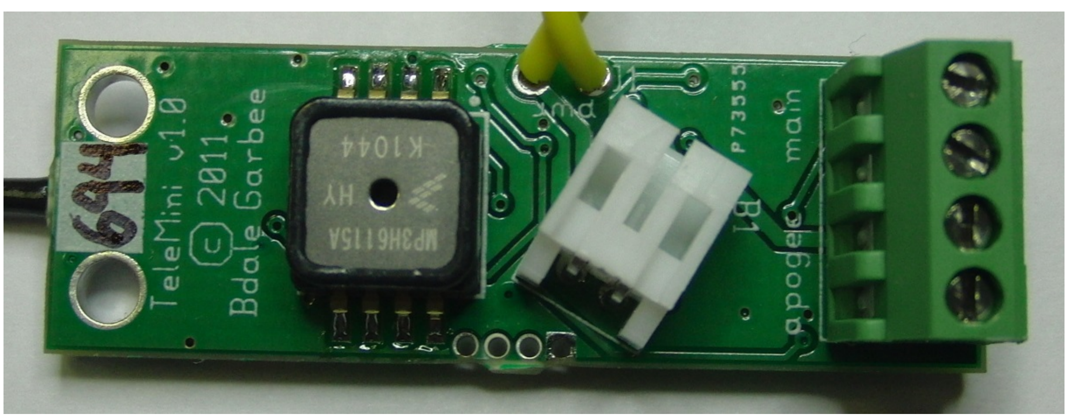
Our primary altimeter that we are using for our dual deployment system is the Altus Metrum TeleMini v1.0. It is a non-accelerometer altimeter which means that it could be installed in any direction. The readings are given by barometric readings which is good to 45,000 feet. The altimeter has included a software that allows us to view the flight data during launch. The data is streamed to our laptop using a telemetry transmitter. The data is sent ten times per second during ascent, and one time per second after apogee. The software has also many tools for post-flight analysis of the rocket. A rechargeable lithium ion polymer battery powers the altimeter. The TeleMini has the capability of firing two separate ejection charges for dual deployment. Our inputs into the software will tell the altimeter when to fire the ejection charges. The altimeter also has on-board memory storage



Example of Data from Software

that will allow for the collection of data post flight. The Consortium will also provide another altimeter at the competition.

The first step in our process of installing the electronics and wiring the avionics bay was installing nylon screw standoffs for the altimeter to rest on. The altimeter has two holes at the front of it to mount it with screws. We also added one more standoff at the rear just for it to sit on to take the stress off of the front. The next step was installing the battery. We first wrapped the Li-Po battery with packing foam to give it more padding during flight. We then drilled four holes and used six zip ties to mount it to the bottom the avionics board. The next step was the installation of the switch. Our initial idea for the switch was a push switch, but in the process of gluing it to the board, glue got into the trigger mechanism, so we were forced to go a different route. We switched to a rotary switch. We mounted the switch to the outside of the rocket wall. Then we had to solder leads on the switch for it to be connected to the altimeter. We did install wires that have easy disconnect switches on them, so we can remove the avionics board if needed. We then proceeded to wire the altimeter to the ejection charges. Overall, the process went very smoothly with a few minor setbacks.



TeleMini v1.0

VII. Recovery

1) Deployment Setting: **Dual Deployment** Using a single parachute recovery system for the model rocket is convenient only for the light weight sports rocket with maximum altitude of less than 1,000ft AGL. With only single parachute, the rocket hitting higher than 1,000ft AGL takes longer to hit the ground and, therefore, possesses higher chance of drafting due to the wind. Dual deployment system is the ideal solution for the wind drafting of the rocket frame during recovery. Our dual deployment system was based on the use of e-matches. The altimeter has wires run to terminals on both ends of the avionics bay. The terminals are then wired to the e-matches that contain black powder. Our altimeter will be able to fire these ejection charges at different times. The e-matches are cardboard tubes with current running to them. The current becomes hot, lights the black powder, which then ejects the parachute. The motor also has an ejection charge, but we will only use this as a backup in case the ejection charges fail. The motor is capable of having different times for when the charge will fire. We will set this time for after apogee to allow for the ejection charge to fire close to apogee. The first ejection charge will eject the drogue parachute, and then the second ejection charge will fire the main parachute later on in the descent. The e-matches must be replaced every time, but they are very simple to replace.

a. Drogue Chute - Using a single parachute recovery system for the model rocket is convenient only for lightweight sport rockets with maximum altitudes of less than 1,000ft AGL. With only a single parachute, the rocket hitting altitudes higher than 1,000ft AGL takes longer to hit the ground and, therefore, possesses a higher chance of drafting due to the wind. Dual deployment systems are the ideal solution for the effects of wind on the rocket frame during recovery. The smaller chute called the **'Drogue Chute'** is activated first at

Apogee via an electrically charged ejection system at the rocket's apogee, preventing free fall of the rocket frame. The Drogue Chute's descending rate could be as high as 75 ft/s but ideally set for 60~70ft/s range. For 3.9" diameter tube, **1g of Black Powder/11in. Pressurized Compartment Length** is required. The pressurized compartment for the rocket frame is **18in**. Therefore, **1.64g of Black Powder** is required for the drogue chute deployment.

b. Main Chute - While the drogue chute prevents free-fall of the frame for more than 2/3 of the recovery altitude, the altimeter activates the main chute deployment at 820ft AGL, decreasing the descending rate of the rocket down to 15-20ft/s, a safe velocity for impact. The length of pressurized compartment for the main chute deployment system is **20in.** Therefore, **1.82 g of Black Powder** is required for the main chute deployment.

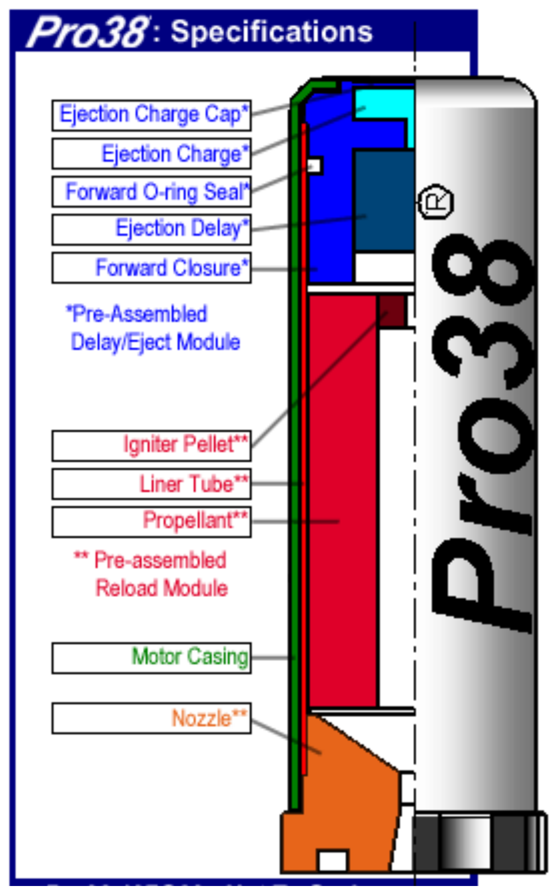
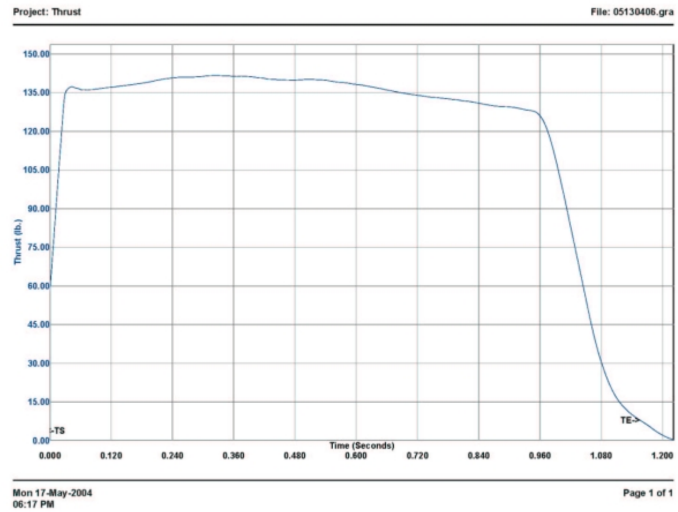


Diagram of Cesaroni P38 Series

VIII. Motor Retention System

The rocket kit purchased came with a preassembled, ready to use “kwik switch”, however, the team received advice from the CIA that this switch would be inadequate for the needs of the rocket and the mission profile. Therefore, the purchase of a different motor retention system was required and the team decided to purchase a “HAMR” motor mount. After much deliberation, the decision was made to choose this system because of its simplicity. Once the initial motor mount is installed into the booster, the retention system is simple to use. Easy to use “twist on” mounts are then installed depending on the motor mount required for flight. By “twist on” this refers to a simple screwing device used to screw in and securely fasten the system to the mount. After this has been completed the final stages of preparation are met by fastening on the remaining pieces for the motor mount. In conclusion, the HAMR motor retention system was selected for its simplicity and ability to meet the needs of the mission parameters.



Cesaroni Thrust Curve

IX. Motor Choice

The motor we are given for the competition is the Cessaroni I540. This motor is capable of launching our rocket to 3000 feet. The rocket model number is Pro 38 634I540-16A. It is a reloadable engine. The weight of this engine is 598.20 grams when loaded and 269.40 grams when unloaded with propellant. The motor’s dimensions are 38.00 x 367.00 millimeters. The motor has an impulse of 635.00 N-s with a maximum thrust of 625.93 N and an average thrust of 540.80 N. The engines burn time is 1.18 seconds. The engine has a series of delays that can be used for ejection, and these include 16,13,11,9,7 seconds after launch. We are using the motor ejection system as a backup to our ejection charges. We modified our rocket to have dual deployment in order to have easier recovery. If our ejection charge fails, we will have the motor charge set for a little bit after apogee, so our drogue chute will deploy. Our rocket uses the Kwik Switch motor mount system that allows us to swap out for different sizes of motors. It allows for

29, 38, or 54 millimeter diameter engines. However, we are only going to use the 38 millimeter mount. Our rocket also uses a motor retention system that is threaded, and it allows for the motor to be inserted into the mount, and then a cap is screwed on the bottom in order to keep the motor in place.

X. Aerodynamics

In order to optimize aerodynamic features, the team selected a standard plastic nosecone that came pre-selected from the rocket kit. The nosecone is an ogive shape that has a profile of a segment of a circle. This particular design allows for "a smooth transition to the body tube" (openrocket), thus enhancing and supporting the aerodynamic features of the rocket. The paint can add significant weight to the aircraft that would increase drag thus affecting the performance of the rocket. In order to get past this, it is required to predetermine a weight for the paint. Furthermore, it is crucial to select certain types of paints, such as selected spray paints, which will be used on the rocket. To ensure that all edges from the fins or any other boundaries are smooth, primer will be used in addition to selected 400 grit sand paper which will help finish the rocket for aesthetics but also make it slick for aerodynamic properties. The launch lugs have been preselected to have a negligible effect on this rocket for its mission. Simply said, because it is a low altitude, subsonic flight, it is difficult to have a major effect on the aerodynamics. It has been well documented that trapezoidal fins have proved to be an effective fin at an appropriate thickness predetermined for the rocket by the kit manufactures, the team had little to no input as to the thickness of the fins, but came simply "standardized" for the flight objectives. Although a boattail is a sufficient tool for drag reducing, Ad Astra II will not be employing this in our rocket. Again, given the objectives of the mission, the parameters or specs for the rocket called for increased lift over drag thus this was quickly discussed as an over measure not required.

XI. Stability

Stability was one of the most significant factors the team had to consider once building commenced. It was crucial to ensure that the goal altitude of 3000 ft. was met by ensuring weight and other constraints such as center of gravity and center of pressure were considered. For example, an extra mass was required to keep the rocket from going too far over the apogee goal that was solved by first finding the pre-flight center of gravity. Initially the team wanted to place the added weight at the center of gravity (this would allow for a more stable flight as the center of gravity variance would remain smaller), however, the center of gravity was at a spot too close to the parachute. Next, the team decided to check the center of pressure, but this too proved to be too close to the motor. Ultimately the team's solution was to put the added mass in between these two points (center of gravity and center of pressure). This seemed the most logical and met the needs of the rocket for stability; though not optimal it is the next best option in the team's opinion. Center of gravity will be calculated once all construction has been completed (including paint). It is a relatively simply calculation in which the team will take the weight of each component and multiply it by the distance from the reference point and set that equal to the center of gravity multiplied by the total weight. The area of the nose body and fins will be taken into consideration when calculating the final center of pressure. It is a similar equation to the center of gravity; expect instead of mass the team will be assessing area multiplied by the distance from the reference line. Both the center of gravity and the center of pressure are located for now on the booster section of the rocket, with the center of gravity higher up the tube than the center of pressure. This proceeds into a discussion of static margins, as this is the margin between the center of gravity and the center of pressure on the rocket. As previously mentioned Ad Astra II will have a positive static margin since the center of gravity is in front of the center of pressure. This will provide the adequate restoring moment as the rocket will respond to any disturbance by pointing the rocket toward the angle it was at before the disturbance. These points will be measured before and after launch to analyze how close the predictions were to the actual apogee and if static margins played an influential role in whatever may occur during flight.

XII. Launch check Off List

Assembly: Based on the weather conditions that day, we will be able to add the necessary mass with copper pellets in our weight canister. After the top is secured to our canister, we move onto the avionics bay.

Altimeter: The TeleMini altimeter has a series of steps to follow to prepare for launch. The altimeter is able to recognize the orientation of the rocket, and the orientation determines whether the altimeter goes into flight mode or idle mode. When powered on, the altimeter will give off three beeps or three flashes that mean “S” in Morse code for startup. After it has booted up, the altimeter will do a self-test and decide what mode to go into next. In flight mode, the altimeter will go into transmit-only mode. This is will be indicated by “di-dah-dah-dit” which is “P” for pad. After this sound, more sounds or flashes will appear indicting what type of deployment is being used. One beep indicates apogee continuity, and two beeps means main continuity. Three beeps mean both apogee and main continuity which is what we need. At this point, the altimeter is ready for launch. One long beep means no continuity. Idle mode is indicated by the sound “di-dit”, and two short flashes which mean “I” for idle. This mode means no ejection charges will fire, and this mode is mainly used for collecting data and configuring the altimeter. Using the software, the rocket can begin horizontally and boot up in idle mode, and then be switched over to launch mode for easier startup.

XIII. Safety Plan

Safety Officer: Je Won Hong

Fail Safe System: 1) Double Altimeter Setting: 2nd Altimeter could be installed to ensure the parachute deployment in case the Primary Altimeter fails 2) Shock Chord Material - Kevlar Shock Chord installed instead of Nylon Chord to prevent Parachute damage due to the ejection gas ignited during the recovery process

Testing Plan:

Field Selection: Non-Residential Area with minimum radius of 2,000ft, Soft soil

Maximum Wind Condition: Assuming a 72.43 ft/s descending rate with the Drogue Chute it will take 28.34sec from 3,000ft AGL to reach 820ft AGL. Then, assuming a 17.2 4ft/s descending rate with the Main Chute takes 47.56sec from 820ft AGL to reach the ground. Therefore, it takes total 75.9sec to recover the rocket frame from 3,000ft in ideal condition. If the rocket is tested in Non-Residential field of 2,000ft radius, **the Absolute Maximum Wind** for testing the rocket safely is **26.35ft/s**. It is recommended to test the rocket with the wind speed less than **20ft/s**, ideally between **0~16ft/s**. It is **0~10ft/s** in weather forecasting.

Essential Equipment: Binoculars - Tracking Visual Path, AltOS - TeleMini Altimeter Tracking Software to track the precise path of the rocket frame.

Appendix: Wisconsin Rocket Competition Parts List and Budget

Jacob Dray, Grant Kramer, Je Won Hong, Nick Fulton

Item	Part Number	Manufacturer	Price $
TeleMini Dual Deployment Altimeter	09126	Apogee Components	225.00
Endeavor Kit	Endeavor 38KS	Public Missiles	175.45
Quantum Airframe Tubing 48”	QT-3.9-48	Public Missiles	32.95
Construction materials	See lower chart		70.86
Ed out Materials			18.00
Blast Caps		Blast Cap Rocketry	22.00
10 PACK OF EJECTION LIGHTERS WITH CARDBOARD TUBES	WM01-EJECTION LIGHTER W/CB	Wildman Rocketry	17.95
Battery Holder		Dog House	2.25
Altimeter Bay Wiring Kit		Dog House	12.50
Motor Retainer and Adapter	HAMR-KS-SET	PML	42.50
Drogue Chute	PAR-18	PML	18.95
Shock Chords	TUK-1/4" 3600 lb test for 3"-5" rockets	Top Flight Recovery	35.00
Avionics bay	PSK-3.9X9-QT	Public Missiles	13.87
Electronics Mounting Kit	09132	Apogee Components	40.00

Construction Materials

Epoxy (X3)	DEV233	Tom Thumb	48.36
Sand-paper		Tom Thumb	7.50
Paint and Primer		Tom Thumb	15.00
Pulley	852717.0	ACE Hardware	9.00
Lines		(home)	
weight		(aero lab)	
Work gloves		(home)	
Popsicle Sticks/chopsticks		(home)	
Wood for Avionics Bay			
Wood Glue		(home)	