UNL ROCKETRY TEAM

Critical Design Review

2011-2012
NASA University Student Launch Initiative

University of Nebraska-Lincoln

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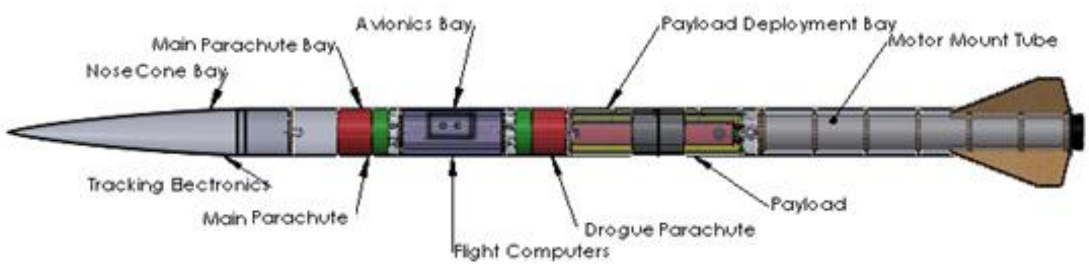
1.0 Summary of CDR Report

1.1 Team Summary

University of Nebraska – Lincoln Rocketry Team		
Location:	Lincoln, Nebraska	
Faculty Advisor:	Dr. Kevin Cole	Professor-Mechanical and Materials Engineering
Certified Mentor :	Thomas Kernes	National Association of Rocketry #82141
Project Director:	Matthew Mahlin	
Payload Team Leader:	Alexandra Toftul	
Safety Coordinator:	Paul Kubitschek	

1.2 Launch Vehicle Summary



Length:	124.5”	
Diameter:	5.5”	
Nose Cone:	27.5”	Von Kármán (LD-Haack), 1:5 Fineness
Fin Span:	14.5”	(3-fin configuration)
Weight:	23.7 lbs	(No Motor – No Payload)
Motor Mount:	98mm	37” long – rear retaining ring

Selected Motor:

Designation	Total Impulse (N*S)	Thrust/Weight	Maximum Payload (lbm)	Rail (in)
L1170FJ-P	4214	6.14/1	9.5	144

Recovery System:

Component	Characteristic Dimension	Comment
Main Parachute	108”	Hemispherical with 24” Spill hole
Drogue	34”	Mach 1 Ballistic X-Form
Shock Cord	52’ Main / 30’ Drogue	1” Tubular Nylon
Nomex Wadding	24”	2 x Fire resistant protective cloth

1.3 Payload Summary

The deployable payload will be designed to separate fully from the rocket and descend under a spiraling parafoil. The structure will house an experimental energy scavenging system, which will autonomously activate shortly after separation and will collect and transmit data throughout descent.

2.0 Changes Since Preliminary Design Review

2.1 Vehicle Criteria

The overall plan and design for the vehicle has been reevaluated to better meet the challenges and requirements of the USLI competition. This is expected to be the final design iteration of the vehicle. Specific vehicle criteria that have been finalized since the preliminary design review are the airframe construction, recovery system, and motor selection.

Aspects of the airframe construction that have been finalized are the nosecone and avionics bay hatch. Originally, the nosecone was to be made out of a mold by students, but it was discovered an affordable nosecone matching the mold dimensions was available commercially. This option reduced the required time construction time greatly, would be of greater strength and fit well in to the budget. So, a filament wound fiberglass nosecone matching desired specifications was purchased. The avionics bat hatch has been designed to be 5 inches tall and 3 inches wide. There will be two rotary key switches for the flight computers mounted in the hatch. It will be secured by machine screws set in threaded inserts mounted to the airframe. The purpose of this bay is to allow access to the avionics for integration with the key switches, charging batteries, configuring flight computers and facilitate evaluation after flight.

Critical components and operation of the recovery system have been finalized to ensure total satisfaction of mission requirements. A larger drogue parachute has been purchased, the shockcord for the drogue has been increased to 30 feet, the main parachute has been moved to the front of the vehicle, and the main deployment will occur at 1000 feet AGL. The drogue parachute will be a 36-Inch x-form, mach 1, ballistic nylon parachute. This is sized to reduce the main deployment to 77.8 feet per second.

The kinetic energy during descent has been brought to within allowable limits by increasing the size of the drogue parachute by one foot and the drift has been mitigated by deploying the main parachute at the lower altitude of 1000 feet. The drift of the vehicle with the main parachute deployed at 1000 feet should be within the acceptable 2500 feet for zero to 15MPH winds but the deployment altitude will have to be decreased to 500 feet for 20MPH winds This can be further mitigated by launching slightly in to the wind. These measures should ensure satisfaction of the mission requirements.

Finally, a different motor with a lower, more appropriate, total impulse has been selected for the mission. The Aerotech L1170FJ-P was shown to be a more favorable choice as the payload mass was revised to be lower. A more acceptable thrust to weight ratio of 6.14 to 1 or is allowed by this change. The case for this motor matches with the previous motor and makes this an easy change to accommodate.

2.2 Payload Criteria

Since the preliminary design review, the payload structure has been modified, the release mechanism has been changed, and a parafoil has been selected. The structure was modified to create a channel for the shockcord to bypass the payload. This modification was necessary to connect the sustainer to the booster without interruption. With the main parachute being switched to the forward bay, the payload will now be drawn out of the vehicle at apogee with the drogue parachute and remain tethered until remotely commanded to release. When commanded, a servo on board the payload will release the shockcord, and the packed parafoil. These changes should make the design more reliable and prevent the payload from interfering with the vehicle recovery.

2.3 Activity Plan

Team activities have continued through the winter break and the team will remain on schedule. Although the team wanted to move the first test launch up to January, unfavorable winds have moved it back to the original plan of launching in February. Almost all vehicle components have been ordered or have arrived at this point. Major construction of the vehicle's sections has been completed. Testing with flight computers and ejection charges is set to begin shortly. Open lab hours are maintained on all week and along with scheduled full and sub team meetings allow the team to work regularly.

The team's outreach activities have involved 67 local middle school students and 3 educators in two classes. This involved three sessions of teaching rocketry basics, designing and building, and launching water rockets. These young students were then quizzed in order to attain feedback on what they learned. Our outreach efforts have gained momentum and are set to continue this semester with more classes. We are also planning on encouraging a local high school to participate in the Student Launch Initiative for the next competition year.

3.0 Vehicle Criteria

3.1 Design and Verification of Launch Vehicle

3.1.1 Mission Statement

The objectives of this project are to design and build a launch vehicle to reach an altitude of 5,280-Feet above ground level, use a dual deployment recovery system, deploy an engineering payload by remote on command, and recover all components in a re-launch able condition.

3.1.2 Mission Success Criteria

Mission success of the launch vehicle is based on three primary goals.

Altitude:

The desired altitude is exactly 5,280-Feet above ground level. In order to achieve this goal several measures will be taken. A motor with a greater total impulse than is needed will be used. All components will be weighed before launch and ballast will be added to ensure the right altitude is attained with this motor. The ballast added will be based on OpenRocket simulations. The simulations will be verified by multiple test launches. Verification of altimeter accuracy will also be performed during these launches.

Deployment:

The recovery system will be a dual system deployed in stages. The first event will pressurize the payload deployment bay to separate the vehicle in half and deploy the drogue parachute apogee. The engineering payload will be secured to the shockcord of the drogue until commanded to release independently. The vehicle will descend under the drogue until 1,000-Feet where the second event will separate the nosecone from the forward section to release main parachute. Each event will have a secondary charge set to go off five seconds after the event's primary charge.

Recovery:

The vehicle must be recovered in re-launch able condition. So, the parachutes will be sized to ensure a low energy landing. The vehicle and UAV shall be equipped with GPS transmitters to enable swift recovery.

3.1.3 Major Milestone Schedule

Table 1 - Major Milestone Schedule

Major Milestone Schedule	
26 September 2011	**Proposal due**
	Finalize design for prototype rocket
	Finish CAD modeling of rocket, order individual rocket components
	Finalize OpenRocket simulations; begin stress analysis
	Begin construction of Rocket
	Finish model of UAV
	Define experiment
28 November 2011	**PDR report due**
	Begin construction of UAV
5-14 December 2011	**PDR Presentation**
	Evaluate necessary design changes
	Complete testing of ejection system
January 2012	First Test Launch
	Begin testing of UAV systems
	Finish construction of Rocket
25 January 2012	**CDR report due**
1-10 February 2012	**CDR Presentation**
February 2012	First Test Launch
	Choose competition motor
	Finish construction of UAV
	Verify Altimeter Accuracy and Agreement
26 March 2012	**FRR report due**
	Second Test Launch
	Finalize Travel Plans
2-11 April 2012	**FRR Presentation**
19-20 April 2012	**Flight hardware and safety checks**
21 April 2012	**Launch Day**
7 May 2012	**PLAR due**

3.1.4 System Level Overview

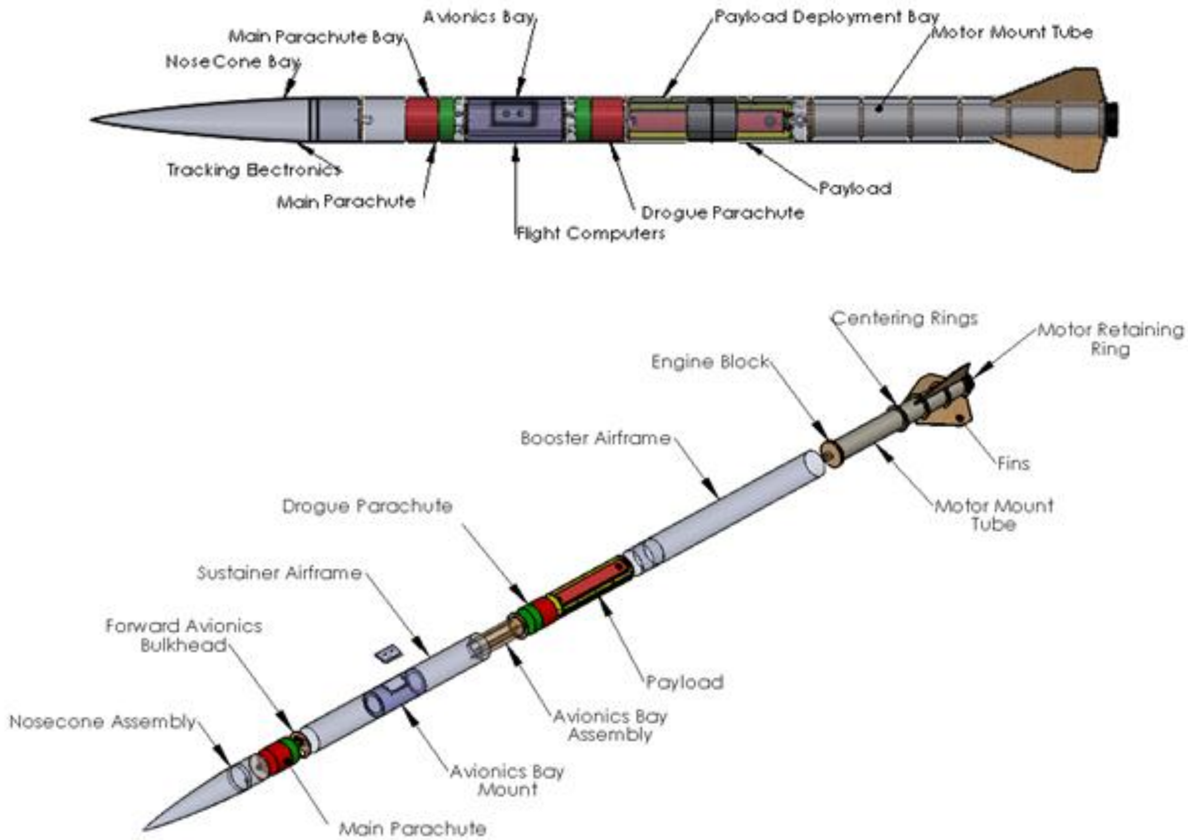


Figure 1 Compartment assignment and major components of vehicle.

The UNL Rocketry Team's launch vehicle has been named Deimos. It has gone through final design iteration and is nearing completion. The project will fully adhere to the design requirements outlined in the USLI Handbook. Simulations indicate that the vehicle mass is as expected and the vehicle can attain the desired altitude with the chosen propulsion. The design philosophy focused on maximizing the payload capacity and creates a workhorse capable of lifting a large volume. The positioning of the payload bay near the vehicles unloaded center of gravity allows for a relatively massive payload to be loaded without dramatically affecting the vehicle's stability. Notably, it reduces the tendency of a rocket to cone. This bay also facilitates the deployment of the payload with the main parachute event. Compartment assignments are displayed above (Fig. 1).

Competition Design Requirements

How the design requirements outlined in the USLI Handbook are fulfilled by the project is listed below in Table 2. Also included is how fulfillment of the requirements will be verified.

Table 2 Fulfillment of Competition Design Requirements.

Requirement	Fulfillment	Status
Scientific Payload	Experimental Ambient Wind Energy Scavenging System	Static test rig completed. Testing in progress
Launch AGL	Careful calculations using OpenRocket simulations and adding necessary ballast to slightly over powered motor.	Design
Official Altimeter	PerfectFlight StrattoLogger	In our Possession
Recovery	A subassembly is being used to separate the Avbay, as well as two key switches each having its own LiPo battery	In our Possession and under Construction
Magnetic shielding	Using a thin metal foil to shield components	Under Construction
Subsonic flight	Our simulations have shown that this will be far under supersonic flight	Design
Reusablility	Safe landing at low velocity with low impact energy.	Design/Construction
Drogue-Main Parachute Recovery	Drogue to deploy at apogee. as well as a Main parachute to deploy at 1000ft to 700ft AGL	Design
Shear pins	Three 2-56 Nylon 6/6 screws to be used at each section.	Testing in Progress

Requirement	Fulfillment	Status
Tethered sections	We have 3 sections tethered together, Nosecone, Sustainer, Booster	Design/Construction
Launch Window	With proper pre-flight checklists we will use all minutes of the preflight time well	In our Possession
Rocket on Pad	All our components should last many hours on the pad, our batteries will last much more than a hour.	In our Possession and under Construction
Launching Vehicle	Ten second count down standard.	Standard for all launches
External launch circuitry	Only our motor will need external circuitry, which lies under the equipment needed to launch	Standard for all launches
Flight Data	We will have a person(s) that will collect the data after launch	Standard for all launches
Flight Tracking	We have a GPS tracking system and are considering adding a radio transmitter as well.	Standard for all launches
Rocket Motor	Motor in question is an Aerotech L1170 FJ-P	Final calculations will determine if this will be our motor of choice
Rocket Motor Requirements	Like stated above it is a L class motor	This motor has been certified
Full test launch	Planned for February with back up date in March	Planned

Requirement	Fulfillment	Status
Prohibited items	None of the listed items are in our rocket design	N/A
CheckList	We have an extensive checklist we have used before, and will always use	In our Possession
NAR Mentor	Tom Kernes	He has done many flights and qualifies
Payment	Budget shows we will fall short of $5000 dollars on the launch pad.	N/A

Functional Requirements

The vehicle structure is divided in to three primary sections that will be referred to as the Nosecone, the Sustainer Assembly, and Booster Assembly. The functional requirements of each are listed in Table 3.

Table 3 Vehicle System and Subsystem Functional Requirements.

System	Subsystems	Functional Requirement
Nosecone	*Primary System*	-Reduce drag force -Must not deform under flight loading -House communications array -Mount drogue parachute -Couple with Sustainer
	Communications Array	-Transmit GPS location to Ground Station
Sustainer Assembly	*Primary System*	-House recovery and avionics bays -Must not deform under flight loading -Couple to Nosecone -Couple to Booster
	Recovery Systems	-House Drogue Parachute -House Main Parachute -House Payload
	Avionics Bay	-House Flight Computers -Mount Ejection Charges -Allow external access -Mount both parachutes to bulkheads
Booster Assembly	*Primary System*	-House motor mount tube

	-Fin Mounting -Couple to Sustainer -Must not deform under flight loading -Transfer fin moment
<u>Fins</u>	-Stabilize vehicle for flight -Must not deform under flight loading
<u>Motor Mount Tube</u>	-Transfer axial motor thrust load -Mount Parachute to Engine Block -Retain motor -Allow quick installation of motor

Risk Definitions

A general assessment of risks, associated consequences and precautionary measures are enumerated in Table 4 as follows.

Table 4 Tabulated overview of risks, consequence, and Precautionary measures associated with the project.

Risk	Consequence	Precautionary Measures
Contact with Hazardous Chemicals and Materials	-Bodily Injury: Irritation, burns, and allergic reaction -Work stoppage	-Material Safety Data Sheets of all hazardous chemicals and materials will be available to and reviewed by all members. -Facilities with fume hoods will be used for caustic materials. -Protective equipment including, but not limited to, gloves, safety glasses, and filtered face masks.
Misuse of Power Tools	-Bodily Injury: Cuts, Abrasions, and Bruises -Work stoppage	-Instructions will be given prior to student use of equipment. -Experienced technicians or upper classmen must be present for all machining.
Unintentional Ignition of Igniters or Electric Matches	-Bodily Injury: Minor Burns -Fire -Lose of critical supplies	-All electric matches will be shorted together at their ends. -Proper storage in secure grounded case
Unintentional Detonation of Black Powder	-Bodily Injury: Serious Burns, and hearing loss	-Ejection charges will be filled last with flight computers deactivated. -Handlers will wear work gloves and Ear Plugs.

Unintentional Ignition of Motor	-Bodily Injury: Serious Burns, Bruises, Loss of Life -Cancellation of Flight -Property Damage	-All motors stored unloaded without igniters. -Prepared motors will not be loaded with igniters until mounted on pad. -Loading must be supervised or performed by Certified personnel.
Component Damage Through Testing	-Increased costs -Project Delays -Redesigns	-Grounded equipment used when handling sensitive electronics. -Wearing necessary and precautionary safety equipment. -Only required personnel allowed in proximity to components during testing. -Checklists utilized to ensure proper procedures during operation.
Launch and Recovery Problems	-Loss of Vehicle -Loss of Payload -Serious Bodily Injury or Death -Property Damage	-Following TRA/NAR Safety Code -Use of checklists. -Cancellation of Launch in event of adverse weather conditions. -All personnel must be at safe distance before ignition system is armed.

Dimensional Drawing of Entire Assembly

A dimensional drawing of the entire assembly is provided in Fig. 2. Further dimensional drawings of the systems therein are provided for each section.

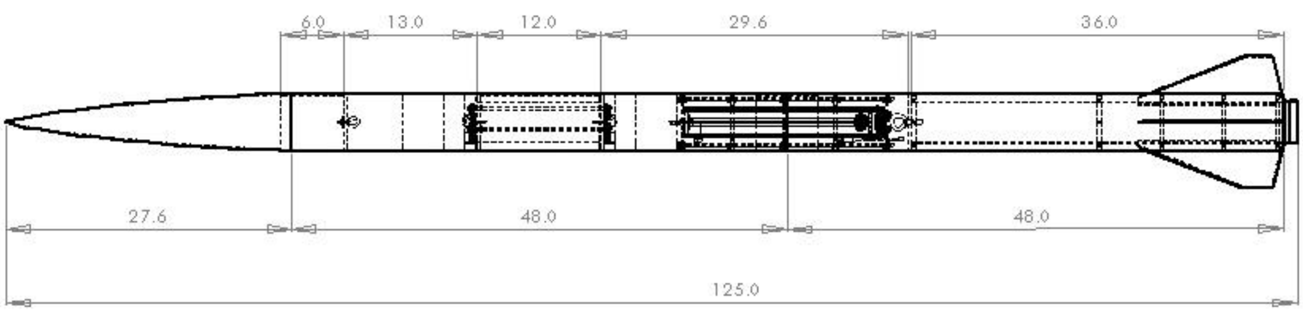


Figure 2 Dimensional Drawing of entire assembly. Dimensions are in inches.

Mass statement

Components and sections of the vehicle have been weighed for the total mass calculation coming out to 23.7 pounds mass. These measurements were performed with a digital scale to the nearest tenth of an ounce and are listed in Table 5 below. The total vehicle mass previously estimated using the OpenRocket simulation software was about 27 pounds. Several components, notable the body tubes, came out to be less dense than what was modeled in the software even after reinforcement. The OpenRocket model was originally used to predict the mass of the vehicle and motor selection. A full listing of components used in this prediction is provided in the appendix. Comparing this prediction to the weights of actual components it can be seen that the estimate erred on the high side. This was done to ensure a powerful enough motor was selected. Not included in actual measurements are the motor mass, which is given, and the actual nosecone mass because it is still being shipped. It is not expected for the lift off mass of the vehicle to increase beyond 44.2 pounds mass and it is expected that up to 4.5 pounds of ballast may need to be added.

Table 5 Table of measured and predicted vehicle section masses.

Section	Component	Weight
Nosecone	Structure + Hardware (Estimated)	4lb
Sustainer	Structure + avionics bay	7lb 9.8 oz
	Drogue + shockcord	1lb 11.2 oz
	Main Parachute + shockcord	2lb 15.2 oz
Booster	Structure + MMT + Fins + Adapter	7lb 13.8 oz
	Sub Total:	23.76 lb
Other Components		
	Motor Hardware	4lb 13.3 oz
	Propellant	6lb 2.7 oz
	Payload(5lb) + Ballast	9lb 8 oz
	SubTotal:	20.5 lb
	Lift Off Total:	44.26 lb

Nosecone

The Nosecone will be a minimum drag for the given diameter Von Kármán profile with a 5:1 fineness ratio. The dimensions are 27.5 inches in length cone with a 5.5 inch diameter base and the inside will be left hollow to allow room for tracking equipment. The materials will be a filament wound RF transparent fiberglass structure with a screw on aluminum tip. A laser cut mold was also created by the team to allow multiple nosecones to be fabricated with E-glass sheets should they be needed. Finally, a 5 inch long shoulder at the base of this and capped with a screw in bulkhead to allow fitting and tethering to the top of the sustainer section.

Currently, the nosecone is being shipped but the bulkheads and bay have already been fabricated. The team will continue working on fiberglass mold in order to improve the techniques and facilitate replacement if necessary. This is the last major component required for the vehicle before assembly is completed.

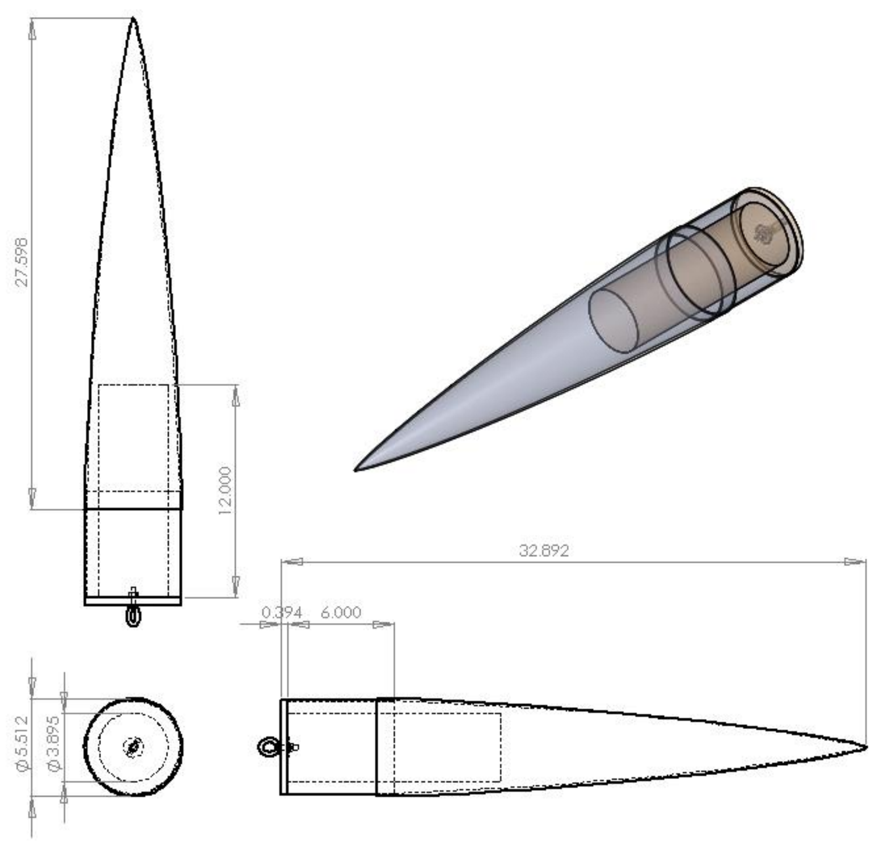


Figure 3 Nosecone drawing and model, dimensions are in inches.

Sustainer Assembly

The 4-foot long 5.5-inch diameter Body section has been constructed of Blue Tube reinforced with a fiberglass cloth for added fracture resistance and covered in a fine glass sock to create a smooth finish. The internal space will be divided into three bays. The forward bay will house the Main Parachute with 52’ of tubular nylon shock cord. It will be 13 inches long with the nosecone attached. Below the forward bay is the 12-inch long avionics bay that will be compression mounted on to a fixed coupler tube segment and house the flight computers. Finally, there will be the compartment housing the drogue parachute and the deployable payload. For maximum volume, the compartment will be open to the top of the Booster section creating a 29-inch long 5.2-inch diameter bay. An allowable 20 inches of this length have been allocated to payload volume with the remainder accommodating recovery components and hard points.

Currently, avionics bay and sustainer assembly have been completed. A counter bore was used to create a reliable sloped guide for the all thread rods of the bay to slide in to during assembly. Alignment of the rods in the sustainer may now be accomplished on the first attempt.

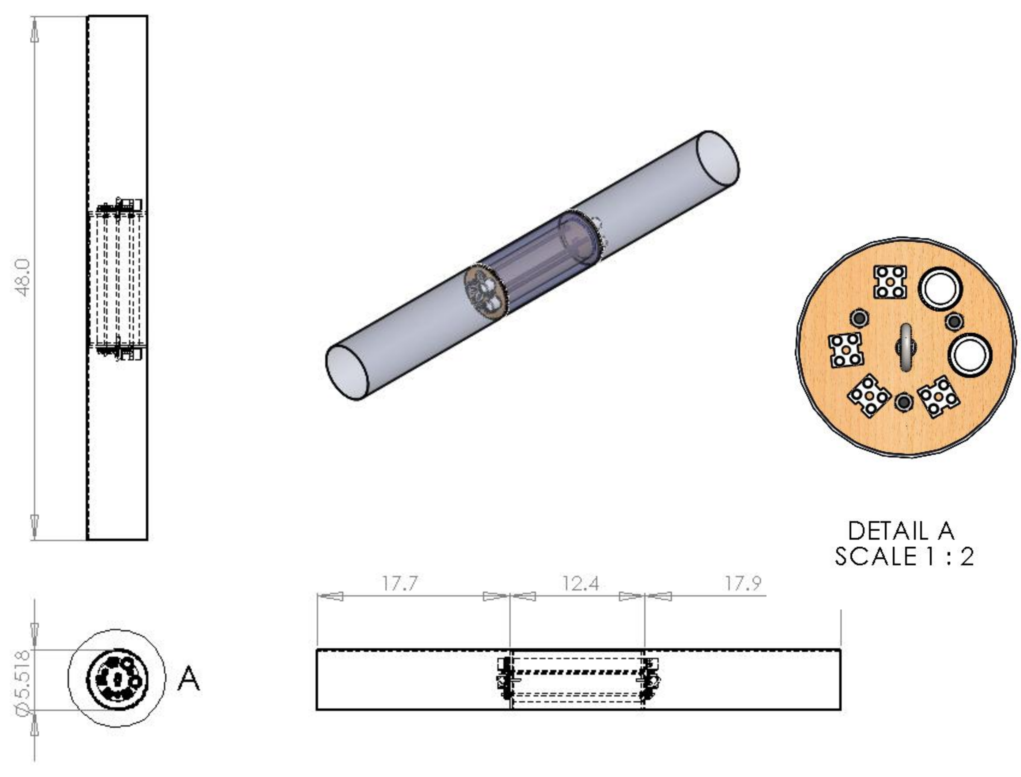


Figure 4 Sustainer Assembly with Avionics Bay. All dimensions are in inches.

Booster Assembly

The rearmost section will be referred to as the Booster and has been constructed in the same manner as the Body section before it. The two will be joined by a 6 inch coupler bonded to the Booster section. The purpose of this section is to contain and retain the motor. A 36-inch long 98-mm motor mount tube have been assembled with centering rings, engine block, and the three delta fins. Fin slots are cut in the tube and this motor mount assembly will be bonded with epoxy to the lower 36 inches of the section.

To further reinforce the connection, fiberglass fillets will be built up at the joints and overlaid with fiberglass sheets laid from fin tip to adjacent fin tip. Motors will be retained by a rear mounted cylindrical 98-mm machined aluminum Aero Pack motor retainer. This also allows a 98 to 75-mm adapter in our possession to be used to hold smaller diameter motors.

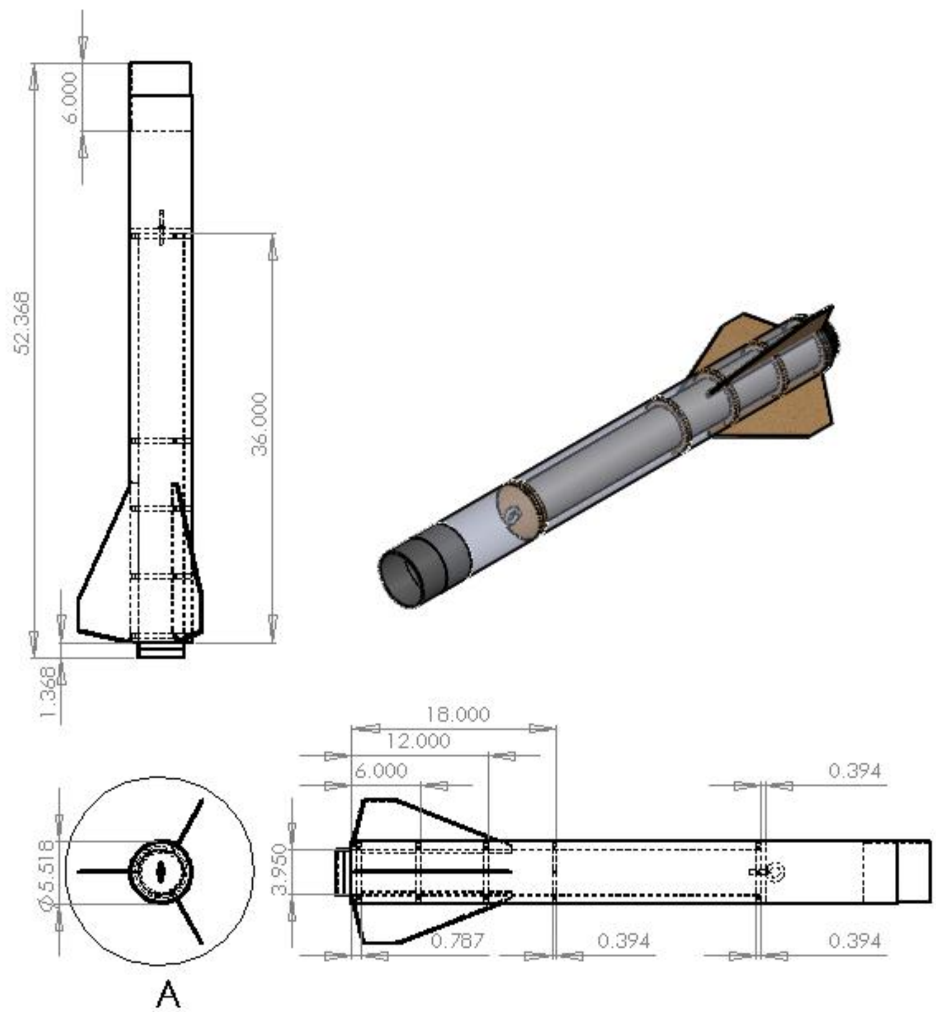


Figure 5 Booster Assembly with Fins and Motor Mount Tube. All dimensions are in inches.

The fin profiles of the rocket were designed in OpenRocket. The delta is clipped to reduce the likelihood of breaking the tips. Each fin will be made of three layer plywood. As this plywood is not reliably strong alone, each fin has been wrapped in two layers of 4-Ounce fiberglass Eglass cloth and cured in a vacuum bag. The fins are mounted without a cant angle as a spin has been deemed undesirable for the payload. Fin alignment was facilitated by matching groves cut in the fins to corresponding ones cut in the centering rings mounted on the Motor Mount Tube.

Currently, the fins have been epoxied to the Motor Mount Tube and will soon be filleted with the booster section and wrapped in a further two layers of fiberglass cloth to create a continuous structure with a solid bond.

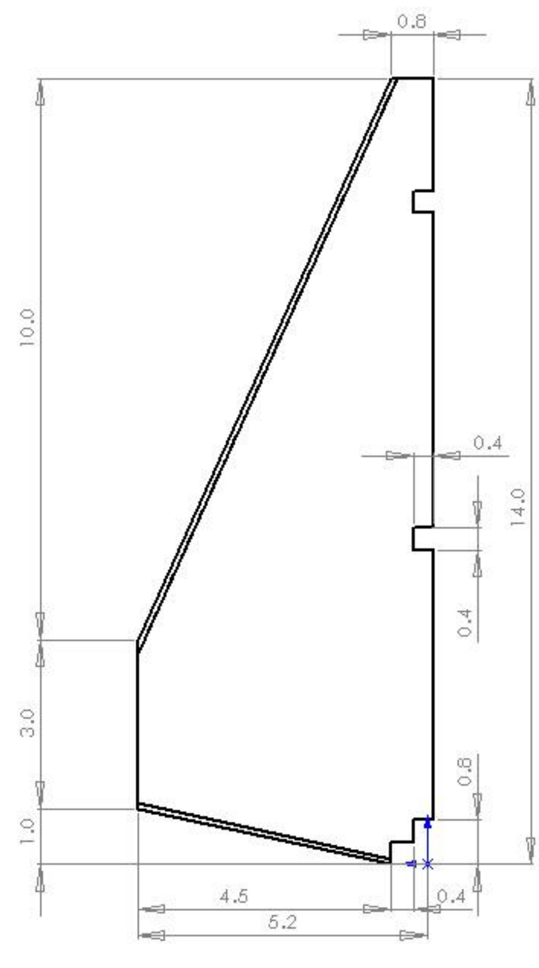


Figure 5 Fin profile. All dimensions are in inches.

The configuration of the motor mount tube allows for great versatility in motors used. It is capable of holding 98mm and 75mm (with adapter) motor hardware of all available lengths. Shorter motor casings are held in by a rear mounted retaining ring while those casings longer than 36 inches can be screwed in to the Engine Block and allowed to overhang.

Load Paths

Loads will be transferred through the shock cord, recovery hard points, all thread connecting the avionics bulkheads and motor thrust ring. Under powered flight, the motor will provide thrust that is transferred to the vehicle at the aft motor retainer, and all the way to the nosecone through the airframes shell. This is kept centered by the coupler tubes between the Booster, Sustainer, and Nosecone.

During descent and after apogee, the load will be transferred through the 1inch tubular nylon shock cord to the drogue parachute near the middle connected by a quick link. At one side this shock cord is attached at the forged eye-bolt in the engine block of the booster and the opposite holds the sustainer at a U-bolt at the bottom of the avionics bay. Load is transferred through the avionics bay by two all thread rods and to the still attached nosecone through the shear pins. After the main parachute deploys, the load is transferred through the avionics bay by the all thread to the U-bolt at the top of the avionics bay, through the shock cord attached to the main parachute at one end with the main parachute mounted on a swivel link and attached by a quick link to the nosecone and shock cord.

The use of swivel links will decrease the likely hood of tangling the parachute lines. Quick links on the parachutes and self tightening figure-8 knots connecting the hard points elsewhere will form solid connections. The recovery system hard points are reinforced with washers on eyebolts and backing plates on the U-bolts against fiberglass reinforced bulkheads.

Proper Assembly Procedures

The planned steps for assembly of the vehicle are as follows:

1. Prepare Avionics and Sustainer
    a. Prepare Main ejection charges on top Avionics Bulkhead
    b. Connect main ejection charges to flight computers
    c. Connect main parachute shock cord with quick link to top Avionics Bulkhead U-bolt
    d. Insert electronics sled in to Sustainer with top Avionics Bulkhead
    e. Prepare Apogee ejection charges
    f. Connect Apogee ejection charges to flight computers
    g. Insert Bottom Avionics Bulkhead in to Sustainer

    h. Secure with washers and nuts
    i. Connect electronics to switches mounted in hatch
    j. Replace hatch with screws
2. Prepare Nosecone
    a. Attach main parachute shock cord to U-bolt of Nosecone
    b. Attach Main parachute with quick link to Nosecone
    c. Secure tracking electronics in Nosecone (BRB 900)
    d. Secure Nosecone Bulkhead with Screws
3. Pack Main Parachute and shock cord in to forward section of sustainer
4. Fit Nosecone to sustainer with shear pins
5. Prepare Booster Section
    a. Attach Drogue shock cord to forged Eye-bolt of engine block.
    b. Attach Drogue parachute to shock cord
    c. Attach Payload release mechanism to shock cord
    d. Fit payload in to booster with shock cord bypassing through channel
6. Fit Sustainer with Nosecone over booster and secure with shear pins

Assembly Status Summary

In summary, the construction of the vehicle is nearly completed. The main tasks that need to be completed are bonding the motor mount tube and fins to the booster tube and attaching the filament wound nosecone as soon as it arrives. The team had great success in using the vacuum bag system to reinforce the blue tube based body tubes, fins and even bulkhead with fiberglass sheets. The work space used is kept open to allow the team to work on fabrication regularly. The vehicle should be ready as scheduled.

3.2 Recovery Subsystem

3.2.1 Analysis

The selection of recovery subsystems components depends on the mass of the vehicle and deployment scheme. The mass of the vehicle with the payload is important for the drogue parachute but not for the main parachute. The deployment scheme chosen for this mission is a dual deployment.

1) A Drogue Parachute will be deployed upon reaching apogee.
2) The vehicle will descend under the drogue until 1000-Feet AGL and will then deploy a larger Main Parachute from the forward bay
3) The Payload will be pushed out in front of the main parachute

The attachment scheme for the recovery systems is well defined. All vehicle components will be tethered and the payload will be tethered until deployed independently. The drogue parachute will be in the rear sustainer bay attached between the Booster and Sustainer Assembly at the bottom of the Avionics Bay. The main parachute will be in the forward sustainer bay attached to the top of the Sustainer Assembly and the U-bolt at the bottom of the Nosecone.

Required analysis pertains to the necessary FFFFg blackpowder to sufficiently pressurize the deployment bays, and the impact force experienced at the attachment bulkheads during deployment.

Required testing will involve assembly of the vehicle in the desired flight configuration and simulating a flight on a flight computer. By doing this the necessary amount of blackpowder can be determined to separate sections with shear pins. This will also verify proper programming and wiring of the flight computers.

Descent Energy

The descent energy of the vehicle has been calculated under projected descent rates after apogee in three sections and after main deployment in four sections. Most importantly, the descent energies at landing are below the limit of 75 foot-pounds force . The deployment main deployment velocity has been reduced to under 100 FPS and the landing velocity is still under 20 FPS. These calculations are tabulated in Table 7.

Table 6 Descent energy calculations with simulation descent speeds and measured section weights.

Event	Section		weight (lbf)	Speed(ft/s)	Energy (ft-lbf)
Apogee	1	Nosecone + Sustainer	10.6	77.9	998.8
	2	Booster	12.6	77.9	1187.3
	3	UAV(Tethered)	9.5	77.9	895.2
Main 1000'	1	Nosecone	4	18	20.1
	2	Sustainer	6.6	18	33.2
	3	Booster	12.6	18	63.4
	4	UAV(Released)	9.5	5	3.7

Drift Calculations

Dual deployment of the parachutes will reduce descent time and therefore drift of the vehicle from the launch pad after apogee. By launching slightly in to the wind the drift distance may also be reduced at the cost of altitude. Calculations involved in drift assume that wind speed is the same at all altitudes. By reducing the altitude at which the main parachute is ejected it can be shown that drift from the pad may be reduced, for the range of wind speeds in question, to fall within the limit of half a mile from the pad. Notably, at 20MPH wind conditions it is necessary to reduce the main deployment to 500 feet AGL to reduce drift sufficiently.

Table 7 Tabulated drift calculations

DescentTime (s)	Wind Speed(MPH)	(Ft/s)	Drift Distance(ft
(1000' Deployment)			
108.1	0	0	0
108.1	5	7.3	792.7333
108.1	10	14.6	1585.467
108.1	15	22	2378.2
(500' Deployment)			
88.1	20	29.3	2584.267

Proper mitigation of drift in 20 MPH winds with a 2MPH variance is also supported by the OpenRocket simulation with the vehicle launching with a 1 degree inclination in to the winds. The vehicle is predicted to land within half a mile of the launch pad with both methods.

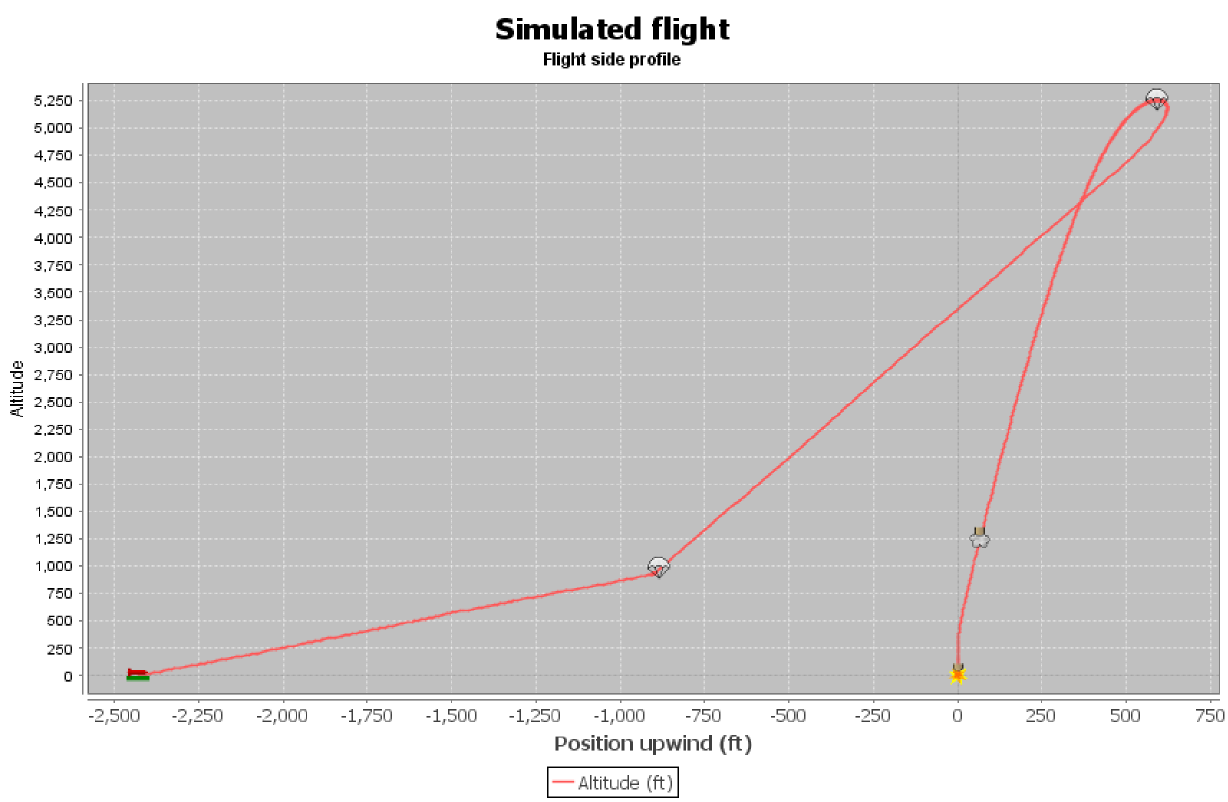


Figure 6 OpenRocket simulation drift data in 20MPH winds.

3.2.2 Major Components

Table 8 Major components of recovery subsystem

Component	Characteristic Dimension	Comment
Main Parachute	108”	24” Spill hole
Drogue	24”	X-Form
Shock Cord	52’	1” Tubular Nylon
Nomex Wadding	24”	

All attachment points of the recovery systems to the vehicle will be forged steel u-bolts or eye-bolts. These will be properly secured with nuts and washers or backing plates to distribute the loads experienced during recovery. Each bulkhead will be one half inch thick plywood reinforced with fiberglass. Self tightening figure eight knots will be used to

3.3 Mission Performance Predictions

3.3.1 Mission Performance Criteria

Criteria for a successful mission are as follows: The launch vehicle must reach an altitude of 5,280-Feet above ground level, use a dual deployment recovery system, deploy a payload at 2,700-Feet above ground level, and recover all components in a re-launch able condition.

3.3.2 Simulation Data

What follows are the dimensions and models used in OpenRocket simulations. Predicted weights therein are tabulated in the appendix. The motor used in the simulation is an Aerotech L1170 FJ. The Propellant used is the Fast Jack formulation of APCP.

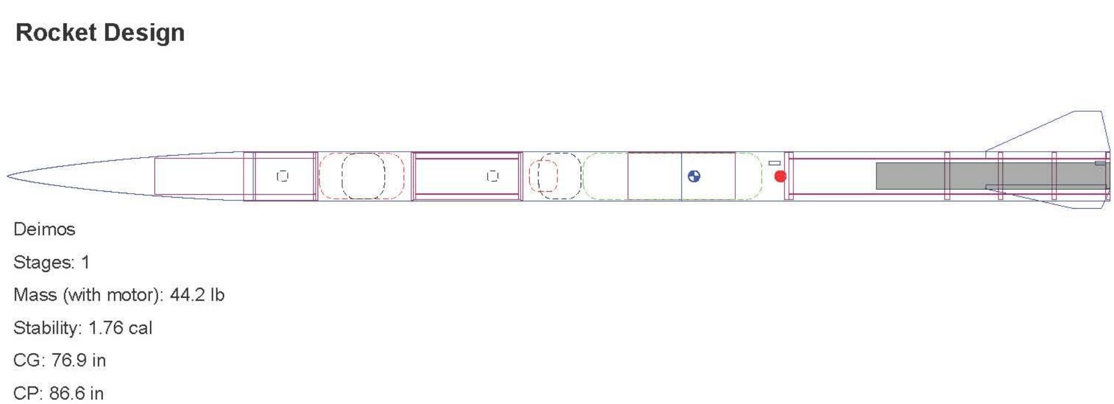


Figure 7 OpenRocket model of vehicle with selected motor and 9.5lb payload.

Table 9 Candidate motor evaluated in simulation.

Altitude	5280 ft
Flight Time	128 s
Time to Apogee	18.8 s
Velocity off Pad	53.3 mph
Max Velocity	408 mph
Landing Velocity	12.1 mph

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
L1170FJ	1207 N	3.49 s	1473 N	4214 Ns	6.14:1	6.17 lb	75/665 mm

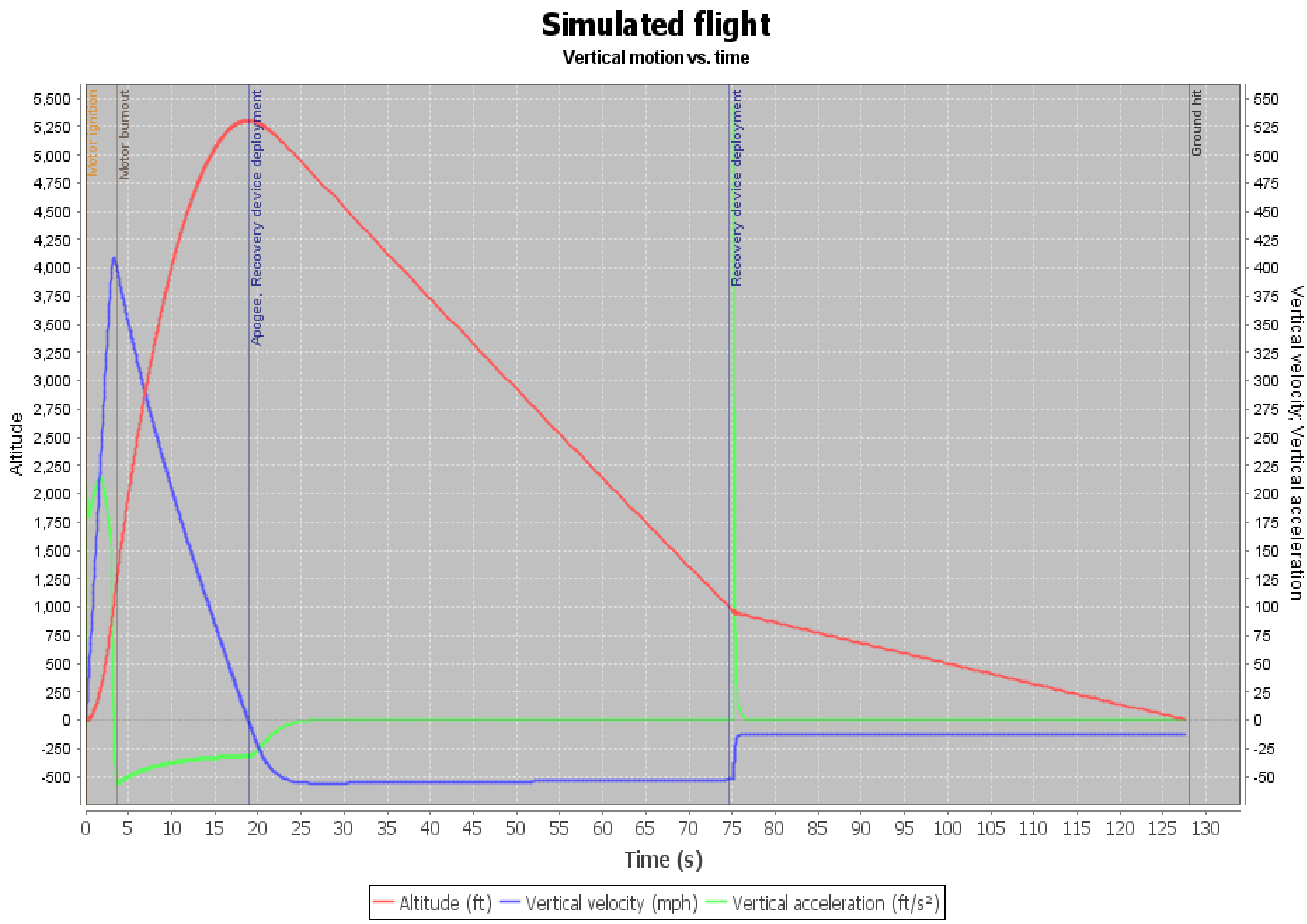


Figure 8 Vertical motion vs. Time. (Altitude, Velocity, Acceleration)

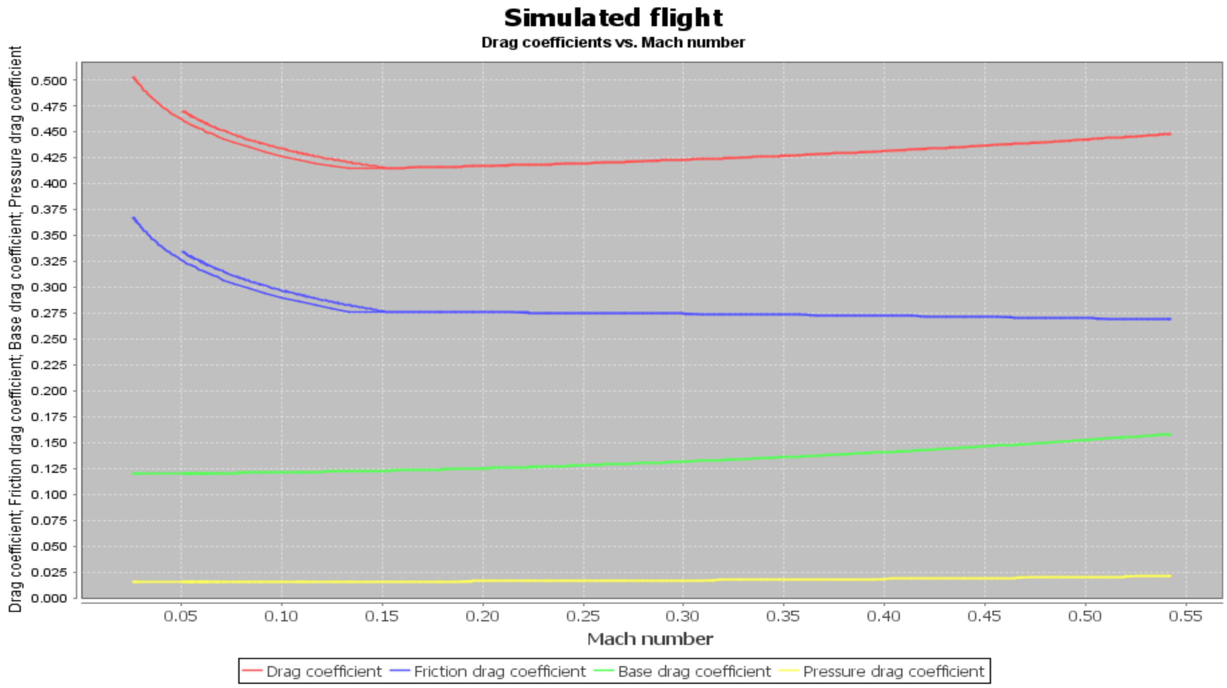


Figure 9 Drag coefficient of vehicle up to expected mach number.

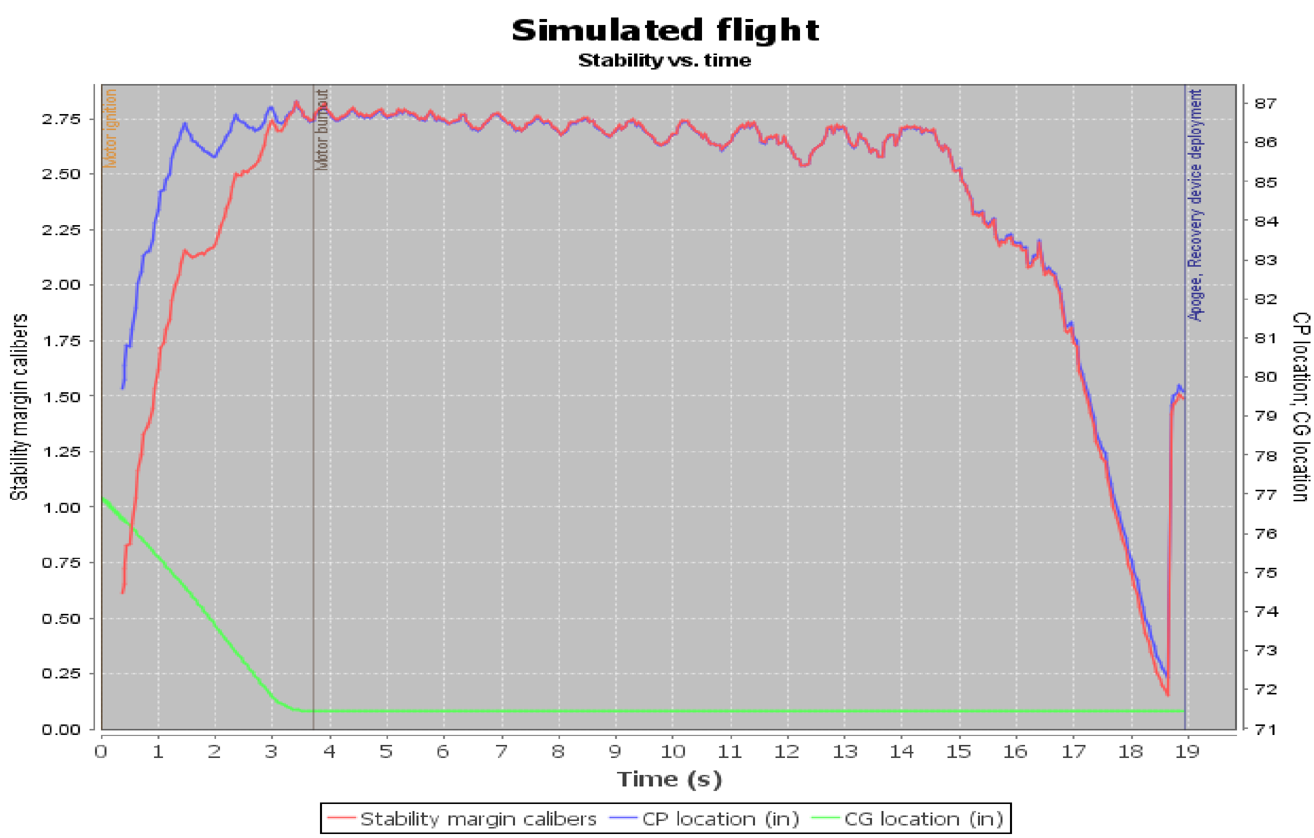


Figure 10 Stability margin of vehicle throughout flight.

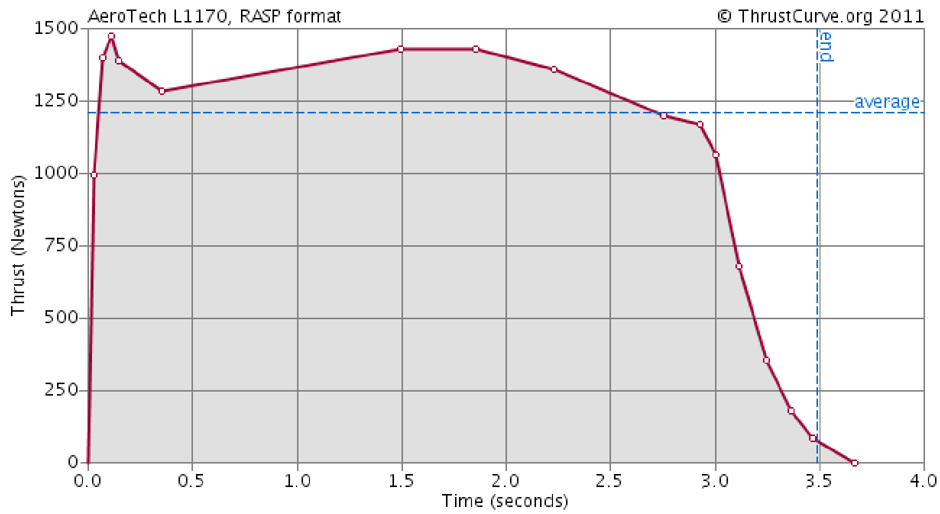


Figure 11 Motor Thrust Curve

The conclusion drawn from this simulation is that the L-1170 FJ motor has more than enough impulse for the mission at hand. Considering the payload will weigh less than 9.5 pounds and the vehicle itself will not grow beyond earlier predicted masses, it is then likely that ballast will need to be added to adjust the altitude toward the goal. This is a desirable situation as it is harder to take weight off than to add it anyway. The change in motor is largely in response to the vehicle weight being previously over estimated. Large components such as the reinforced blue tube airframe turned out to weigh several pounds less than predicted. Other components, such as electronics and recovery components were also previously predicted to weigh more. All these factors add up a motor with lower total impulse being more desirable for the mission. Anything larger would increase the chance of over shooting the altitude goal.

Otherwise, it is shown that the total drag coefficient of the vehicle remains below 0.5 throughout the flight for this simulation. It decreases to 0.45 at peak velocity and the largest contribution to drag is from friction. The base drag could be reduced by adding a boat tail to the rear of the vehicle but advantages would be reduced by the resulting increase in surface area and the reduction in stability. Larger fins would be needed in that case because the boat tail would shift the center of pressure forward. It can also be seen that the vehicle maintains a fair margin of stability all the way through the ascent of the flight. This is very desirable as over stability can cause wind cocking and loss in altitude or even tumbling and deployment issues.

The vehicle design seems suitable as is with this motor. The results here will be evaluated by the first full-scale test launch in February. If it becomes apparent that the vehicle doesn't perform as predicted then a different motor will be tested in March. Otherwise, the vehicle will go through a full test on the currently selected motor in March.

3.4 Interfaces and Integration

3.4.1 Avionics

The flight computers will have an interface between both the upper and lower avionics bay bulkheads as well as to the exterior of the vehicle through a removable hatch or panel. At the upper bulkhead there will be four wiring terminals allowing both computers to have two connections each to a primary and secondary drogue ejection charges. At the upper bulkhead there will be four wiring terminals allowing both computers to have two connections each to a primary and secondary main parachute ejection charges. Secondary charges will be set to fire five seconds after the primary charges. This allows for each computer to have double redundancy and be redundant with one another.

The avionics bay hatch will allow the flight computers to be activated from outside the vehicle by way of locking key switches. The communications system will transmit to the ground station laptop connected receiver at 900 MHz. This will send GPS data allowing the vehicle to be tracked and recovered and the GPS flight data to be logged.

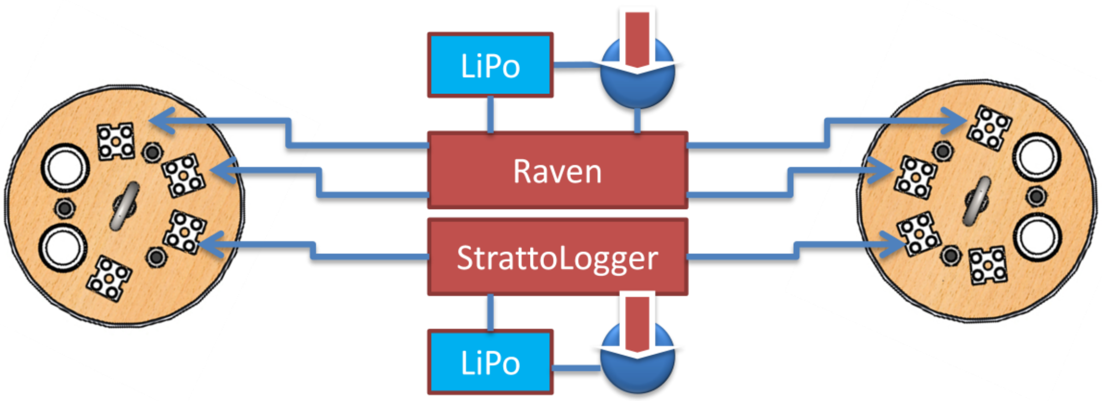


Figure 12 Block Diagram of Avionics connections.

3.4.2 Payload

The payload must be designed so that it doesn't adversely affect the launch vehicle. So it must not interfere with the main parachute deployment. It must weigh less than the allowed weight the motor is capable of lofting to the required altitude. It must not shift the center of mass of the vehicle from the central axis. It must be strong enough to survive the launch and ejection events.

The basic requirements for integration include system initialization, fitting clearance, and place in main parachute bay loading order. As the Payload is a fully independent system it must be activated and powered by itself prior to loading. As the payload may expand beyond the bay's diameter it must be locked in to a collapsed state to prevent interference during ejection. As it occupies the same bay as the main parachute there is a very specific order that must be followed when the payload is integrated with the launch vehicle. In short, the operations of integration are:

1) Powered on, systems initialized and communicating with ground station
2) Collapse wings in to undeployed state
3) Parafoil secured to payload airframe and packed
4) Parafoil inserted in bay below main parachute
5) The payload airframe inserted below parafoil with enough clearance for shock cord to top of booster assembly
6) Booster section slid over payload and coupled to bottom of sustainer section
7) Shear pins inserted in to coupler between sustainer and booster sections.

3.4.3 Launch System

The vehicle will be mounted with rail buttons on a 15-Series 80/20 based launch rail. The total length of the rail is 12-Feet and is figured in to all simulations. The vehicle's motor will be ignited remotely by a launch ignition system provided by The Heartland Organization of Rocketry.

3.5 Launch Operation Procedures

Flight Computers

Verify flight computer configurations ___
Replace Flight Computer Batteries ___
Check Battery Voltage ___
Check Flight Computers ___
Wire E-Matches ___
Set Charges ___

GPS

Activate/check battery voltage ___
Connect Antenna to receiver ___
Mount Antenna ___
Connect Receiver to laptop Serial connection ___
Confirm GCS Link ___
Place transmitter in casing ___
Insert in Nosecone communication bay ___

Avionics Bay

Replace Electronics bay in airframe ___
Rewire Flight computers to key switches ___

Recovery System

Insert Nomex wadding ___
Prepare main parachute ___

--Fold ___
--Place in bag ___
--Gather Shroud Lines ___
--Connect to bottom of AV-Bay ___
--Place in rear bay ___

Connect drogue chute to nosecone ___
Place drogue in foreword sustainer bay ___
Gather shock cord in airframe ___
Position nosecone ___
--Insert shear pins ___

Payload

Activate Experimental Payload ___
Insert Experimental Payload in rear bay ___
Position Sustainer on Booster ___
--Insert shear pins ___

Loading Motor

Place Motor in motor mount tube ___
Lock engine retainer ring ___
Insert igniter rod through center of engine grains to top ___
Tape igniter rod into place ___
Visually confirm ignition system disconnected (saftied) ___
Unshort leads ___
Connect to ignition system ___

Launch Procedure

Activate Flight Computers ___
Clear launch pad ___
Confirm continuity ___
Signal launch readiness ___

The launch rail previously used by the UNL Rocketry Team is a 12-Foot tall 15-Series 80/20 guide rail (Fig.6). Guide rail buttons are used to mount the vehicle on to this rail. The ignition system used for testing is provided by The Heartland Organization of Rocketry.

Figure 13 The 15-Series 80/20 launch rail used by The Heartland Organization of Rocketry

Our previous idea for a rocket launch pad was to use The Heartland Organization of Rocketry (THOR) launch pad. We came together and decided that owning our own launch pad would be a better idea. We also decided on a design for the launch pad made of mostly 80/20 aluminum featured on the 80/20 website. Ordering of parts for this launch pad will be completed in January and construction of this should begin in February.

3.6 Safety and Environment (Vehicle)

Safety Officer: Paul Kubitschek

Table 10 Vehicle failure modes and mitigations.

Possible Failure	Effect of Failure	Mitigation
Catastrophic explosion either on the pad or in flight	The possible destruction of the rocket and/or pad	Properly load motor by qualified personal
Fins shear off of airframe	Loss of stability crashing of vehicle is imminent	Proper fins should be constructed
Failure of airframe separation	Rocket comes down at high velocity, possible tumble, or nose dive	Make sure ejection charges are properly packed as well as shear pins
Parachute failure	Parachute becomes tangled in cords and possible destruction of vehicle	Properly load parachute in parachute bag and properly place in airframe with shock chords
Loss connection to radio tracker	Rocket may become lost	Make sure radio equipment is securely attached, charged and highly visible

Before construction the people in our group have read and reviewed the NAR safety codes. These safety guides give all the needed details for proper construction and operation of high power rockets. Safety in our team is very important and we take all precautionary measures to protect personnel from injury. Our team doesn't use many chemicals for our rocket as our motor is pre-made, but we do use other chemicals that release toxic fumes. For this we have a well ventilated room (Large overhead Fume), as well as face masks.

4.0 Payload Criteria

4.1 Selection, Design and Verification of Payload Experiment

4.1.1 System Level Overview

The deployable payload will be designed to separate fully from the rocket and descend under a parafoil. The structure will house an experimental energy scavenging system, which will autonomously activate shortly after separation and will collect and transmit data throughout descent. The relevant systems are as follows:

1) Airframe
2) Experimental ambient wind energy scavenging system

Payload Airframe Functional Requirements

Performance Characteristics:

The airframe must strong enough to be suspended from a parachute, stable during flight and fit within the launch vehicle. The payload airframe will be designed to house the experimental ambient wind energy scavenging system. The design must allow for the wind belts to be oriented in the direction the vehicle is traveling. It will be required to protect the required electronics during ejection from the launch vehicle, aerodynamic forces and impact at landing.

Options:

1) Horizontal Deployable Windbelt
2) Vertical Static Windbelt

Selection Rational:

The structural housing the payload electronics on bulkheads and parachute attachment is common between all considered options, but the method by which the windbelts are oriented is more variable. Thus, the criteria for selection involve maximizing the effectiveness of the windbelt system. This enables the experiment to be optimally performed. So, the option that allows the windbelts to be most easily oriented in to the wind will be chosen.

Selected Concept:

The selected concept is the Horizontal Deployable Windbelt. Having the windbelt mounted on a fold out wing allows greater control of the windbelt orientation. A vertically mounted windbelt would not be able to angle downward. The wing will be allowed to rotate around its hinge mounting. As the payload will be descending vertically and translating horizontally the vector of the incoming airstream will be directed up and to the rear of the payload. Thus, it is advantageous that the windbelt may be angled downward. The selected payload design can be seen in Fig. 14 below.

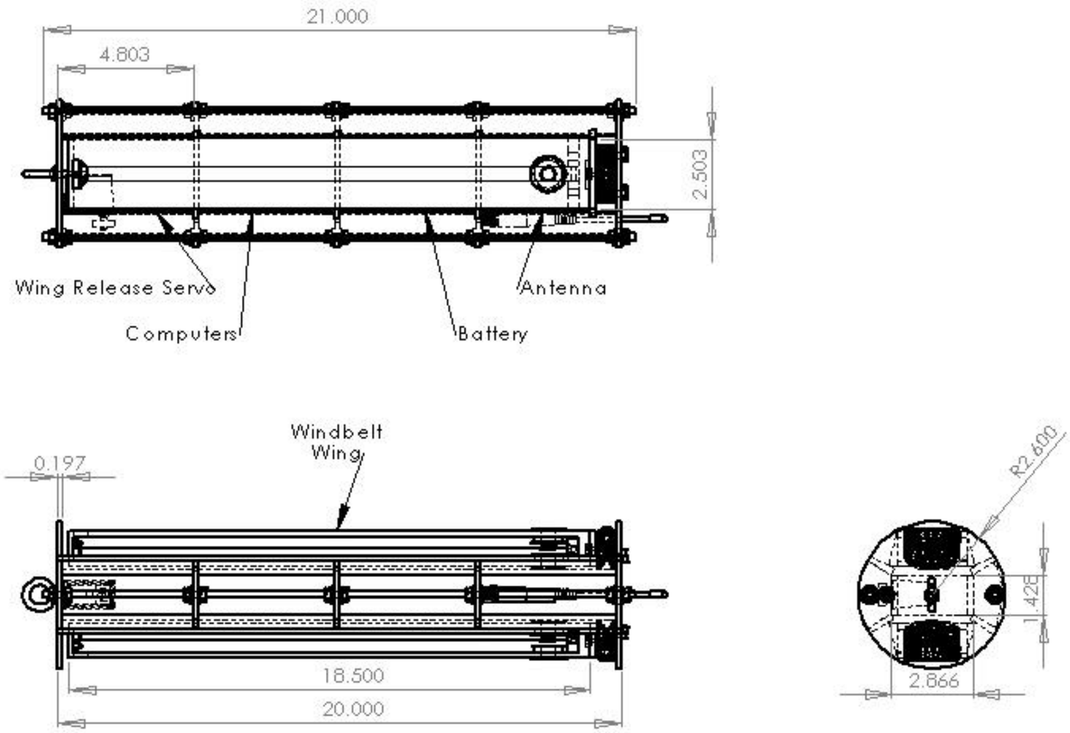


Figure 14 Selected Payload Design with deployable wings. All dimensions in inches.

Experimental Ambient Wind Energy Scavenging System Functional Requirements

The ambient wind energy scavenging system consists of two rigid wind structures that unfold outward from the main payload body shortly after the payload is deployed from the rocket (Fig. 16). Each wing structure supports a separate wind belt assembly (Fig. 15). This consists of a flexible ribbon with a permanent magnet attached to the ribbon at each side. During descent, the motion of the ribbon due to the wind moving past the wings causes the magnet to move relative to two copper coils. This induces a voltage in the coils in accordance with Faraday's Law.

Figure 15 Wing structure with embedded windbelt assembly.

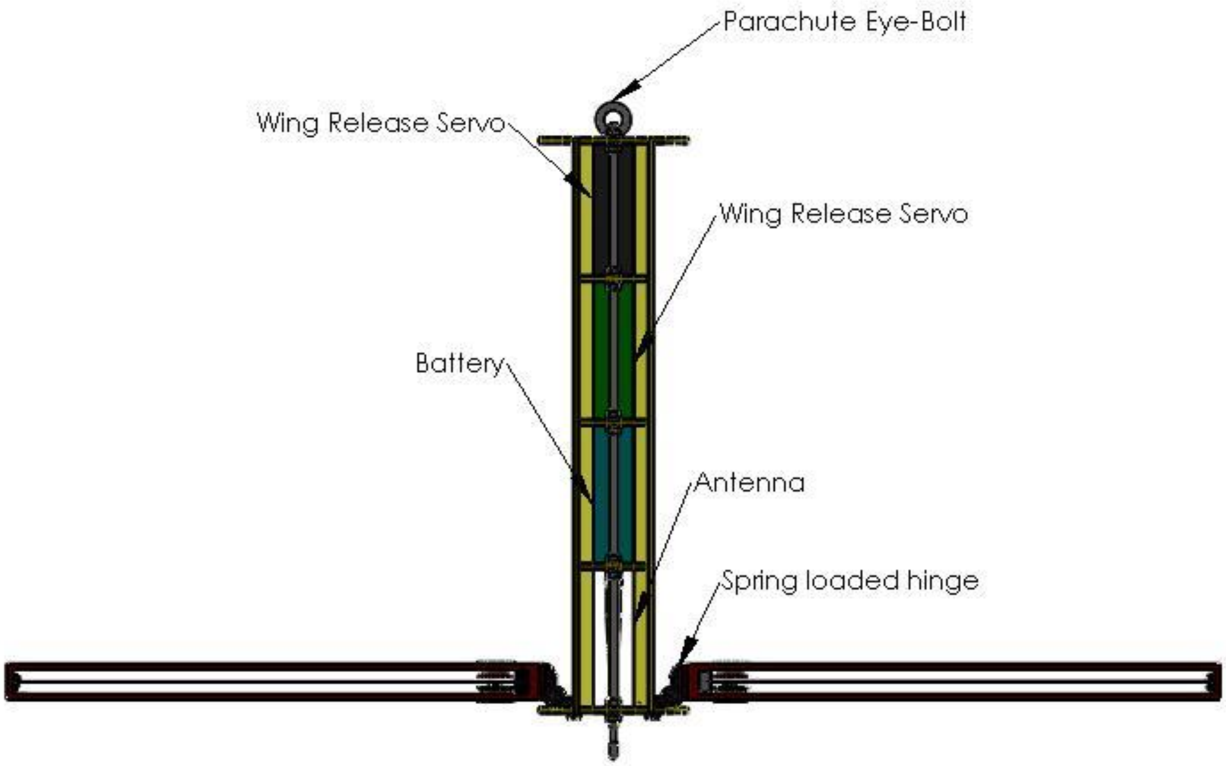


Figure 16 Deployed profile of payload and compartment assignments.

We propose that the power generated by a windbelt system is a function of the oscillation mode of the ribbon excited by the incident airflow. To investigate this, an active control system will be used to adjust the tension in *one* of the windbelts at regular intervals throughout descent. The other windbelt will serve to provide a baseline to which we will compare the performance of the primary windbelt. The belt tension required to optimize the windbelt motion for a measured wind speed will be determined through pre-flight tests.

Performance Characteristics:

The active belt tension control system will be required to autonomously adjust the tension in one of the windbelts beginning shortly after the wing structures are locked into place and terminating shortly before wing retraction. In addition, the magnitude of the voltage generated by each windbelt will be transmitted to the ground station computer every five seconds throughout this time period.

Subsystems:

The main subsystems necessary to accomplish the payload objective are as follows:

1) **Primary and secondary windbelt systems.** Each is supported by one of the wing assemblies that fold outward from the payload body shortly after separation from the rocket. Each windbelt system is identical and symmetric. The key components of this subsystem are as follows:

    a. Windbelts (taut membranes of mylar-coated taffeta)
    b. Permanent magnets
    c. Copper coils

    Evaluation and verification consists of demonstrating that a voltage is induced in each copper coil due to motion of the ribbon and magnet. This is determined by connecting the ends of each coil to an oscilloscope.

2) **Active windbelt tension control system.** This subsystem autonomously controls the tension in the primary windbelt in order to maintain a resonance condition with the incident airflow. The wind speed is read and the adjustment made every three seconds during the time that the wing structures are unfolded. The key components are as follows:

    a. Arduino Nano microcontroller
    b. Geared servo motor

    Evaluation and verification consists of demonstrating that the microcontroller can control the servo motor to loosen or tighten a belt based on an input wind speed and a hardcoded lookup table.

3) **Sensors and transmitter.** This subsystem provides information to the microcontroller about the wind speed, as well as acquires and transmits altitude and GPS data to the ground station computer during flight. The key components are as follows:

    a. Anemometer
    b. Altimeter
    c. GPS
    d. Transmitter

Evaluation and verification consist of conducting benchtop tests of each sensor and comparing the acquired data to know values. The operation of the transmitter will be verified by attempting to transmit data over progressively longer distances.

4) **Power conversion system.** The voltage generated in the copper coils must be combined, rectified and smoothed before it is sent to the analog input of the microcontroller for measurement. This will be accomplished using a power conversion circuit board containing the following components:

a. Operational amplifier summing circuit
b. Full-wave rectifier and smoothing circuit

Each circuit will be verified individually before they are combined. The complete circuit will then be tested on a breadboard before the final version is transferred onto a PCB. Finally, the PCB will be tested before it is integrated into the remainder of the payload system. A basic block diagram of the power conversion system is shown in Fig. 17:

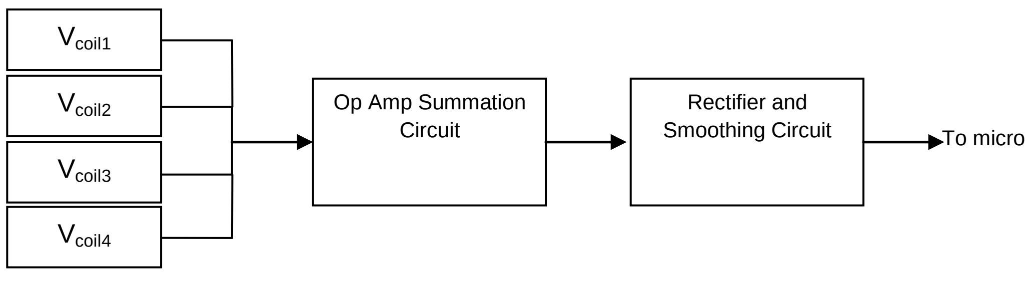


Figure 17 Block diagram of power conversion system.

The block diagram in Fig. 18 shows how the subsystems and key components will work together to achieve the payload objectives.

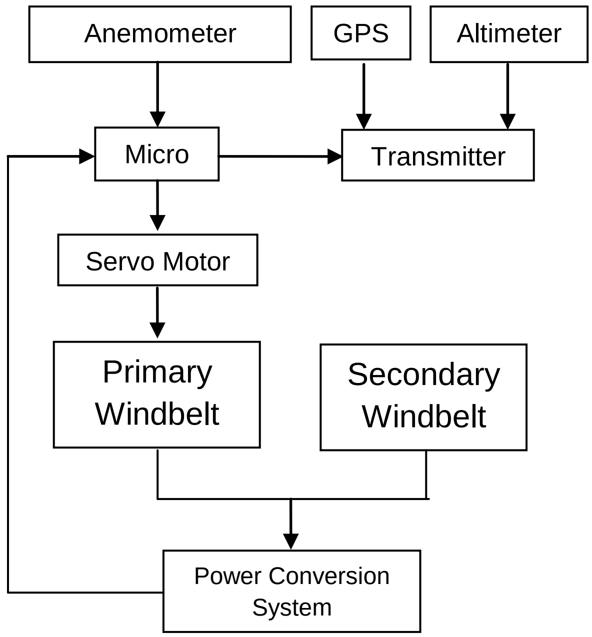


Figure 18 Interaction of subsystems and key components.

4.1.2Verification Plan and Status

Table 11 Summary of verification plan.

Payload Requirement	Design Feature	Verification Method	Status
Payload deploys from rocket	Ejection charge	Testing	Pending
Payload parafoil deploys	Order of Parachute Packing	Testing	Pending
Wings unfold	Retractable Cable	Testing	Pending
Resonance condition maintained in primary windbelt	Active tension control system	Testing/Analysis	Pending
Generated voltage transmitted every 5 seconds	Power Conversion & Transmitter System	Testing/Inspection	Pending
GPS and Altitude data transmitted every 5 seconds	Sensor & Transmitter System	Testing/Inspection	Pending
Wings retract	Retractable Cable	Testing	Pending

4.1.3 Preliminary Integration Plan

The basic requirements for integration include system initialization, fitting clearance, and place in main parachute bay loading order. As the Payload is a fully independent system it must be activated and powered by itself prior to loading. As the payload may expand beyond the bay's diameter it must be locked in to a collapsed state to prevent interference during ejection. As it occupies the same bay as the main parachute there is a very specific order that must be followed when the payload is integrated with the launch vehicle. In short, the operations of integration are:

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6) Booster section slid over payload and coupled to bottom of sustainer section
7) Shear pins inserted in to coupler between sustainer and booster sections.

4.1.4 Repeatability of Measurement

If this experiment were repeated several times, each collected dataset would be expected to vary greatly from one test to the next. This is because the generated voltage is a function of the wind speed encountered, and this is in turn dependent on environmental conditions. However, the general trend of the data would be expected to remain the same from one test to the next. For example, if it was determined in one experiment that the average generated power from the primary windbelt was significantly greater, about the same, or significantly less than the average generated power from the secondary windbelt, we would expect this general relationship to hold if the experiment was repeated.

4.1.5 Recovery System

The components of the recovery system simply include a parachute and the necessary hardware to attach it to the payload airframe. A Ram Air Parafoil was chosen to allow the payload to gain a horizontal velocity that would provide ample airspeed to feed the windbelt energy scavenging system. The nature of a Parafoil makes it difficult to determine the descent velocity because of its ability to gain lift. The controllability of the parafoil does allow us to set the payload into a spiraling descent that would be advantageous for the mission. The Parafoil would be connected to a swivel link to an eye-bolt at the top center of the Payload Airframe. A slider over the shroud lines will be employed to slow the parachute opening.

4.2 Payload Concept Features and Definition

4.2.1 Creativity and originality

While the use of energy scavenging schemes is in itself not novel, the windbelt ambient wind energy scavenging system that we propose is unique in several ways. Firstly, we will demonstrate the use and autonomous control of such a scheme on an airborne system. While it is relatively straightforward to install and maintain such energy scavenging devices on the ground, it is not immediately obvious whether such a system is practical to use on an aircraft. In addition, while the basic operating principle of a windbelt may, at first glance, appear simple, it is difficult to tell when such a system is optimized. In this experiment, we take a systematic approach to determining which factors affect the system's performance and the interrelationships between these factors.

While most modern windbelt energy scavenging systems are designed to generate electricity over a range of wind speeds, the performance is not optimized over this range. Our unique design will investigate the use of an active belt tuning system that aims to optimize the windbelt performance as the wind speed varies. This will be discussed in detail in later sections. In addition, bearings at the base of the UAV's wing assemblies (designed to support the windbelts, magnets, and coils) will be employed to passively orient the windbelts in the direction of maximum wind speed.

4.2.2 Significance

Since only one of two windbelts on the UAV will utilize the tuning scheme, the collected data (generated voltage, transmitted at regular intervals throughout UAV descent) will allow us to determine whether the performance of a windbelt system is significantly improved by using such active controls. It is important to determine whether the improvement in performance is considerable enough to justify the use of the active control system, which itself requires power to operate.

If this is found to be true, this may have significant applications to the improvement of ground-based windbelt energy scavenging systems used for power generation in developing countries, as well as those on airborne systems, which many be used to power various sensors and instrumentation on board the aircraft.

4.2.3 Suitable level of challenge

This experiment involves many challenging aspects. Primarily, many pre-flight tests must be conducted to investigate a variety of design options, ranging from the characteristics of the windbelt itself, to the magnet strength and placement. Various tradeoffs must be carefully considered, including those between such factors as the number of turns in the copper coils, magnet strength, belt tensile strength and weight of the wing assemblies and overall structure. Detailed testing must be carried out to accurately relate wind speed, belt tension, and belt oscillation modes. The accuracy of this empirical model will be crucial to the success of the active windbelt tuning system.

In addition, the mechanical challenges of designing, assembling and deploying the payload and wing structures, materials and weight considerations, the development of the software necessary to autonomously control the energy scavenging system throughout descent, and the transmission of voltage, GPS, and altitude data at regular intervals all pose a significant challenge to our team.

4.3 Science Value

4.3.1 Payload Objectives

The main objective of the payload is to analyze the effectiveness of an active control system for maximizing the power output of a windbelt energy scavenging system. Other objectives include investigating the relationship between various factors affecting the windbelt system's performance, and determining the practically of using such an energy scavenging scheme on an airborne system.

4.3.2 Success Criteria

Payload success criteria are as follows:

1) Payload is deployed successfully from rocket (complete separation, proper orientation)
2) Payload parafoil deployed successfully
3) Successful deployment and locking of windbelt wing assemblies following payload separation
4) Windbelt active control system autonomously adjusts tension in primary windbelt every three seconds beginning shortly after wing assemblies deploy and terminating prior to wing assembly retraction
5) Analog voltage from both primary and secondary windbelt systems is transmitted to ground station computer every five seconds beginning shortly after wing assemblies deploy and terminating prior to wind assembly retraction
6) Altitude and GPS data transmitted every five seconds from deployment to landing
7) Retraction of windbelt wing assemblies at a predetermined altitude prior to landing
8) Collected voltage data allows for a conclusion to be drawn regarding the effectiveness of the windbelt active control system

4.3.3 Experimental Logic, Approach, and Method of Investigation

Experimental Logic

In a basic windbelt system, a flexible belt is caused to oscillate by incident airflow. A permanent magnet attached to the belt moves relative to a conducting coil, thereby generating a voltage in the coil. We propose that the amount of power generated is strongly dependent on the mode of vibration of the belt. In particular, we believe that the generated power is maximized when the belt oscillates at its fundamental frequency. This will occur when the vortex shedding frequency of the airflow is matched to the fundamental frequency of the belt.

Approach

The goal of the experiment is to investigate whether the amount of power generated by a windbelt can be maximized by using an active control system to maintain the fundamental mode of vibration in the belt, even as the wind speed varies throughout descent. Tests will be conducted to directly relate an observed wind speed to the resonance frequency of a belt at a given tension. The details of this are discussed in the next section. Recalling that the fundamental frequency of a string is determined by its length, tension, and mass per unit length, we will also conduct tests to determine the analytical relation between these parameters for the belt used.

Based on this approach, the active control system will be designed to maintain the resonance condition between the vortex shedding frequency for a measured wind speed and the belt fundamental frequency by periodically adjusting the belt tension. The logic flow is shown graphically in Fig. 19.

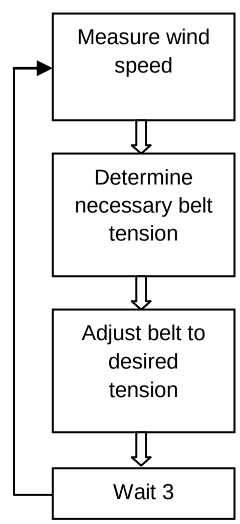

Figure 19 Logic flow of active belt tensioning system.

Investigation Method

In order to investigate our hypothesis, the UAV will have two separate wing assemblies, each with an independent windbelt system. The systems will be identical and symmetric. The "primary system" will utilize the active control mechanism to maintain a resonance with the incident airflow, while the "secondary system" will not. The voltage obtained from both windbelts will be transmitted to the ground station every 3 seconds throughout descent. The resulting data will be processed post-flight and analyzed for trends indicating higher power generation for the system which utilizes the active control mechanism versus that which does not.

4.3.4 Test and Measurement Methods, Variables, and Controls

Pre-Flight

Extensive testing will be carried out prior to launch. The goal of several of these tests will be to investigate design options. This will include testing various belt widths, magnet weight and strength, and magnet placement. In these tests, the belt tension and wind speed are kept constant and the oscillation modes and power generation are observed by measuring the resulting voltage waveform with an oscilloscope.

We will also carry out testing that will allow us to predict relationships between various variables of interest. These include the following:

1) Relationship between wind speed, belt tension, and belt fundamental frequency
2) Relationship between length, tension, mass per unit length, and oscillation frequency of belt

In the first case, we will vary the tension of a belt and apply a variable wind speed until the fundamental oscillation mode is observed for each tension. This will be determined both by visual observation and by monitoring the output voltage waveform. Wind speed will be controlled using a fan run by a variable speed motor.

In the second case, a belt of fixed length and mass will be adjusted over a range of tensions and excited by plucking. The resulting frequency of oscillation will be measured by looking at the frequency of the resulting voltage waveform. The data will be compared to the analytical model of oscillation modes on an elastic string.

In-Flight

Throughout the payload descent, voltage generated by each of the symmetric windbelt systems will be converted to DC using a full wave rectifier circuit, and then measured using an Arduino Nano microcontroller. The measured values will be transmitted to the ground station computer every five seconds. Post flight, the power output data for the actively controlled windbelt system will be compared to that of the secondary system. This secondary system represents the control variable of the experiment. The average power output of the secondary system will give us a baseline value for the generated power. This value will allows us to determine whether or not the use of the active control system improved the windbelt system's performance.

4.3.5 Relevance of Expected Data

The expected data will allow us to determine whether the performance of a windbelt system depends on the oscillation mode of the belt, and whether such a system's performance may be optimized by utilizing an active control scheme to tune the belt to the resonant frequency of the incoming airflow. Clearly, an active control system requires power to operate, and the question to be answered is whether the gain in generated power is significant enough to justify the use of such a system. While our system is mainly a proof-of-concept, a larger system that generates relatively large amounts of power may be able to produce several times the amount of energy by employing a tuning scheme. In such a case, the power necessary to run the control system would be far outweighed by the gain in energy output.

4.3.6 Accuracy and Error Analysis

The expected voltage data will have relatively small values (on the order of mV), so that we anticipate a moderate amount of noise to be present in each measurement. However, since we are only interested in overall trends and the relationship between the data for the primary and secondary windbelts, this should not be a problem. Each dataset will be averaged post flight, and these average values will be compared to determine whether there was a significant difference in power generation between the two systems.

4.3.7 Preliminary Experimental Process Procedure

The experimental process procedure for the in-flight energy scavenging system test will be as follows:

1) Visually confirm deployment and locking of windbelt wing assemblies
2) Confirm start of voltage data transmission (will commence autonomously once wings have deployed and locked)
3) Monitor and record voltage data throughout descent
4) Confirm termination of voltage data transmission (will occur autonomously based on altitude data)
5) Visually confirm retraction of wing assemblies

4.4 Safety and Environment (Payload)

The primary concern with the payload is successful deployment of the recovery system. Otherwise, the payload poses no environmental hazard if successfully recovered. Please refer to the Safety and Evironment (Vehicle) section for further information.

5.0 Activity Plan

5.1 Budget Plan

Currently, the total estimated expense of the project is $10,000. This is divided between project supplies, fabrication, testing and projected travel expenses. The project supplies, fabrication and testing have been allocated on a team basis. This amounts to $7,000 of the total budget and a preliminary list of supplies is listed in Table 7 on the following page.

The primary source of the project funding is be derived from the $10,000 NASA Nebraska Minigrant. Additionally, $500 of this has been raised from other sources. So far, $400 has been donated to the chapter by corporate sponsors and $120 from volunteering at the Guardian's of Freedom Air Show. This funding primarily goes towards the overhead of running the club. The team has successfully covered any previous gap in funding.

Travel and accommodations for 6 team members to the competition is estimated at $3,000. This will include van rental, gas, three hotel rooms, and meals. The team may also request a travel grant from the NASA Nebraska Space grant in order to cover this. Although, the current budget appears to be sufficient to cover both project expenses and travel. A more detailed list of travel expenses will need to be set forth by March.

Table 12 Projected project expenses and current expenditures.

Sub-group	Item Needed	Price	#	Estimate	# Purchased	Purchase Cost
Airframe	BT 5.5in	56.95	2	113.9	2	113.9
(allocated:$2000)	BT Coupler	55.95	1	55.95	1	55.95
(Updated 1/25/2012)	Kevlar Sock(per ft)	3.51	24	84.24	30	105.22
	Glass Sock(per ft)	1.8	16	28.8	25	45.04
	98 mm MMT	15.47	1	15.47	2	30.95
	75 mm MMT	14.49	0	0	1	14.49
	5 mm Plywood 4x8	10	1	10	1	11.63
	All-Thread	6	3	18	1	5.99
	U-Bolts	5	4	20	3	3.9
	Misc Hardware	50	1	50		18.41
	Main Parachute	150	1	150		
	Shock Cord	3	50	150	30	21
	Drogue Chute	40	1	40	1	43
	Nosecone Mold	30	1	30	1	120
	Subtotal Estimate			766.36	Current Subto	589.48
Avionics	Flight Computer A	100	1	100	1	66
(allocated:$1250)	Flight Computer B	155	1	155	1	75.5
(Updated 1/25/2012)	Key Switches		2	0	3	15
	Batteries	11	4	44	4	44
	Antenna	20	1	20		
	Transciever	70	2	140		
	Electronic Compone	25	1	25		16
	GPS	30	1	30		400
	Subtotal Estimate			514	Current Subto	616.5
Payload	Ram-Airfoil	75		0		
(allocated:$2000)	Servos	30	6	180		
	Arduino	40	2	80		80
	Sensors	400	1	400		
	Antenna	20	2	40		
	Transciever	70	2	140		
	Misc Components	610	1	610		
	Subtotal Estimate			1450	Current Subto	0
Propulsion	L-Class Motor	200	2	400		
(allocated:$1000)	75 mm Motor Hardv	300	1	300		
(Updated 1/25/2012)						
	Subtotal Estimate			840	Current Subto	0
Outreach	Water Rocket Pad	120	1	120	1	100
(allocated:$250)	Stomp Rockets	50	1	50		
(Updated 1/25/2012)	Misc Supplies	80	1	80		
	Subtotal Estimate			250	Current Subto	100
			Total	3820.36	Current Total	$ 1,305.98
					Allocated Tota	$ 7,000.00
					Unspent:	$ 5,694.02

5.2 Timeline

Planning for the UNL Rocketry Team's entry into the USLI competition began immediately after completion of the IREC competition in June. Since that time, the project director has secured funding and the team has designed a vehicle that fulfills the mission requirements. The team became organized and filled out since the beginning of the fall semester. Since then the whole UNL Rocketry Team has met on a weekly basis. The sub-teams have been divided in responsibility to reduce interdependence but bolster cooperation through shared membership. This was made possible through extensive planning. These teams have also begun meeting independently to solve their assigned tasks. From here on out, the all teams will meet together every other week and meet independently on the weeks in between at the discretion of their team leaders.

Oversight is practiced by the Project Director by attending the majority of these meetings and ensuring proper communication and modification of the plan when needed. Open lab hours are also held throughout the week.

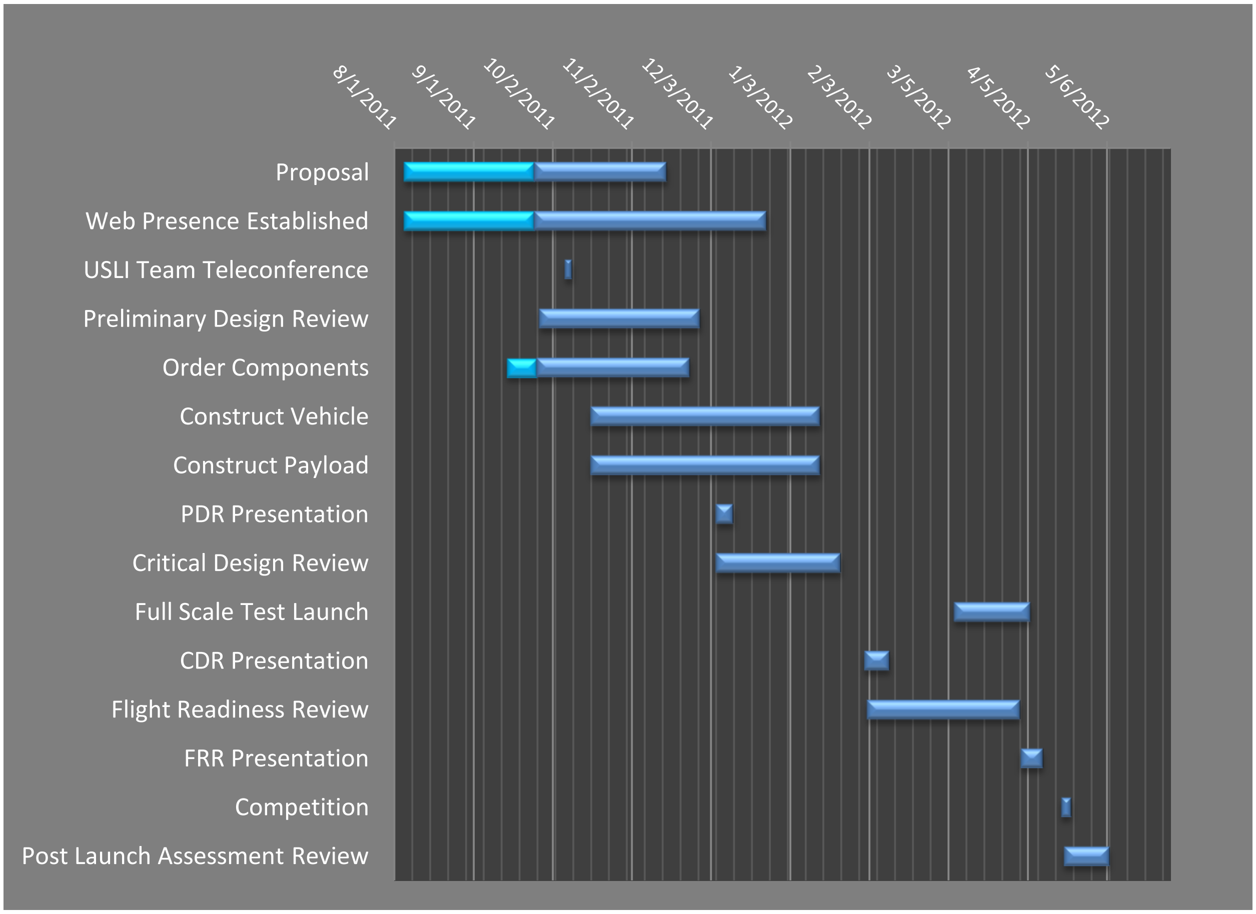

Figure 6.1.1: Gantt chart of project tasks.

5.3 Educational Engagement

The first day working with students was basic. We discussed how the water rockets worked so they could fully understand the safety precautions that were needed to be taken. After covering safety we built a rocket in a step by step process in front of the class. By doing this we could show the entire class the tricks of construction that we have learned over the years.

The next day the class finished the construction of the rockets. We then did some preliminary air tests by tilting the launch pad sideways and launching rockets horizontally down the hallway. We also showed the students that making hemispherical fins can make the rocket rotate analogous to rifling bullets.

Figure 20 Launching rockets down hallway.

Figure 21 Picture of some involved students with completed rockets.

The final day we inspected the rockets and made sure they were ready to fly. We then went out to the middle schools soccer field and launched the rockets. Most of them were unbalanced and in result didn't fly very successful. However we had a few that flew beautifully and we used the differences in the unsuccessful and successful rockets to teach the kids how to improve the rocket.

In the end we told the students, "This process of repetitive adjustments and improvements to the rocket is engineering". That makes everyone in this class an engineer!

6.0 Conclusion

Overall, the project is moving forward as expected and has become more promising. The additional funding has afforded greater freedom in the design and more testing to take place. The design is already matured to the point of beginning manufacture but this will lead to greater confidence and more improvements. The payload system will also prove to be quite insightful in to aircraft mounted tuned windbelts used for energy scavenging.

The conclusion drawn from this simulation is that the L-1170 motor has more than enough impulse for the mission at hand. This will allow a larger payload and accommodate any unforeseen growth in mass we may encounter. It can also be seen that the vehicle maintains a fair margin of stability all the way through the ascent of the flight. This is very desirable as over stability can cause wind cocking and loss in altitude or even tumbling and deployment issues. Thus, this will be the first motor the team intends to test on in February.

Appendix – OpenRocket Part Detail

Parts Detail

Sustainer

Nose cone	Fiberglass (1.85 g/cm³)	Haack series	Len: 27.5in	Mass: 1.719lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 5.343in	Len: 0.25in	Mass: 0.128lb
Nose Tube	Kraft phenolic (0.95 g/cm³)	Dia$_{in}$ 3.961in Dia$_{out}$ 4in	Len: 18in	Mass: 0.152lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 3.961in	Len: 0.25in	Mass: 0.07lb
Comm Systems		Dia$_{out}$ 1.181in		Mass: 2.5lb
Centering ring	Plywood (birch) (0.63 g/cm³)	Dia$_{in}$ 4in Dia$_{out}$ 5.343in	Len: 0.25in	Mass: 0.056lb
Centering ring	Plywood (birch) (0.63 g/cm³)	Dia$_{in}$ 4in Dia$_{out}$ 5.343in	Len: 0.25in	Mass: 0.056lb
Tube coupler	Kraft phenolic (0.95 g/cm³)	Dia$_{in}$ 5.232in Dia$_{out}$ 5.31in	Len: 8in	Mass: 0.179lb
Body tube	Quantum tubing (1.05 g/cm³)	Dia$_{in}$ 5.3in Dia$_{out}$ 5.5in	Len: 48in	Mass: 3.089lb
Booster Coupler	Fiberglass (1.85 g/cm³)	Dia$_{in}$ 5.2in Dia$_{out}$ 5.3in	Len: 12in	Mass: 0.661lb
Payload 10 lb		Dia$_{out}$ 5.2in		Mass: 9.5lb
Parachute	Ripstop nylon (67 g/m²)	Dia$_{out}$ 108in	Len: 9.449in	Mass: 2.76lb
Shroud Lines	Tubular nylon (11 mm, 7/16 in) (13 g/m)	Lines: 16	Len: 162in	
Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 624in	Mass: 1.013lb
Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 360in	Mass: 0.585lb
Drogue Parachute	Ripstop nylon (67 g/m²)	Dia$_{out}$ 36in	Len: 3.11in	Mass: 0.237lb
Shroud Lines	Tubular nylon (11 mm, 7/16 in) (13 g/m)	Lines: 4	Len: 48in	
Avionics Bay	Kraft phenolic (0.95 g/cm³)	Dia$_{in}$ 5.182in Dia$_{out}$ 5.3in	Len: 12in	Mass: 0.4lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 5.182in	Len: 0.25in	Mass: 0.12lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 5.182in	Len: 0.25in	Mass: 0.12lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 5.382in	Len: 0.25in	Mass: 0.129lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia$_{out}$ 5.382in	Len: 0.25in	Mass: 0.129lb

Inner Tube	Kraft phenolic (0.95 g/cm^3)	Dia_{in} 3.858in Dia_{out} 4in	Len: 11.5in	Mass: 0.345lb
Avionics Mass		Dia_{out} 1.181in		Mass: 1.5lb
Booster Section	Fiberglass (1.85 g/cm^3)	Dia_{in} 5.3in Dia_{out} 5.5in	Len: 48in	Mass: 5.442lb
Freeform fin set (3)	Plywood (birch) (0.63 g/cm^3)	Thick: 0.197in		Mass: 0.652lb
Inner Motor Mount Tube	Kraft phenolic (0.95 g/cm^3)	Dia_{in} 3.858in Dia_{out} 4in	Len: 36in	Mass: 1.081lb
Engine block	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 5.3in Dia_{out} 5.3in	Len: 0.5in	Mass: 0lb
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 4in Dia_{out} 5.3in	Len: 0.5in	Mass: 0.108lb
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 4in Dia_{out} 5.3in	Len: 0.5in	Mass: 0.108lb
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 4in Dia_{out} 5.3in	Len: 0.5in	Mass: 0.108lb
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 4in Dia_{out} 5.3in	Len: 0.5in	Mass: 0.108lb
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia_{in} 4in Dia_{out} 5.3in	Len: 0.5in	Mass: 0.108lb
Launch lug	Polycarbonate (Lexan) (1.2 g/cm^3)	Dia_{in} 0in Dia_{out} 0.394in	Len: 1.181in	Mass: 0.006lb
Launch lug	Polycarbonate (Lexan) (1.2 g/cm^3)	Dia_{in} 0in Dia_{out} 0.394in	Len: 1.181in	Mass: 0.006lb