NORTHWEST INDIAN COLLEGE
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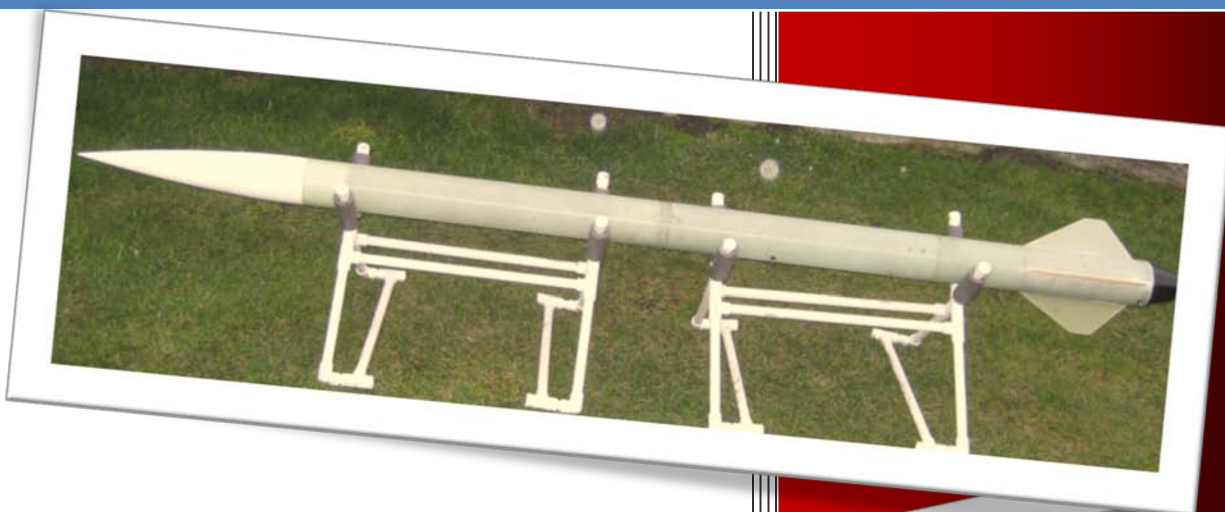
2011

Northwest Indian College Space Center
Team SkyWalkers
USLI Critical Design Review



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Northwest Indian College Space Center – Team Sky Walkers
Preliminary Design Review Report

I) Summary of Preliminary Design Review Report

I.1 Team Summary

I.1.a Team Name

Northwest Indian College Space Center – Team Sky Walkers
Project Skybolt

I.1.b Location

Northwest Indian College, 2522 Kwina Road, Bellingham, Washington, 98226,

I.1.c Team Officials and Mentor

Gary Brandt – Team Advisor	William Munds – NAR L2 Mentor
David Oreiro – Assistant Team Advisor	

I.2 Launch Vehicle Summary

I.2.a Dimensions without motor (inches)

Length	112.625	Diameter	4.025
Weight	23.906 lbs	Fin Span	12.025
Center of Gravity	63.424	Center of Pressure	76.287
Static Stability	3.2 (1.91 w/CTI L640 motor)		

I.2.b Motor Choice

Full-scale motor: Cesaroni Technology Inc L935-RL

I.2.c Recovery System

Our rocket is equipped with a redundant recovery system consisting of two PerfectFlite MAWD altimeters that are electrically independent of each other. Each will have ejection charges. The drogue will be deployed at apogee and the main will be deployed at 700 feet. Landing will have a maximum kinetic energy of 75 ft-lbf.

I.2.d Rail Size

Two 0.5 inch rail guide buttons are bolted and fiber glassed to the fin can that will guide the rocket up the 72 inch long T-Slotted Aluminum.

I.2.e Launch Vehicle Fly Sheet

Please see Appendix A

I.3 Payload Summary

The scientific payload will measure temperature, humidity, pressure, ultra-violet radiation, and solar irradiance and take photos in accordance with the competition specifications.

II) Changes Made Since Preliminary Design Review Report

II.1 Changes made to Vehicle Criteria

The power management system has been modified by replacing the hinged flaps with two “dams” the will extend and retract using the same hi-torque servos described in the Preliminary Design Report.

We had initially contemplated using a Cert-3 Xtra Large parachute; however, we had made an error in calculating the KE and our rocket is four pounds lighter, thus the change to a Cert 3 Large parachute.

II.2 Changes made to Payload Criteria

Our science payload is lighter by four pounds than what was reported in the Preliminary Design Review.

The science payload is continuously being refined as team members improve their programming and construction skill. We have shifted from the BASIC Stamp microcontroller to the Arduino microcontroller because of cost, size, and increased performance.

Another change that is being evaluated is adding a transparent section of body tube. This offers the possibility of providing a more straight forward method of mounting the sensors that rely upon visual criteria.

II.3 Changes made to Activity Plan

Adverse weather conditions in the form of high winds or low cloud ceiling have forces our flight schedule to be moved to later dates. Our schedule has many opportunities for flights. Other than that, no changes have been made at this time regarding the activity plan. It is still progressing as listed in the proposal.

III) Vehicle Criteria

III.1 Design, and Verification of Launch Vehicle - Flight Reliability and Confidence

III.1.a Mission

<u>III.1.a.1 Mission Statement</u>

1. Through the USLI program, the Northwest Indian College Space Center’s Sky Walkers Team enhances its involvement in science, math, engineering and technology and encourages others in Tribal communities to do the same. (We are taking a considerable amount of credit for encouraging Haskell Indian Nations University to make a USLI proposal this year.)

2. Furthermore, we plan to:
    a. design and build a recoverable, reusable rocket
    b. carry a science payload to an altitude of no more than one mile
    c. collect and analyze in-flight data from the science payload
    d. achieve the 5280 foot altitude via a power management system

    This objective will be achieved by thorough design and testing of the rocket and its scientific payload.

III.1.a.2 Mission Requirements

Sky Walker's Rocket will, in addition to the USLI competition requirements:

- Build a rocket that will be water resistant
- Build a rocket whose electronics will be protected from water
- Use a power management system that will ensure the target altitude requirement is met
- Test atmospheric conditions and use the information as part of the Native Environmental Science Degree environment data collection plan.

III.1.a.3 Mission Success Criteria

Criteria number 1 is no individual is harmed or put at risk through the team's failure to successfully identify and mitigate a hazard.

Flight success criteria:

- rocket launches as designed
- attain an altitude within .01% of 5280 feet with the power management system
- drogue parachute deploys at apogee
- main parachute deploys at 500 feet above ground level
- descent rates are within design parameters
- rocket is recovered with minimal damage and able to be launched again within four hours
- rocket and electronics sustain no damage from a damp landing

Picture success criteria:

- Pictures are oriented within 95% of normal viewing orientation

Science payload success criteria:

- 85% of the measurement applications function as designed
- 100% of the data is collected from the functioning science applications

III.1.b Schedule and Time Line (Key Events)

III.1.b.1 Manufacturing and Construction

By adhering to our time line, we have been able to focus our attention to accomplishing the myriad of tasks involve in our USLI project.

We are on very good terms with the major component vendors and they have responded very timely to our purchases. Constructing both the subscale and competition rocket have proceeded smoothly. Working with fiberglass airframe and rocket components is new to us. It is surprising how heavy the rocket is, even though our planning and simulation in Rocksim 9 indicated it would weigh this much.

The power management system is proving to be quite a challenge. We have built a working model; however, getting all of the parts to fit into the rocket is a challenge and our programming prototype is just now beginning to show promise.

The science experiments are being built. We have had no issues in building them. Programming is coming along.

III.1.b.2 Verification

Verification is done through multiple inspections by both team advisors and key team members. Each item is verified for strength, construction techniques, neatness, and compliance with instructions.

Team Sky Walkers Major Milestone Schedule		
Proposal Submitted	**Completed**	**9/6/11**
Scale Rocket	**Design Complete**	**10/5/11**
Scale Rocket	Construction Complete	10/17/11
	Completed Flight Test	11/12/11
Selection Notification	**Selected!**	**10/17/11**
USLI Team Teleconference	**Completed**	**10/21/11**
Web Presence Established	**Completed**	**11/4/11**
Competition Rocket	**Initial Design Considerations**	**9/9/11**
Competition Rocket	Design Finalized	10/20/11
	Construction Started	10/28/11
	Construction Complete	11/22/11
Competition Rocket	Recovery System Ground Test-Completed	11/23/11
	Test Flights as needed	~~12/3/11~~
		1/14/12
		1/28/12
		2/4/12
		2/18/12
		3/3/12
		3/17/30
		3/31/30
Science Payload	**Initial Design Considerations**	**9/6/11**

Science Payload	Design Finalized (Completed)	10/31/11
	Construction Started	11/1/11
	Construction Complete	2/15/12
	Operational Testing	2/15/12
	Testing Complete	3/20/12
	Test Flight	3/31/12
Preliminary Design Review Submitted	**Completed**	**11/27/11**
Preliminary Design Review Presentation	**Completed**	**12/6/11**
Critical Design Review Submitted	**Completed**	**1/25/12**
Critical Design Review Presentation		**2/7/12**
Flight Readiness Review Submitted		**4/21/12**
Flight Readiness Review Presentation		**4/11/12**
Launch		**4/21/12**
Post flight Analysis Review		**5/7/12**
Announcement of Winning USLI Team		**5/18/12**

The full time line is in Appendix B.

III.1.c Design Review at System Level

III.1.c.1 Final Drawings and Specifications

The overall vehicle stands slightly over 112 inches tall with an airframe diameter of four inches. The entire rocket is fiberglass, G10 for everything except tail cone which is aluminum. All components, except the tail cone, are from Performance Rocketry. The tail cone is from Aero Pack and is constructed from aluminum. Three fins are attached through the wall to the 54 mm motor tube 1/2 inch above the aft edge of the airframe. The fins are fastened in place with West Systems 2-part epoxy resin and reinforced with a fiberglass inlay across the inside. Table 1 and Figure 2 list the dimensions.

Length	112.625	Diameter	4.025
Weight	23.906 lbs	Fin Span	12.025
Center of Gravity	63.424	Center of Pressure	76.287
Static Stability	3.2 (1.91 w/CTI L640 motor)		

Figure 1 - Rocket Dimensions

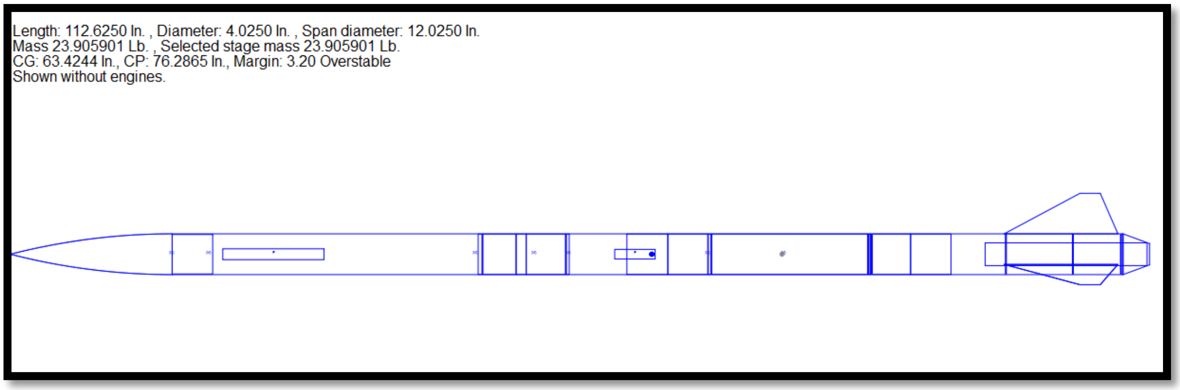

Figure 2 - Rocksim 9 Side View

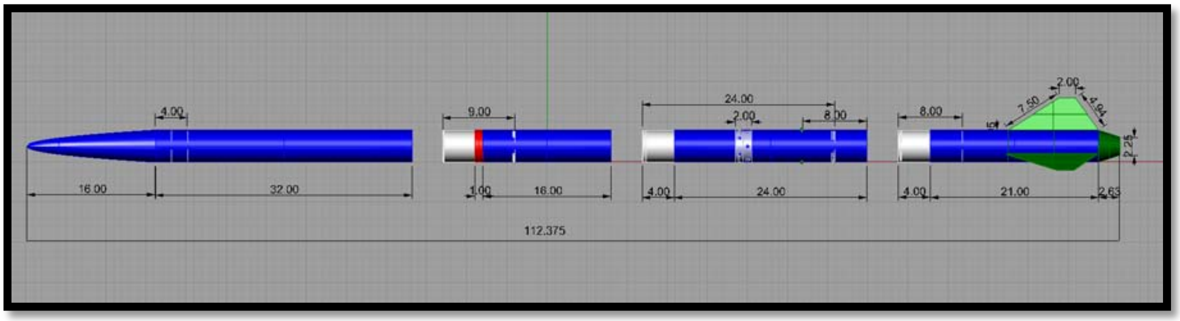

Figure 3 - Airframe Component View

The airframe houses the parachutes, recovery electronics, science payload, power management system, velocity retardation device, motor and motor mounts, bulkheads, nosecone, fins, and other instruments in an aerodynamic structure. The airframe is constructed from G10 fiberglass manufactured by Performance Rocketry. We chose fiberglass for two reasons: 1) strength to handle the stresses of launching a heavy load, and 2) water resistance because of our often flooded recovery area. The airframe components are illustrated in Figure 3 and will be described in detail in Section III.1.h.

III.1.c.2 Final Analysis and Model Results

Not having an actual test flight, we are at this time unable to compare the simulation predictions to actual flight results. Its weight, minus the science payload) of the actual rocket, compares very closely with the Rocksim model's weight.

III.1.c.3 Test Description and Results

Weather, weather, weather! The week of January 14-19 has seen high winds and snow. NWIC has been closed since the Martin Luther King Holiday. Previous testing days have been cancelled because of high winds.

III.1.c.3.a Power Management System

The mechanics of the power management system, the extension and the retraction of the air dams has been tested and it works smoothly.

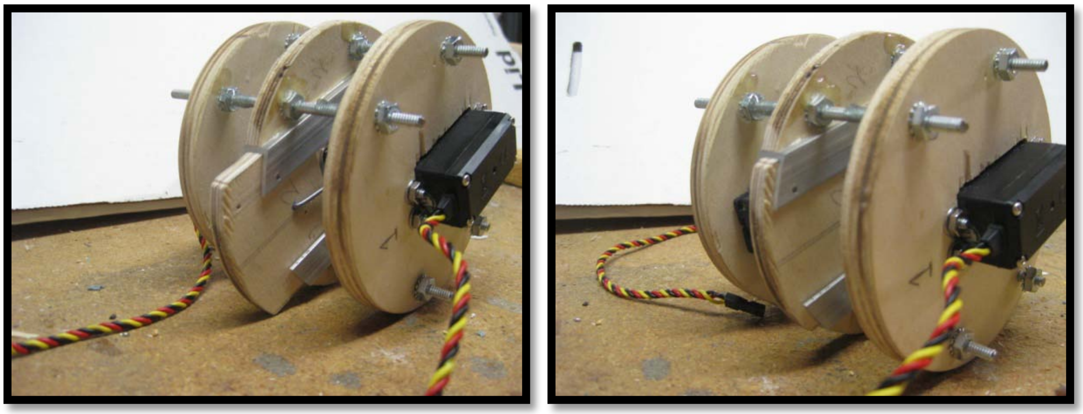

Figure 4 - Velocity Reduction Dams Extended   Velocity Reduction Dams Retracted

III.1.c.3.b Black Powder (BP) Ejection Charge Determination

Factors that affect the amount of BP that will be needed:

- Diameter of airframe (base of nose cone)
- Volume of parachute chamber
- How tightly parts (airframe/coupler) fit
- Leakiness of the airframe

A starting point for determining the amount of BP to use is to determine the amount of desired force on the base of the bay that needs to be separated. Typically 150-200 pounds are used in high powered rockets. The next step is to determine the amount of pressure (pounds per square inch - psi) that will produce the desired amount of force.

Shear Pins and Ejection Charges

The use of shear pins avoids the possibility of drag separation during flight. #2 nylon screws (2-56) as shear pins, reliably shear with 35 pounds of force. That force must be generated by the ejection charge. The ejection charge force is calculated by multiplying the cross-sectional area of the body tube by the ejection charge pressure in psi. Divide this force by 35 pounds to get the maximum number of shear pins that can be used. We will not use less than two shear pins because it's possible that the slip joint could cock to one side and jam if only one is used.

The ejection charge equation is: $Wp = dP*V/R*T$

Where:

- dP is the ejection charge pressure in psi.
- R is the combustion gas constant, 22.16 (ft-lbf/lbm R) for FFFF black powder. (Multiply by 12 in/ft to get in terms of inches)

- T is the combustion gas temperature, 3307 degrees R for black powder
- V is the free volume in cubic inches. Volume of a cylinder is cross section area times length L, or from diameter D, V=L*p*D2/4
- Wp is the charge weight (mass, actually) in pounds. (Multiply by 454 g/lb to get grams.)

Ground testing will reveal the minimum amount needed under ***ideal conditions***. We choose to not fly with the minimum amount of BP that works under ***ideal conditions*** .We did several tests of the black powder ejection charge prior to flying the scale model. The calculated amounts, making certain that we slightly exceeded the minimum force, worked as predicted.

We used 0.7 grams of black powder for the main parachute ejection charge and for the drogue separation charge, we also used 0.7 grams. These amounts resulted in successful separation for both ground tests and actual flight. This amount provided 75 pounds of force which sheared the two #2-56 nylon screws acting as shear pins that held the parachute bays secured to the ebay subsystem.

Competition Rocket Drogue and Main Parachute Black Powder Calculations

Black Powder Ejection Charge Calculator - Drogue

by Chuck Pierce

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Volume =	305.4	in^3
Dia =	4.025	inch
Len =	24	inch

Calculation Mass of Black Powder for a desired Ejection Pressure

Desired Pressure =	15	psi	
mass BP =	2.36	grams	m=PV/R/T
Ejection F =	190.9	lbf	F=P*(pi/4)*d^2

Table 1 – Black Powder Calculations, Drogue

Figure 5 - Drogue Ejection Ground Test

Black Powder Ejection Charge Calculator - Main
by Chuck Pierce

Volume =	407.2	in^3
Dia =	4.025	inch
Len =	32	inch

Calculation Mass of Black Powder for a desired Ejection Pressure

Desired Pressure =	15	psi	
mass BP =	3.15	grams	m=PV/R/T
Ejection F =	190.9	lbf	F=P*(pi/4)*d^2

Table 2 – Black Powder Calculations, Main

Figure 6 - Main Ejection Ground Test

Extensive ground testing of the ejection system took place prior to any planned flights. We increased the amount of BP to 4.0 grams of black powder for the main parachute ejection charge and for the drogue separation charge, we used 3.0 grams. These amounts resulted in successful separation for the ground tests These amounts provided 240 pounds of force which sheared the six (3 for the drogue and 3 for the main) #2-56 nylon screws acting as shear pins that held the parachute bays secured to the ebay subsystem.

III.1.c.4 Final Motor Selection

We used Rocksim to analyze and evaluate several motors. Cesaroni Technology Incorporated (CTI) L size motors will be used for the competition flight. We will use Aerotech motors for low level testing.

The primary considerations for the motors were the average thrust and total impulse. The average thrust was used to determine if the motor would provide the necessary thrust to weight ratio for stable flight. Once that was determined, the motor was tested in Rocksim to find the predicted altitudes. Using a predicted altitude, an estimate of the total impulse was found that would meet our target altitude requirements. The motors that are being considered meet the minimum thrust to weight ratio and have the necessary total impulse to reach the competition altitude. The ratio was derived with this formula:

Thrust to Weight Ratio = Pounds of Thrust/Weight of Skybolt

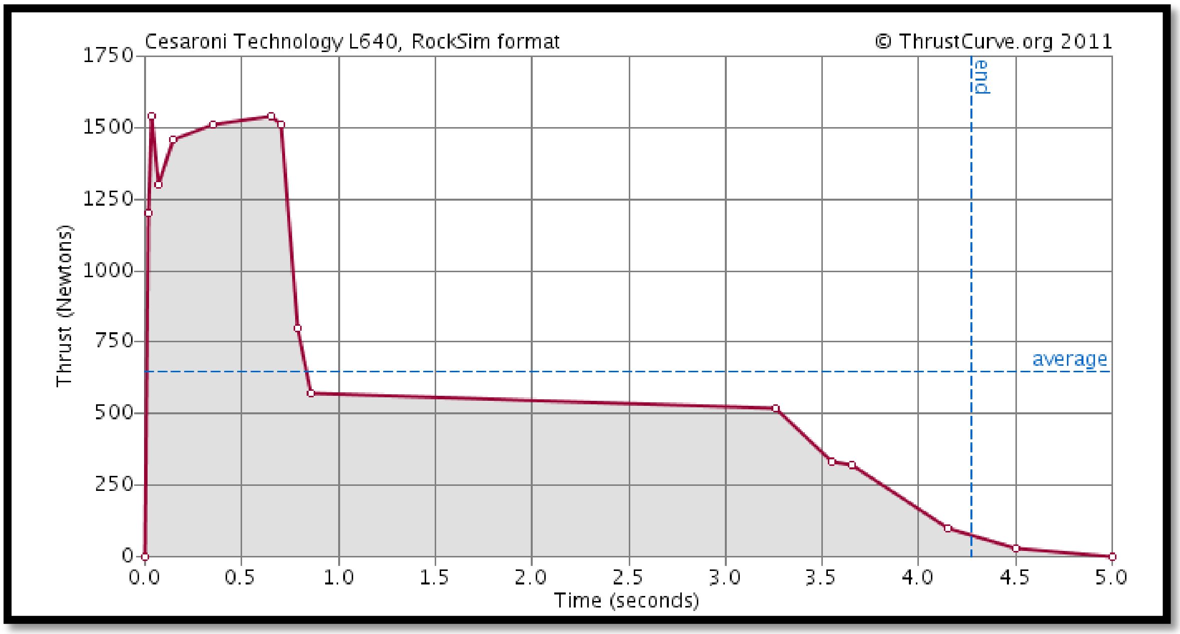
Table 5 illustrates the “best” choices given the information that we have at hand. Test launches will be used to refine the motor selection. The simulation indicates that the motors are big enough to get the rocket safely off the launch rail. We do not and will not know how close the predicted altitude will be to actual altitude. Until we get some actual flight data, our motor choice is based on the Rocksim 9 simulation using the best information that we have available and at this point is the CTI L640.

Skybolt Rocket
Thrust-to-Weight Ratios for Selected Motors

Selection	Manufacturer	Motor	Maximum Thrust		Loaded Weight (lbs)	Ratio	RocSim Altitude	Case	Lift Off (fps)
			Newtons	Pounds					
	CTI	K300	561.80	126.298	27.27	4.631	4303	6GXL	35.12
	CTI	K660	1078.90	242.546	27.00	8.983	4991	6G	54.13
	CTI	L1030	1223.00	274.941	27.87	9.865	6161	6GXL	56.71
Competition	**CTI**	L640	1590.00	357.446	27.67	12.918	5937	6GXL	64.80
	CTI	L730	1214.90	273.120	27.67	9.871	5968	6GXL	56.71
	CTI	L935	1585.60	356.457	28.32	12.587	7133	6GXL	60.35
	CTI	L990	1702.70	382.782	27.65	13.844	6112	6GXL	59.92
	Aerotech	K375	1371.80	308.393	27.36	11.272	3962	54/2560	51.52
Practice	**Aerotech**	K828	1510.99	339.685	27.62	12.299	4032	54/2560	49.88
Practice	**Aerotech**	K1275	1554.00	349.353	27.26	12.816	4112	54/1760	60.97

Figure 7 - -Motor Selection Criteria-Thrust to Weight

Below are the thrust curves associated with the competition and low level test motor choices



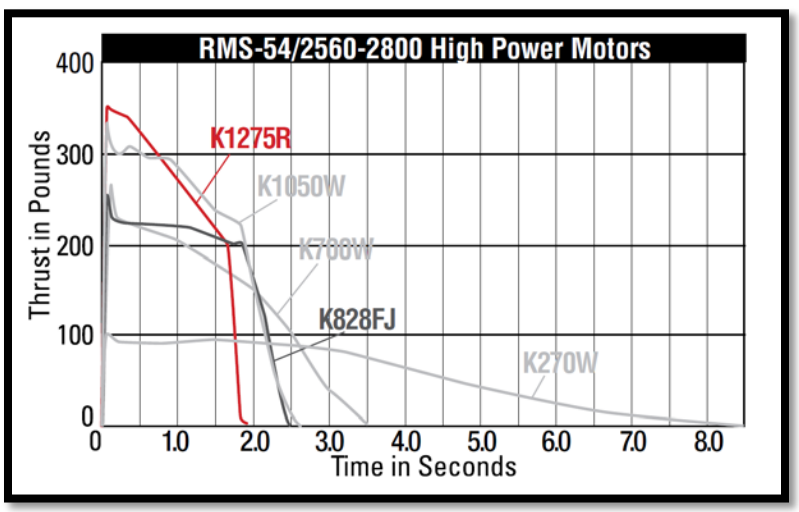


Figure 8 – Thrust Curves

III.1.d Meeting System Level Functional Requirements

III.1.d.1 Subsystems

Subsystems	
Airframe is G10 Fiberglass and is the complete rocket	
Nose Cone	
Contains the GPS tracking unit used to locate the rocket after landing and to provide flight data.	
Recovery	
Main	Contains the drogue parachute and recovery harness
Ebay	Contains deployment electronics
Drogue	Contains main parachute and recover harness
Science Payload Bay	
Contains the sensor electronics and microcontrollers for atmospheric data collection Contains the data transmitter Sensors are mounted on the science payload bay Contains the cameras	
Power Management	
Contains the electronics and the hardware for the velocity reduction system	
Propulsion	
Contains the engine casing and the reload used for flight.	
Ground Support Equipment	
Launch platform, guide rail and launching electronics	
Safety System	
Check lists, fire suppression equipment, cell phones	

Figure 9 - Subsystems

III.1.d.2 System and Subsystems Performance Characteristics

Subscale Rocket		Characteristic			Metrics	
System	Subsytem	Design	Structure	Materials	Evaluation	Verification
Airframe	Nose Cone	Designed in Rocksim 9	LOC Precision Nose Cone	Polystyrene	Rocksim 9 Simulation	Completed Successful Flight Test
	Forward Airframe		LOC Precision Airframe	Phenolic		
	Ebay Ring					
	Aft Airframe					
	Fin Can					
	Fins		LOC Precision Fins	Aircraft Grade Plywood		
Recovery	Main Bay	Designed in Rocksim 9	LOC Precision Airframe	Phenolic	Rocksim 9 Simulation	Completed Successful Flight Test
	Main Parachute		TopFlight Parachute	Ripstop Nylon		
	Ebay		LOC Precision Airframe	Phenolic		
	Drogue Bay			Phenolic		
	Drogue Parachute		TopFlight Parachute	Ripstop Nylon		
	Avionics	Designed to High Power Rocketry standards	Perfect Flight MAWD Altimeter, plywood sled, zinc plated 1/4" threaded rod	Various	Ground Test	
Propulsion	Fin Can	Designed in Rocksim 9	Aerotech Commercial Motor	Aluminum, ACP	Rocksim 9 Simulation	Successful Flight

Figure 10 - Subscale Rocket Performance Characteristics

Competition Rocket		Characteristic			Metrics	
System	**Subsystem**	**Design**	**Structure**	**Materials**	**Evaluation**	**Verification**
Airframe	Nose Cone	Designed in Rocksim 9	Performance Rocketry Airframe	Performance Rocketry G10 Fiberglass	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	Forward Airframe					
	Ebay Ring					
	Aft Airframe					
	Science Payload Bay					
	Fin Can					
	Fins		Performance Rocketry Fins			
	Tail Cone/Motor Retainer		Aero Pack	Aluminum		
Recovery	Main Bay	Designed in Rocksim 9	Performance Rocketry Airframe	Performance Rocketry G10 Fiberglass	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	Main Parachute		Sky Angle parachute	Nylon		
	Ebay	Designed in Rocksim 9	Performance Rocketry Airframe	Performance Rocketry G10 Fiberglass		
	Drogue Bay					
	Drogue Parachute		TopFlight Parachute	Ripstop Nylon		
	Avionics	Designed to High Power Rocketry standards	2 Perfect Flight MAWD Altimeter, G10 sled, zinc plated 1/4" threaded rod	Various	Multiple Ground Tests that demonstrate successful parachute ejection	Successful Ground Tests and Successful Flight
Science	Science Payload Bay	Integration Designed with Rhino 3D	Performance Rocketry Airframe	Performance Rocketry G10 Fiberglass	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Flight
	Atmospheric electronics		Arduino Microcontroller, various manufacturer's sensors	Various	Multiple Ground Tests	
	Cameras		Meritline Mini Camera			
	Power Management		Hi-Torque Servors, Arduino Microcontroller			

Propulsion		Designed in Rocksim 9	CTI Commercial Motors	Aluminum. ACP	Rocksim 9 Simulation	Successful Flight

Figure 11 - Competition Rocket Performance Characteristics

III.1.d.3 Science Payload Bay Subsystem

An Arduino microcontroller provides all of the data collection from the various sensors and sensor modules. It then transfers the data to an SD card for later analysis as well as to the 900MHz transmitter. The transmitter sends the information to a laptop computer on the ground which has a 900 MHz receiver attached.

III.1.d.4 Power Management Subsystem

The Power Management subsystem consists of two primary components, the electronics system and the velocity reduction system.

The PMS electronics is built around an Arduino microcontroller that collects data from a barometric sensor and interacts with its program to determine when to deploy the velocity reduction system. Table 3 shows the information that is used in the calculations and the first 0.8 seconds of data derived from the calculations. The numbers have been limited to 2 decimal places in order for the table to fit on the page in a readable format.

Appropriate motor information is entered as well as key information about the rocket. With these calculations we are able to determine at what altitude/speed combination to deploy the velocity reduction system in order to reach the target altitude at near 0 fps velocity.

The Arduino is programmed to activate the servos when the proper combination of velocity and altitude are reached. See figure 12 for the design images of the working subsystem.

The servos extend a pair of diametrically opposed “dams”. Both servos are connected to both dams. This ensures that both dams will extend and retract regardless of a single servo failure and also it ensures that the dams extend equally and simultaneously.

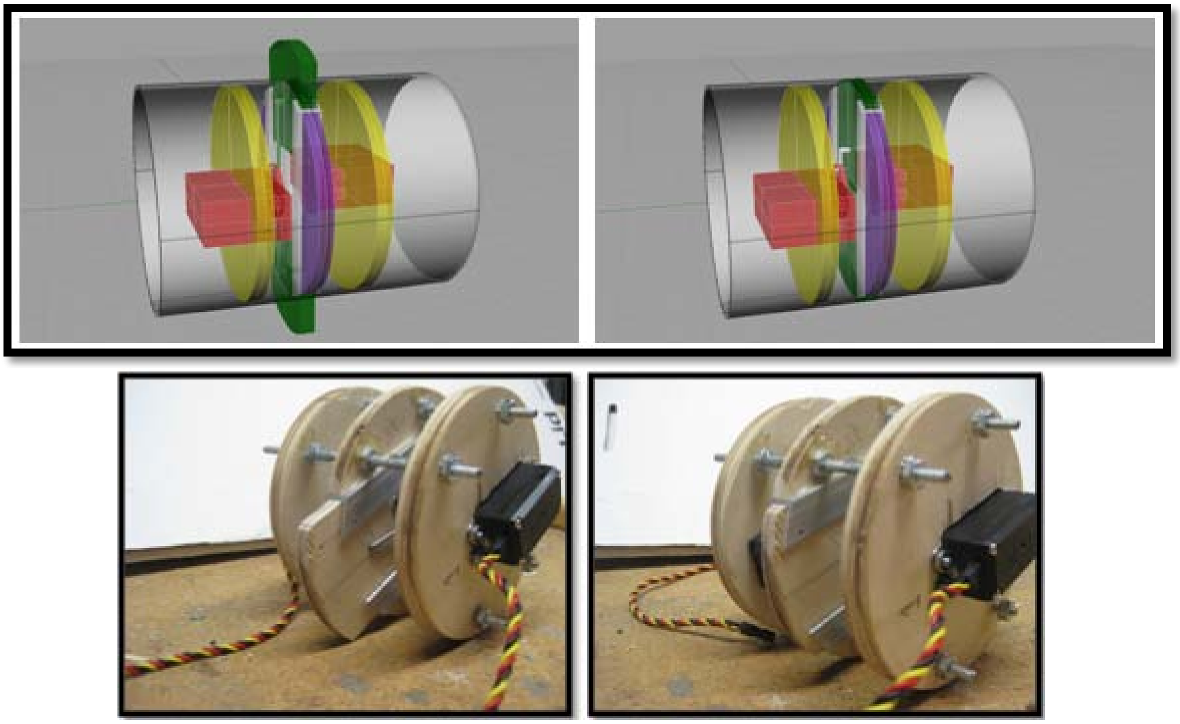


Figure 12 - Velocity Reduction System Air Dams (L) Extended and (R) Retracted

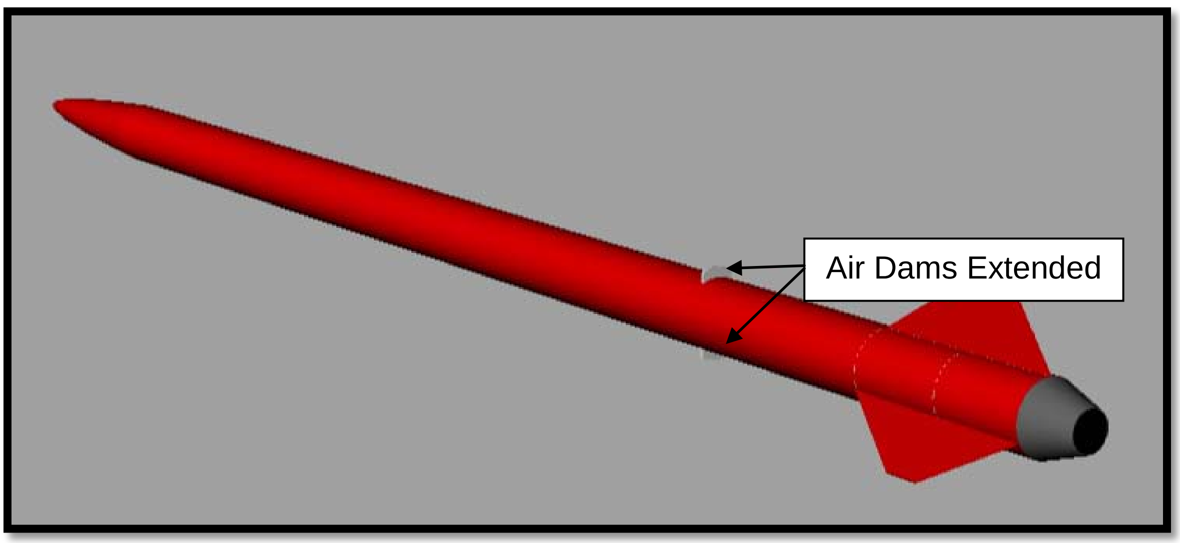


Figure 13 - Position of the Velocity Reduction System

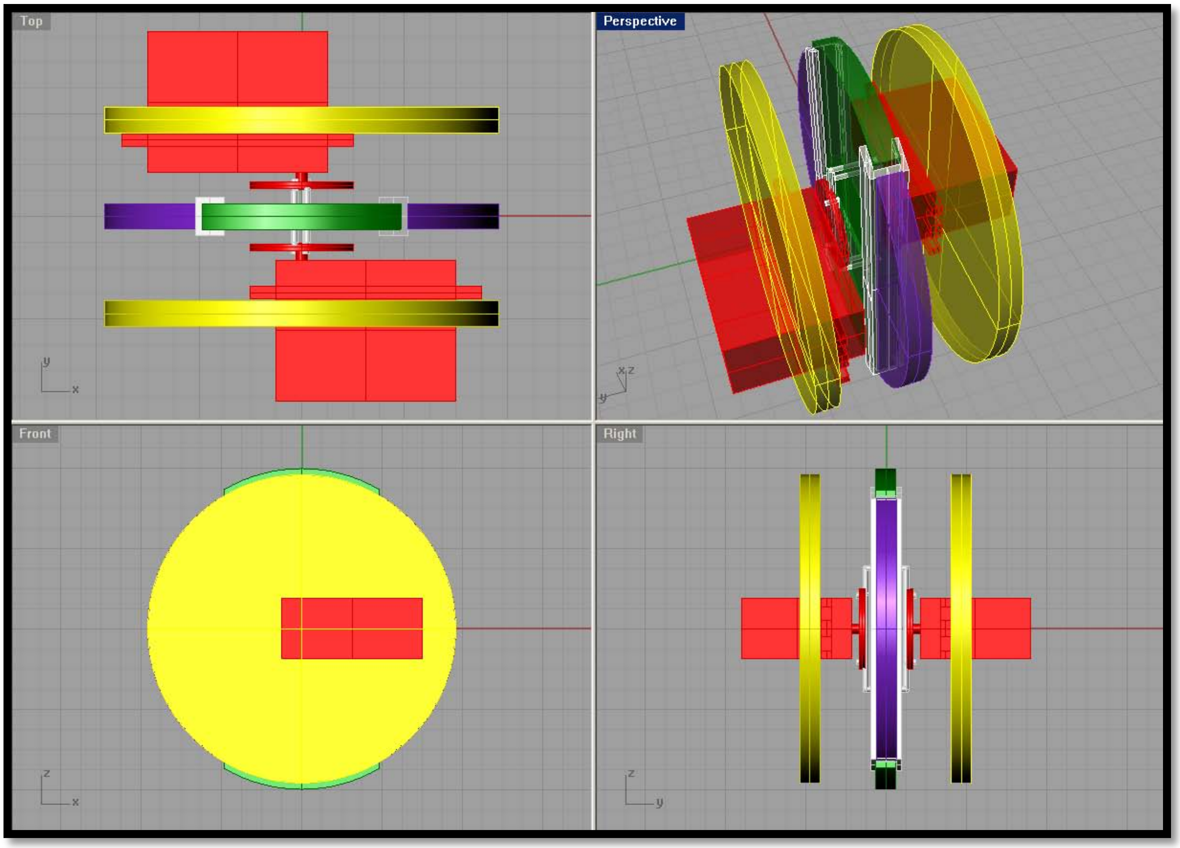


Figure 14 - Three views and Perspective View of the Velocity Reduction System

The dams and servo mounts as well as the partial circular components (purple, green, and yellow) are constructed of ¼" aircraft plywood. The channels (grey) that the dams slide in are u-shaped aluminum sections and the control arms (white) that connect the dams to the servo disks are 3/32" piano wire. The servos have 1 pound of torque each and the servo disks are aluminum. The three sets of circular components are tied together with four 3/16" threaded rod and nuts that support the bulk heads.

The subsystem is mounted in a 5" section of 4" Blue Tube coupler that is held in place with #10 screws and t-nuts that are secured into the ¼" bulk heads that also support the servos. The unit is then secured to the aft airframe with another set of #10 screws and t-nuts that are also secured into the ¼" bulk heads.

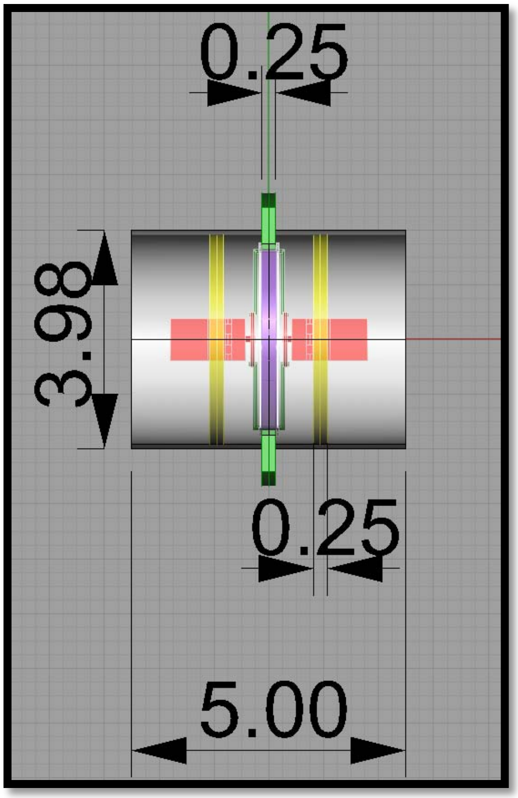


Figure 15 - Velocity Reduction System Dimensions

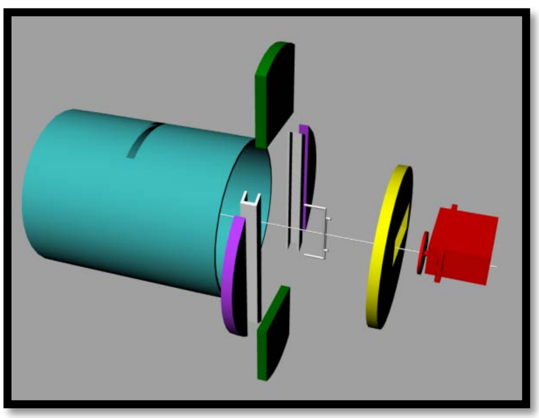


Figure 16 - Exploded view of 1 side of the Velocity Reduction System

Rocksim indicates that the CP moves 0.25 inches forward with the dams extended. The CD increases from 0.52 to 7.0. We're looking forward to the testing to see if these numbers are realistic.

Rocket	**USLI**			**Chute diam**	**Dc**	**2**				
Rckt Mass (empty)	**Mr**	**10.99**		**Time Incr**	**dt**	**0.1**				
Eng. Case mass	**Me**	**0.772**		**Mass Decr (propellant burned)**	**dm**	**0.31897019**		**Avg. Thrust**		
Propellant mass	**Mp**	**1.177**		**Grav. Const**	**gc**	**9.8**		**650.59**		
Diameter, rocket	**Dr**	**0.10244**		**Area, (widest part)**	**A**	**0.008241932**				
Impulse, motor(N-sec)	**Im**	**2437**		**Chute area**	**A_2**	**3.141592654**		**True Impulse**		
Thrust (Newtons)	**Ta**	**659**		**Burn Time**	**tb**	**3.69**		**2400.66**		
Air Density (kg/m^3)	**rho**	**1.2**		**Eject time**	**te**	**17.97**	**Peak kph**	**Peak (m)**	**Peak (ft)**	**Peak mph**
Drag coef	**Cd**	**0.52**					**148.26**	**1192.41**	**3911.10**	**331.66**

Flight Time	**Drag Force**	**Thrust**	**Net Force**	**Mass**	**Acceleration**	**Velocity (m/s)**	**Altitude (m)**	**Rocket Area**		**Air Density**
t	**Fd**	**Ft**	**F**	**M**	**Acc**	**V**	**Y**	**Area**	**mph**	**rho**
0.0	0.00	0.00	-126.80	12.94	0.00	0.00	0.00	0.01	0.00	1.22
0.1	0.00	1065.32	938.83	12.91	72.74	7.27	1.09	0.01	16.27	1.22
0.2	0.19	1020.05	893.69	12.88	69.41	14.21	2.86	0.01	31.80	1.22
0.3	0.71	990.12	863.54	12.84	67.24	20.94	5.29	0.01	46.84	1.22
0.4	1.54	966.76	839.67	12.81	65.54	27.49	8.37	0.01	61.50	1.22
0.5	2.66	949.45	821.55	12.78	64.29	33.92	12.08	0.01	75.88	1.22
0.6	4.04	932.14	803.17	12.75	63.01	40.22	16.42	0.01	89.98	1.22
0.7	5.68	914.83	784.53	12.72	61.70	46.39	21.37	0.01	103.78	1.22
0.8	7.56	897.52	765.66	12.68	60.37	52.43	26.91	0.01	117.28	1.22

Table 3 - Sample Numerical Simulation Data with CD at 0.52

III.1.d.5 Propulsion Subsystem

The selected motor must provide stable flight for the rocket and reach the desired altitude. An appropriate thrust-to-weight ratio, as well as sufficient lift-off speed are necessary for a safe flight. The thrust-to-weight ratio is an indicator of flight stability by making certain that the motor has the necessary power to accelerate the rocket to a safe lift-off speed. Additional stability is provided by the force that the fins on the rocket provide. Sufficient velocity prior to the rocket leaving the stability-inducing guide rail is necessary to increase the fin force so that the rocket is stable once it has left the guide rail. In general, a minimum thrust to weight ratio of five is recommended for flight, but a higher ratio can be necessary for stronger winds

Environmental Conditions (Toney, AL late April example)

Altitude: 827 Ft.
Relative humidity: 77 %
Temperature: 65 Deg. F
Pressure: 30.27 In.
Slightly breezy (8-14 MPH)

Launch Guide Data

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 64.8046 ft/s
- The launch guide was cleared at : 0.246 Seconds
- User specified minimum velocity for stable flight: 43.9882 ft/s
- Minimum velocity for stable flight reached at: 49.0961 In.

III.1.d.6 Ground Support Equipment Subsystem

Our GSE consists of the launch pad, the launch control box, the launch cables, a portable sound system, a First Aid kit, a fire extinguisher, and cell phones.

The equipment has be successfully used for twenty three launches.

III.1.d.7 Safety Subsystem

III.1d5c1 Plan for storage of Hazardous Materials

We plan to use a number of hazardous materials in the construction of the rocket. Below is the most current list:

- West System Three epoxy resin
- West System Three epoxy hardener
- Acetone (Epoxy Solvent)
- Isopropyl Rubbing Alcohol (Epoxy solvent/cleaner)
- Krylon Spray Paint
- Cesaroni ProX Reload Kit

- Cesaroni ProFire Igniter
- Black Powder
- Duracell/EveryReady Alkaline Batteries
- 60/40 Rosin Core Solder

All hazardous materials will be stored offsite at one of the team advisor's residence or in a hazardous materials location at Northwest Indian College in accordance with all federal, state, and local regulations.

All flammable materials are stored away from heat and flame. If required by the MSDS's or any applicable regulations, they are being stored in a shed detached from any occupied room.

III.1.e Mission Success and Workmanship

Measure, build, measure, test, and redo if not correct. We take pride in our workmanship and the quality of what we build. We also need to be very creative in what we design and build because of a very limited tool set and workspace.

Our workmanship has proven itself in the success of our rocketry project.

III.1.f Planned Additional Component, Functional, Static Testing

Currently, the only new component that we are considering is a Plexiglas section over the science payload bay. We have a Plexiglas section and are looking at a variety of methods to fasten it to the rocket's airframe. The component is being constructed this week and will be incorporated in one of Skybolt's test flights, assuming that it meets all of the tests and verification plans.

In addition to the ground testing of the black powder charges, we are testing our instruments to establish baselines for each. If you include the Plexiglas section, we will conduct instrument tests while enclosed in the section and compare them to our baselines to determine whether or not we'll need to compensate for any differences.

III.1.g Plans for Remaining Manufacturing and Assembly

The above mentioned Plexiglas section is the only remaining item that needs to be constructed. The installation of the power management system and the science payload remain to be completely tested and installed.

They are scheduled to be completed and tested by the end of February.

III.1.h Design Integrity

Since our rocket is constructed from High Power Rocketry standard materials, and since we've been meticulous in its construction, we are very confident of the design's integrity. The one unknown at this point is the Plexiglas section, if we incorporate into our design.

III.1.h.1 Nosecone

The nosecone is a fiberglass commercial 16 inch long 4:1 ogive-shaped nosecone with a 3.75 inch shoulder. The GPS transmitter will be housed here, (Figure 4), well away from all other electronics. A ½ inch aircraft grade birch plywood bulkhead secures the GPS platform in the nosecone. The GPS platform is secured to the nosecone with three #6 flathead screws through the nosecone shoulder into the plywood bulkhead.

Figure 17 - GPS Tracker on nose cone insert with hand-held GPS receiver

III.1.h.2 Main Parachute Recovery Bay

The main parachute recovery bay is 32 inches long of which 4 inches at either end are allocated for the nose cone shoulder and the altimeter electronics bay connector.

III.1.h.3 Altimeter Electronics Bay (ebay)

The altimeter electronics bay, Figure 3, adds 1 inch to the rocket's length and itself is 9 inches long. It houses the two PerfectFlite MAWD altimeters for redundant dual deployment. It constructed from G10 fiberglass capped with G10 bulkheads. An eyebolt and four connecting posts for the electric match wires finish each end. The two MAWD altimeters and batteries are held in place on a G10 fiberglass sled that slides on two ¼ inch threaded rods. Everything is fastened together by bolts and wing nuts on either end of the threaded rods.

The vent holes connect to flexible tubing that is curled to inhibit water entry should the rocket land in water.

The ebay altimeters will be shield from stray RF signals with a layer of aluminum foil glued to the ebay's interior.

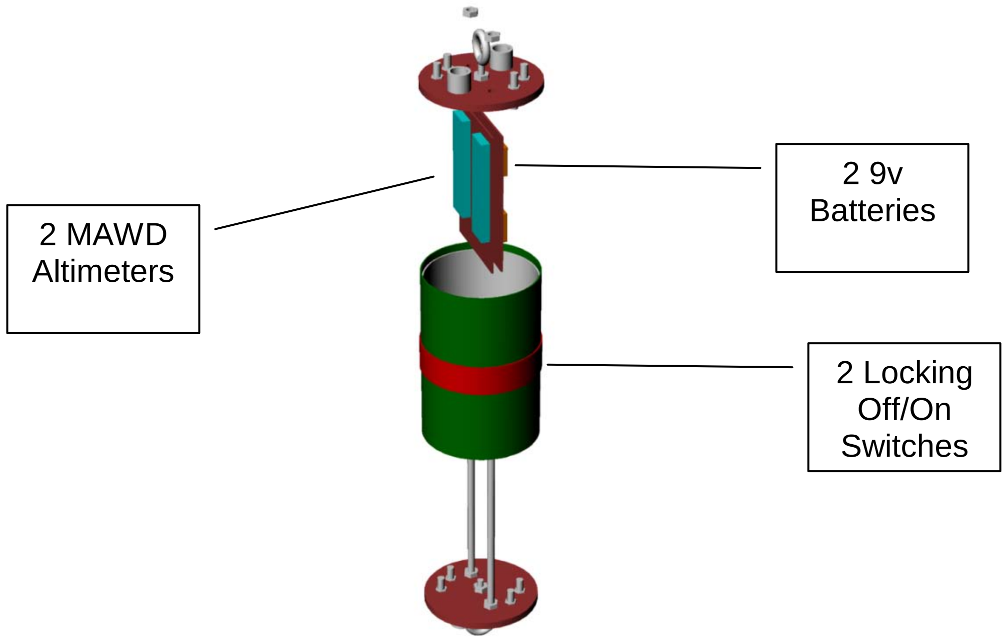


Figure 18 - Ebay Concept

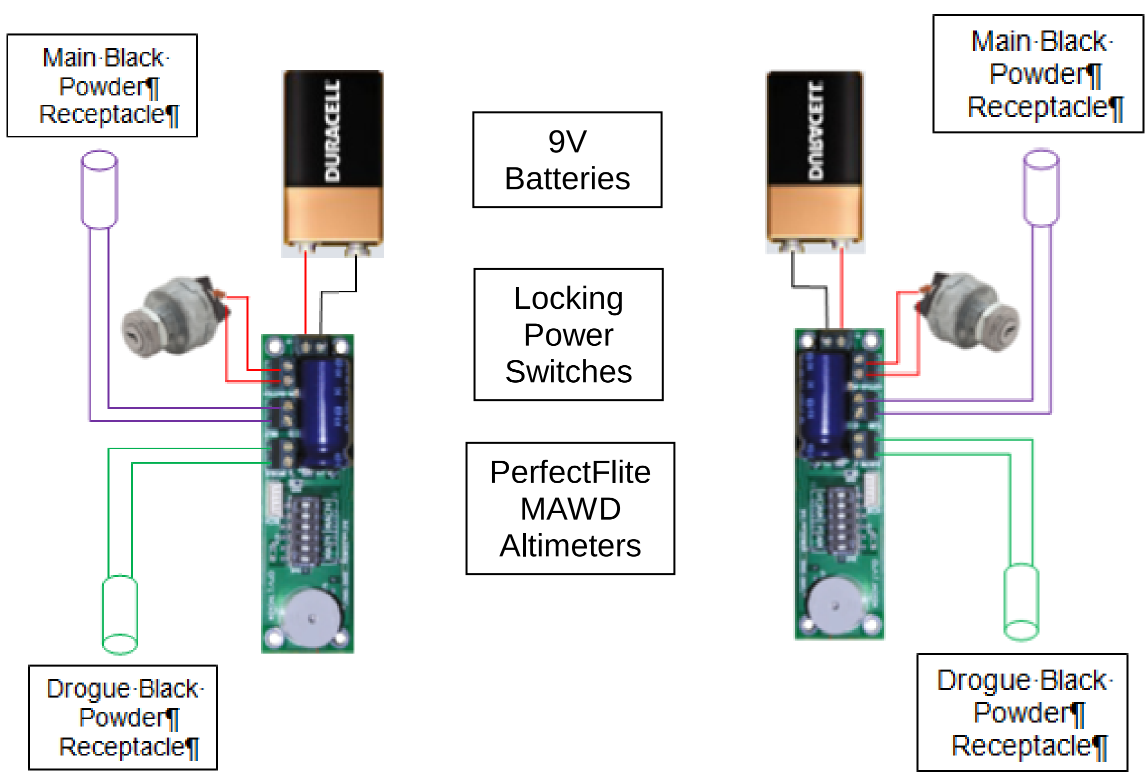


Figure 19 - Redundant Dual Deploy Avionics Block Diagram

III.1.h.4 Drogue Parachute Recovery Bay

The drogue parachute recovery bay is 16 inches long, of which the upper 4 inches are allocated for the connection to the ebay. This leaves 12 useable inches. The bottom slides over the tube connector between it and the science payload bay. The tube remains hollow for the first 4 inches for recovery harness/drogue chute storage.

III.1.h.5 Science Payload Bay

The science payload bay contains the sensors and microcontrollers for the atmospheric data gathering, the data transmitter, and the power management system for the velocity reduction system

III.1.h.6 Power Management and Velocity Reduction System

This system (Figure 4) is located in the after end of the science payload bay. It's comprised of 2 high-torque servos that extend and retract an "air dam". The opening and closing is controlled by an Arduino microcontroller with a barometric shield that measures altitude, calculates velocity and predicts whether or not and when the dams need to be deployed.

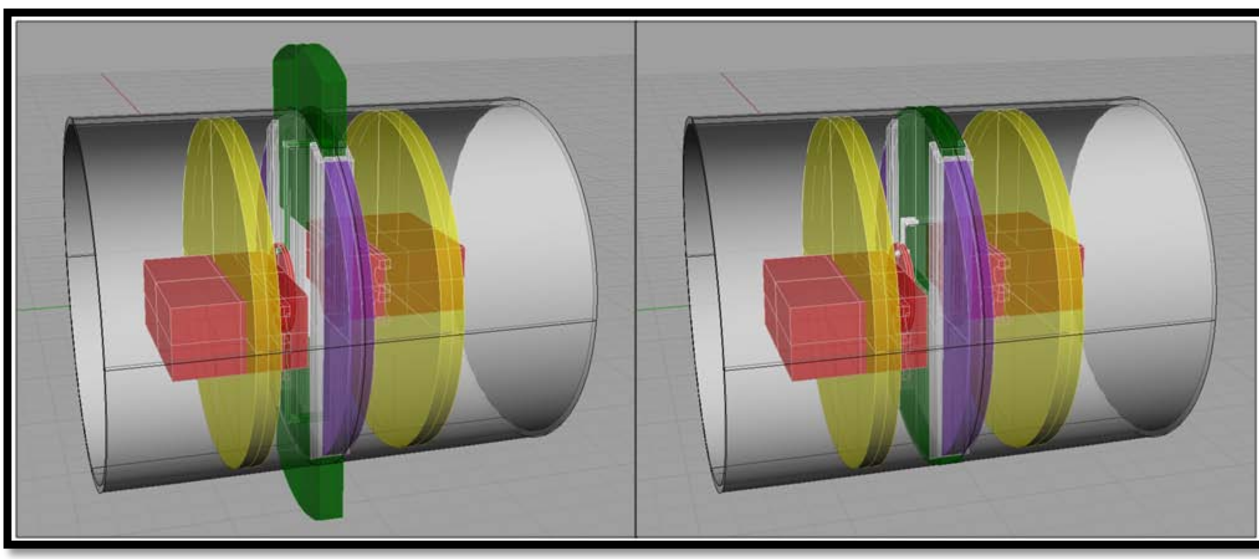


Figure 20 - Power Management System Concept

III.1.1.h Fin Can

The fin can, Figure 8, is 21 inches long and houses the 16 inch x 54mm diameter motor mount which is secured in place with epoxy resin and three centering rings, one at either end of the fin tabs and with the mid ring fitting into a notch in each fin. A layer of fiberglass cloth and epoxy resin provides additional connection support for the fins. An Aero Pack combination fin cone/motor retainer finishes the airframe. It provides both drag reduction and secure motor retention.

III.1.1.h.1 Fins

Three 1/8 inch G10 fins (Figure 9) are placed 98.25 inches from the nose of the rocket to provide stable flight. The fins have a tab and are mounted through the airframe wall (TWT mounting) and butt against the motor mount. They are fastened to both the airframe and to the motor mount with West Systems epoxy resin. Furthermore, the fin tabs are bonded to the motor mount with fiberglass and epoxy resin. The fiberglass runs from the top of one fin tab, over the motor mount and to the top of the adjacent fin tab; the fiberglass is then coated with West Systems epoxy resin to bond all in place. The fins have been notched and an additional centering ring placed between the fore and aft centering rings. This provides a larger bonding surface as well as more support for the motor tube.

Figure 21 - Fin-to-Motor Tube Mounting

III.1.h.9 Bulkheads and Centering Rings

The bulkheads provide recovery harness mounts, confine the different components, and protect the components and electronics from black powder charges ignited during recovery system deployment. Eye-bolts are used on the bulkheads to provide a connection point for the recovery harnesses. The material for all bulkheads is 3/16 inch G10 fiberglass. This material was chosen because of its high strength, durability, it's relatively easy to shape with woodworking tools. It is suitable for protecting the instruments in the payload and the altimeters from the black powder charges used in the recovery system. The bulkheads are secured in place using West System epoxy resin.

III.1. h.10 Motor Mount, Motor retainers and Couplers

G10 fiberglass is used for the motor tube and couplers is from Performance Rocketry. The G10 tubing is structurally stable and is used to protect and house the motor, the avionics, and the science experiments and to provide a stable structure to contain and constrain the motor. The motor tube is 16 inches long with a 54 mm (2.14 inch) diameter and is located 96 3/8 inches from the tip of the nose cone. An Aero Pack fin cone/motor retainer (Figure 8) provides both drag reduction and secure motor retention. The adaptor portion is bonded to the motor mount with J&B Weld high temperature epoxy.

III.1. h.11 Connecting the Components

Three different connection methods are used:

1. Permanent connections use West System epoxy.
2. Those that need intermittent access use #6, #8, or #10 T-nuts and screws.
3. Temporary connections between the ebay and the two parachute compartments use nylon shear pins. The shear pins prevent the rocket from premature separation due a combination of drag, inertia, and momentum. The shear pins are, however, designed to fail when the black powder ejection charge is ignited.

III.1.h.12 Verification Plan

We will verify all components and subsystems for soundness, suitability, and flight worthiness according to our verification plan (Appendix C). We will meticulously examine each system and subsystem prior to either ground testing or flight testing. Our NAR Mentor and NAR L2 Advisors will inspect also. The Rocksim simulations will provide a starting point for safety and flight success probability.

Requirement	Design Feature	Verification	Status
1. Option 2: The Science Mission Directorate (SMD) at NASA HQ will provide a $3,000 sponsorship to any team that chooses to build and fly a deployable science payload meeting the following criteria:	SMD Payload	Inspection	Work in Progress
The payload shall gather data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation. Measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Surface data collection operations will terminate 10 minutes after landing.	Arduino microcontroller-based sensors	Test	Work in Progress
The payload shall take at least 2 pictures during descent and 3 after landing.	Multiple Cameras oriented	Test	Cameras purchased

The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.	appropriately		Work in Progress
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.	RDAS-Tiny transmitter & receiver	Test	Work in Progress
Separation of payload components at apogee will be allowed, but not advised. Separating at apogee increases the risk of drifting outside of the recovery area. The payload shall carry a GPS tracking unit. Minimum separation altitude shall be 2,500 ft.	Not Applicable	Not Applicable	Not Applicable
2. The launch vehicle shall deliver the science or engineering payload to, but not exceeding, an altitude of 5,280 feet. above ground level (AGL). One point will be deducted for each foot achieved below the target altitude. Two points will be deducted for each foot achieved above the target altitude. Any team whose vehicle travels over 5,600 ft. according to their competition altimeter will be disqualified from being able to receive the overall competition award and will receive a score of zero for the altitude portion of their total score.	Design through Rocksim 9, Power Management System	Test	Work in Progress
3. The vehicle shall carry one Perfect Flight MAWD or ALT15 altimeter for recording of the official altitude used in the competition scoring. Teams may have additional altimeters to control vehicle electronics and payload experiments. At the flight hardware and safety check, a NASA official will mark the altimeter which will be used for the official scoring. At the launch field, a NASA official will also obtain the altitude by listening to the audible beeps reported by the altimeter. The following circumstances will warrant a score of zero for the altitude portion of the competition:	Two PerfectFlite MAWD altimeters	Inspection	Complete
a. The official, marked altimeter is damaged and/or does not report an altitude after the team's competition flight.	Safe Recovery will preclude this	Inspection	Work in Progress

b. The team does not report to the NASA official designated to record the altitude with their official marked altimeter by 5:00 pm on the day of the launch.	Check list will preclude this	Inspection	Work in Progress
4. The recovery system electronics shall have the following characteristics:			
a. The recovery system shall be designed to be armed on the pad.	Locking key switches installed	Inspection	Completed
b. The recovery system electronics shall be completely independent of the payload electronics.	Payload electronics in separate science by		
c. The recovery system shall contain redundant altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Designed with two independent systems		
d. Each altimeter shall be armed by a dedicated arming switch.	Locking Key Switches		
e. Each altimeter shall have a dedicated battery.	Designed with two independent systems including batteries		
f. Each arming switch shall be accessible from the exterior of the rocket airframe.	Locking switches located on ebay ring		
g. Each arming switch shall be capable of being locked in the ON position for launch.	Switches that lock with a key are installed		
h. Each arming switch shall be a maximum of six (6) feet above the base of the launch vehicle.	Switches located 64 inches from base of rocket		
5. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system by the transmitting device(s).	Ebay lined with aluminum foil	Inspection	Completed
6. The launch vehicle and science or engineering payload shall remain subsonic from launch until landing.	Designed with Rocksim 9 to stay subsonic	Simulation	Completed
7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Simulation	Completed

8. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery from apogee to main parachute deployment is permissible, provided that the kinetic energy is reasonable.	Designed with Rocksim 9, using drogue at apogee and main at 700 feet	Simulation	Work in Progress
9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	6 (3 each on main and drogue end of ebay) - #2-56 nylon screws will be shear pins	Ground Testing	Completed
10. The launch vehicle shall have a maximum of four (4) independent or tethered sections.	Designed with three	Inspection	Completed
a. At landing, each independent or tethered sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Designed via calculations	Simulation	Complete
b. All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.	Designed with Rocksim 9	Simulation analysis	Complete
11. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the waiver opens.	Designed as required	Check lists	Completed
12. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any onboard component.	Battery power calculated to last at least 2 hrs for each device using a battery	Simulation analysis	Work in Progress
13. The launch vehicle shall be launched from a standard firing system (provided by the Range) using a standard 10 - second countdown	Designed as required	Test	Completed at NWIC
14. The launch vehicle shall require no external circuitry or special ground support equipment to initiate the launch (other than what is provided by the Range).	None are necessary as designed	Inspection	Completed
15. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	Data analysis will be examined post flight	Testing will follow payload completion prior to the competition flight	Work in Progress

16. An electronic tracking device shall be installed in each independent section of the launch vehicle and shall junction with an electronic, transmitting device, but shall not replace the transmitting tracking device.	Garmin GPS unit in nose cone	Ground tested complete. Flight test to follow	Completed
17. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA) and/or the Canadian Association of Rocketry (CAR).	Designed to use CTI/Aerotech reloadable motor	Inspection	Completed
18. The total impulse provided by the launch vehicle shall not exceed 5,120 Newton-seconds (L-class). This total impulse constraint is applicable to any combination of one or more motors.	Designed as required, L motor largest permissible	Inspection	Completed
19. All teams shall successfully launch and recover their full scale rocket prior to FRR in its final flight configuration.			
a. The purpose of the full scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight.	Test flights scheduled prior to FRR	Test flight	Work in Progress
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle	Test flight	Work in Progress
c. The payload does not have to be flown during the full-scale test flight.			
▪ If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Measured mass of actual payload will be either substituted or the payload will be flown	Test flight	Work in Progress
▪ If the payload changes the external surfaces of the launch vehicle (such as with camera housings and/or external probes), those devices must be flown during the full scale demonstration flight.	Test flight will be with rocket as its designed		Work in Progress
d. The full scale motor does not have to be flown during the full scale test flight. However, it is recommended that the full scale motor be used to demonstrate full flight	Both smaller and a full scale motor will be used in test flights	Test flight	Work in Progress

readiness and altitude verification.			
e. The success of the full scale demonstration flight shall be documented on the flight certification form, by a Level 2 NAR/TRA observer.	Our mentor and 3 other NAR L2 individuals are available		Work in Progress
f. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer.	No changes will be made.		Work in Progress
20. The following items are prohibited from use in the launch vehicle:			
a. Flashbulbs. The recovery system must use commercially available low-current electric matches.	None of these have been included in the rocket design	Inspection	Complete
b. Forward canards.			
c. Forward firing motors.			
d. Rear ejection parachute designs.			
e. Motors which expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).			
f. Hybrid motors.			
21. Each team shall use a launch and safety checklist. The final checklist shall be included in the FRR report and used during the flight hardware and safety inspection and launch day.	Check lists are designed	Inspection and actual testing	Complete
22. Students on the team shall do 100% of the work on the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder charges.	Implemented as required	Inspection	Work in Progress
23. The rocketry mentor supporting the team shall have been certified by NAR or TRA for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 15 flights in this or a higher impulse class, prior to PDR.	Implemented as required	Inspection	Complete
24. The maximum amount teams may spend on the rocket and payload is $5000 total. The cost is for the competition rocket as it sits on the pad, including all purchased components and materials and the fair market value of all donated components and materials. The following items may be omitted from the total cost of the vehicle:			
a. Shipping costs.	Implemented as	Inspection	Complete

b. Ground Support Equipment.	required		
c. Team labor.			

III.1.h.13 Drawings

III.1.h.13.a Dimensional Drawings

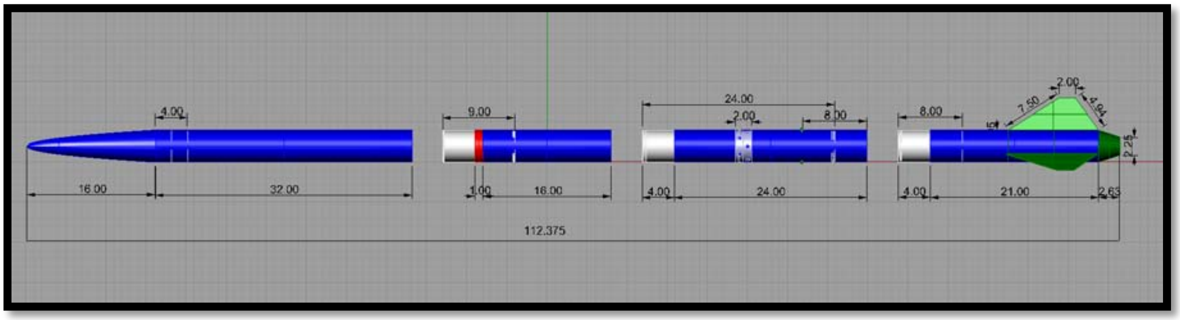


Figure 22 - Entire Rocket with dimensions

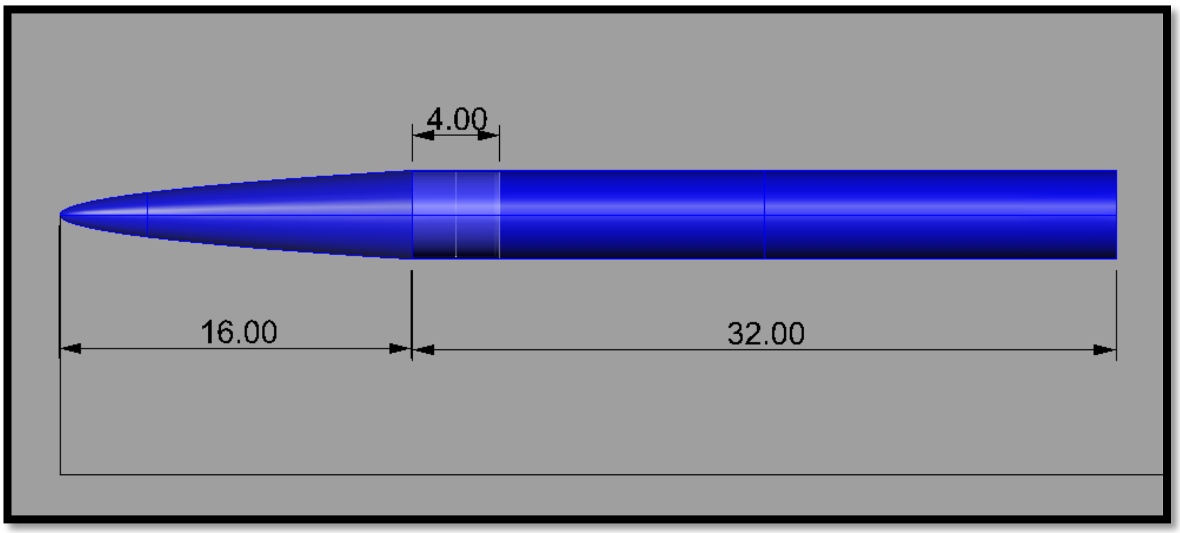


Figure 23 - Nose Cone and Main Parachute Bay

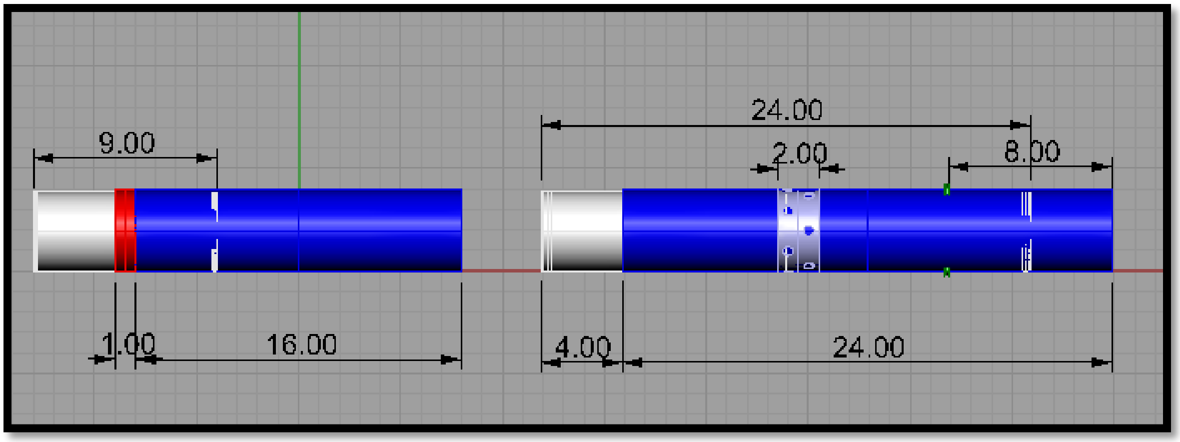


Figure 24 - Ebay, Drogue Parachute Bay, and Science Payload Bay

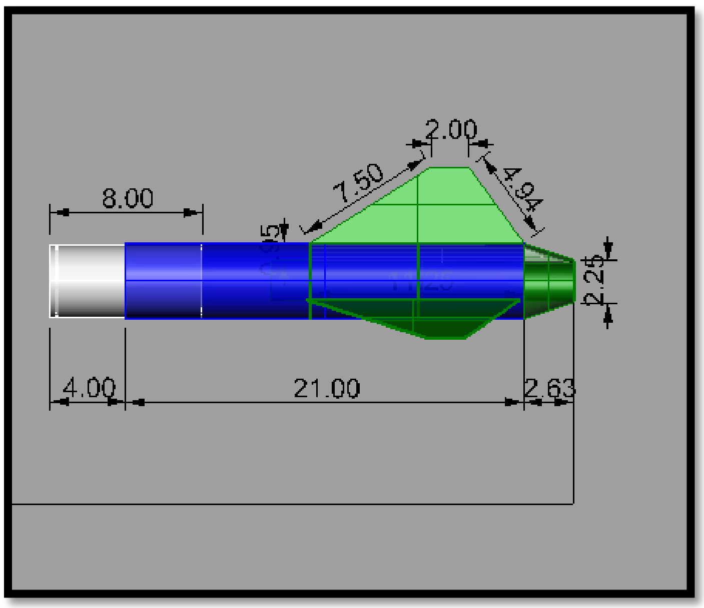


Figure 25 - Fin Can, Fins, and Tail Cone

III.1.h.13.b Power Managements System

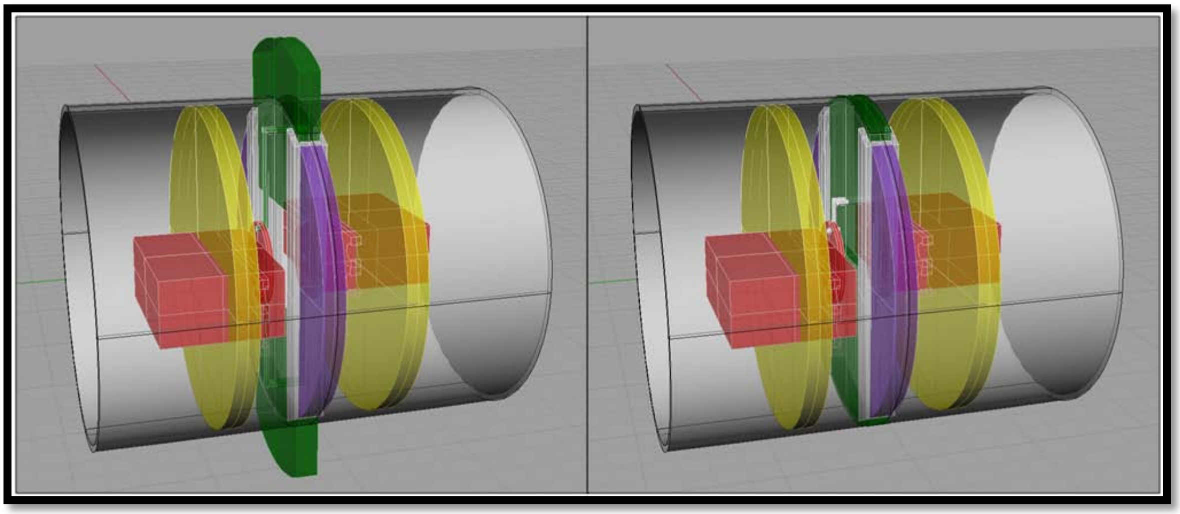


Figure 26 - Velocity Reduction Subsystem (extended & Retracted

III.1.h.13.c Recovery System Electrical Schematics

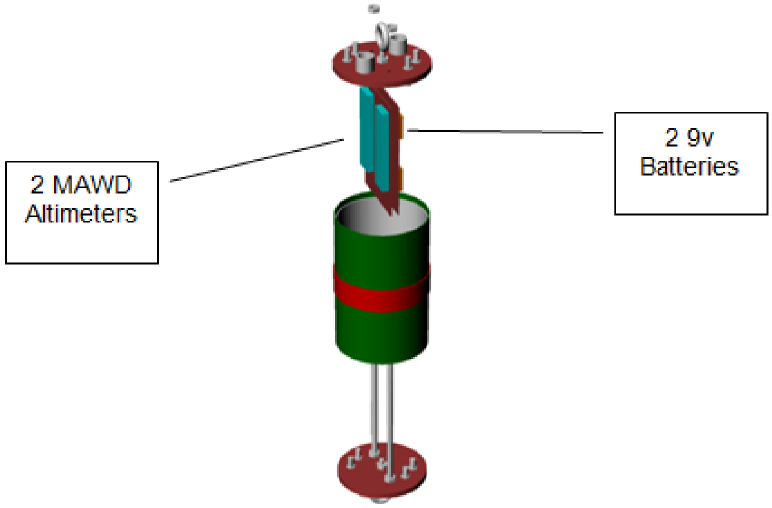


Figure 27 - Competition Rocket Ebay

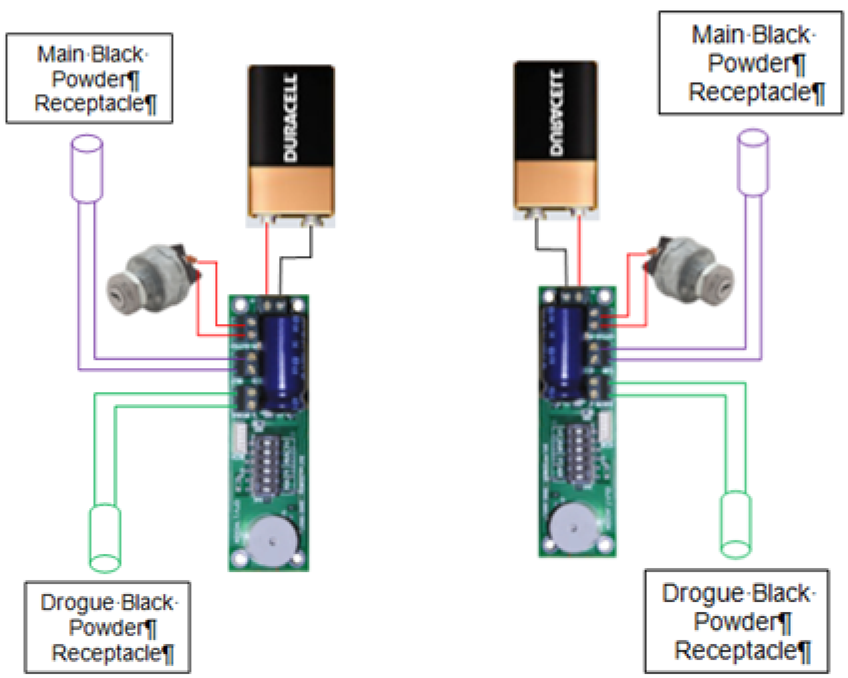


Figure 28 - Recovery Avionics, redundant dual deploy

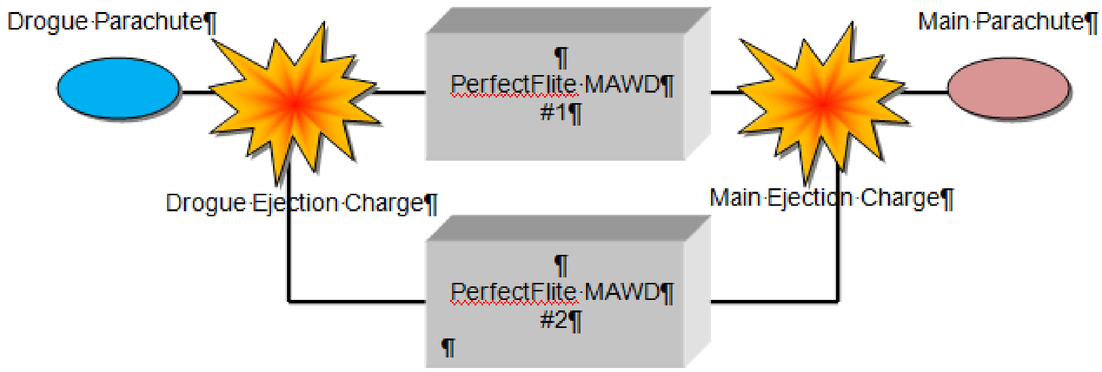


Figure 29 - Redundant Dual Deployment System Schematic

III.1.h.13.d Mass Statement

Mass Statement		
Material	**Component**	**Mass (lb)**
Aluminum	Tail Cone	0.170
G10 Fiberglass	Fin Can	1.125
G10 Fiberglass	Aft Airframe	0.857
G10 Fiberglass	Fwd Airframe	1.714
G10 Fiberglass	Nose Cone	0.823
G10 Fiberglass	Science Payload Bay	0.750
G10 Fiberglass	Ebay Ring	0.071
G10 Fiberglass	Fin Can Tube Coupler	0.478
G10 Fiberglass	Science Bay Tube Coupler	0.478
G10 Fiberglass	Ebay Coupler	0.478
Steel	Threaded Rod	0.375
Steel	Nose Cone Eyebolt	0.125
Steel	Fwd Ebay Eyebolt	0.125
Steel	Aft Ebay Eyebolt	0.125
Steel	Fwd Science Bay Eyebolt	0.125
Steel	Aft Science Bay Eyebolt	0.125
Steel	Fin Can Eyebolt	0.125
Nylon	Main Parachute	1.813
Nylon	Drogue Parachute	0.375
	Avionics (altimeters, batteries)	2.000
	Science Payload (sensors, transmitter, cameras	2.500
Tubular Nylon	Main Recovery Harness	1.500
Tubular Nylon	Drogue Recovery Harness	1.000
	GPS Unit	1.000
G10 Fiberglass	Nose Cone Bulkhead	0.077
G10 Fiberglass	Fwd Ebay Bulkhead	0.077
G10 Fiberglass	Aft Ebay Bulkhead	0.077

G10 Fiberglass	Fwd Science Bay Bulkhead	0.077
G10 Fiberglass	Aft Science Bay Bulkhead	0.077
G10 Fiberglass	Fwd Motor Mount Center Ring	0.075
G10 Fiberglass	Mid Motor Mount Center Ring	0.075
G10 Fiberglass	Aft Motor Mount Center Ring	0.075
	Power Management System	2.500
G10 Fiberglass	Fin Set	0.902
	Epoxy	1.000
	Paint	1.000
	Total Mass=	**23.906**

Table 4 - Mass Table

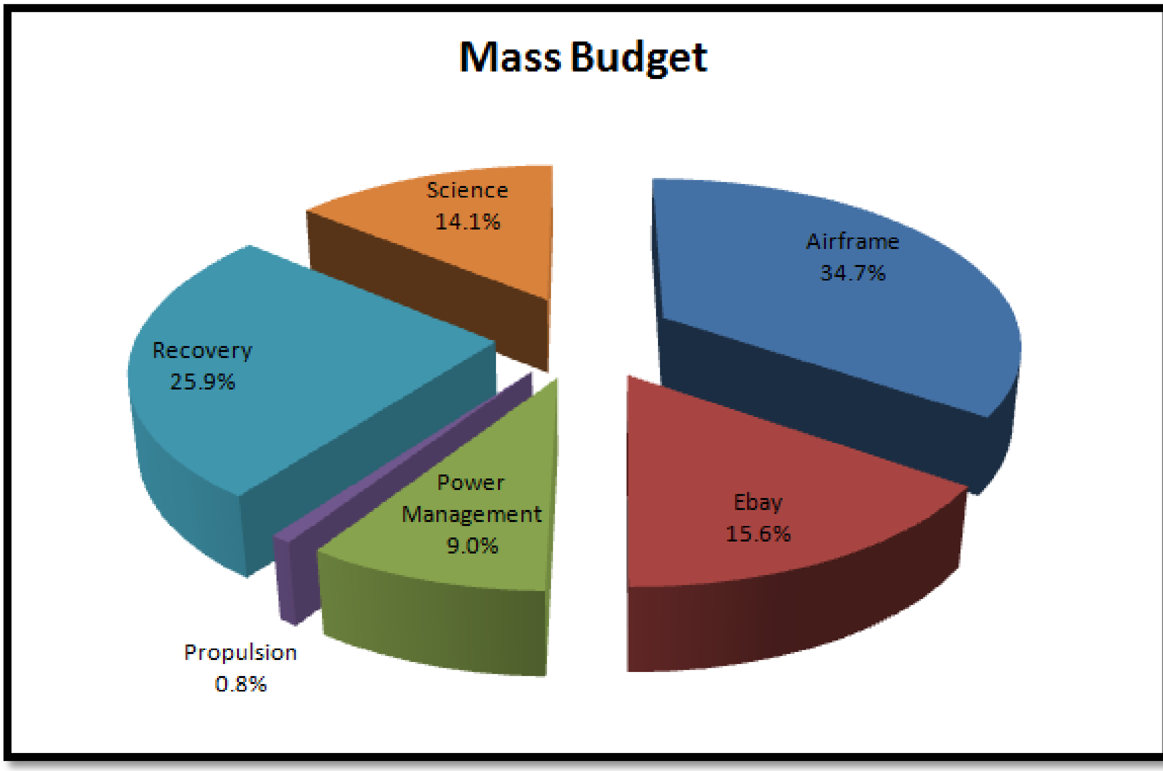


Figure 30 - Mass Budget Graph

All of the masses except the science payload, epoxy, and paint are derived from weighing each of the components. Epoxy and paint used as well as the science payload and power management system are estimates based upon prototypes.

The selected motor has reserve power for six extra pounds, which is about 25% of the designed weight. This extra weight will not adversely affect the stability margin or the target altitude. It moves the CG about 2 inches forward.

III.1.i Risks and Risk Reducing Plans

Native American culture often times necessitates individuals to participate in cultural activities that require absence from school and or work. Therefore our biggest challenge will be to keep the team together and functioning as a unit for the entire duration of this project.

Our design process is build, test fly, evaluate, and make modifications and test fly again. We do not have any engineering, electrical, design, or computer science departments that we can rely on for assistance. We are doing all of this through sheer determination to learn and have fun.

Winter weather in the Pacific Northwest has moderate temperatures, moderate winds and many days of low clouds and precipitation. This definitely impacts our testing ability. Fortunately, our launch area is only 2 miles from the college and we can activate our 5000' FAA and Canadian AA waivers for any Saturday and Sunday mornings from 8:00 am through 12:00 pm. However, flights higher than 5000 feet require a 6 hour drive into Washington's interior which means weather can severely affect our higher altitude test schedule. Given this, we may forego a test flight using the full-scale motor.

General Risks	***Probability***	***Impact***	***Mitigation***
Fluidity in team membership	High	Lack of cohesion resulting in redundant learning/work	Spread the work and ideas among all of the members
Project falls behind	Moderate	Late hours required for task completion	Effective planning
Parts not arriving on time	Low	Incomplete vehicle	Create good relationships with vendors and order early
Design issues	Moderate	More time needed to build a competitive rocket	Make efficient use of time and Mentor
Delayed test flights because of weather	High	Insufficient testing for design validation and data acquisition	Have flexible launch plans for tests
Exceeding budget	Low	Design alterations	Proper budget management and foresight
Lack of expertise	Moderate	Design alterations or outsourcing	Identify needs early and make proper arrangements

Personal Safety Hazards	***Potential Effects of Failure***	***Failure Prevention***
Individual health issues when working with epoxy, fiberglass, paint, etc.	Person will become sick or experience discomfort.	Wear appropriate safety clothing/equipment such as gloves and clothing to cover skin, face masks, etc. Have adequate ventilation. Have MSDS prominently posted.

Accidental injuries such as lacerations, bruises, etc.	Harm to team members (possible hospitalization).	Be attentive to task at hand. First aid kit is available.
Potential fire when working with flammable substances	Harm to team members (possible hospitalization).	Be aware of locations of nearest first-aid kit, fire extinguisher, and eye wash station
Untidy work area	Harm to team members (possible hospitalization). Loss of tools, hazardous working conditions	Everything has a place and everything in its place. Clean up debris during and after working.

Schedule Risks	***Potential Effects of Failure***	***Failure Prevention***
Team members have other obligations that interfere with presentations or launches.	Team participation decreases which results in lower membership.	Notify team members of any presentations, launches, or due dates well ahead of time.
Team has difficulties meeting set deadlines.	Deadlines will not be met.	Assign enough time for the completion of tasks.
Meeting times conflict with certain members' schedules.	Certain members will be unable to attend meetings and will miss important information.	Choose times that best fit the majority of the membership. The team shall also work with members that still have conflicts.
NWIC's exams and/or holidays overlap with deadlines set by USLI.	Reports or presentations might not be completed.	Check the dates of final exams, holidays, and major events against the USLI timeline and PLAN!.
NWIC sessions changes from fall to winter to spring quarter.	Team members' schedules will change.	Vote by majority for meeting times and plan accordingly.

Financial Support Failures	***Potential Effects of Failure***	***Failure Prevention***
Fundraising activities do not generate enough funds.	Team will be unable to have travel money for all of the members	Hold several small-scale fundraisers to allow for more diverse interest in the team.
Incorrect parts or supplies are purchased.	Delay in build sessions, and possible milestones.	Ensure all orders are verified by team officers.
Problems could arise with space grant funding for the team.	Delays in purchasing needed supplies and parts.	Adhere to budget guidelines and discuss financial matters with team advisor.

Structural Failures	***Potential Effects of Failure***	***Failure Prevention***
Fins fail during flight due to shear forces or inadequate use of adhesive.	Rocket will experience an unstable and unpredictable flight trajectory.	Use suitable building materials, through-the-wall fin mounting, and ample application of adhesive and fillets.
Rocket experiences drag separation during flight.	Rocket will prematurely separate, leading to early parachute deployment and a mission failure.	Ensure that all joints are secure and drill a hole in the body tube to equalize pressure between the interior of the rocket and the

		atmosphere.
Rocket joints do not separate at parachute deployment.	Parachute bay will experience over-pressurization from the ejection charge but will not deploy the parachute.	Conduct pre-launch separation testing.
Parachute deploys too early or too late in flight.	High-speed deployment causes the shock cord to produce a “zippering" effect.	Test the altimeter for drogue deployment at apogee and the correct deployment altitude for the main is set..
Rocket components are lost or damaged during transport to launch site.	Team risks not launching the rocket unless repairs can be made.	Pack components safely and securely for transport and have replacement components and needed tools available at the launch site.
Rocket structure is crushed due to in-flight forces.	Rocket will have a ballistic trajectory, and the mission is a failure.	Test, evaluate, test again
Center of gravity is too high or too low.	Rocket will be unstable or over stable.	Adjust weight so that center of gravity is 1-2 calibers ahead of center of pressure.
Center of pressure is too high or too low.	Rocket will be unstable or over stable.	Adjust fin sizing and position so that the center of pressure is 1-2 calibers behind the center of gravity.

Payload Failures	***Potential Effects of Failure***	***Failure Prevention***
Altimeter and/or science payload battery power supply fails	Avionics will fail to record data, resulting in the inability of the altimeter to eject the parachutes.	Check batteries prior to launch and have extra batteries located at the launch site. The team shall also use separate power supplies for each section containing electronic devices to prevent the failure of all electronics.
Wire connections in the rocket loosen during transport or flight.	Data will not be complete, causing a payload objective failure. Ejection electronics may not deploy parachutes, causing a ballistic recovery.	Secure wires with wiring loom and ensure that all wires are properly connected prior to launch.
Altimeter fails to record data during flight.	Altitude may not be properly measured resulting in parachute deployment failure.	Test the altimeter for functionality prior to launch. Calibrate the altimeter before launch.
GPS system fails to record the position of the rocket.	Recovery of the rocket will become more difficult. The rocket may possibly be lost.	Test the GPS before launch and use a secondary tracking system.
Avionics are broken during the transport, storage, or flight.	Data will not be collected, and the payload objective will be considered a failure.	Store equipment in a safe, dry place during both storage and transport.
Static discharge to electronics.	Electronic instruments are damaged.	Team members should properly ground themselves before handling electronics.
Ultraviolet (UV) Sensor		
No data logged but data transmitted to ground station	Partial science mission failure	test data logger, ensure battery strength is adequate
Data logged but no data transmitted to ground station	Partial science mission failure	test transmitter and receiver, ensure battery strength is adequate
Erratic data or inconsistent data	Science mission failure	check proper placement, wiring and calibration of sensor, ensure battery strength is adequate. Faulty sensor.
No data logged or transmitted to ground station	Science mission failure	conduct proper ground testing, ensure battery strength is adequate
Damage during transportation or deployment	Science mission failure	pack carefully and ensure rugged construction techniques
Atmospheric Pressure Sensor		
No data logged but data transmitted to ground station	Partial science mission failure	test data logger, ensure battery strength is adequate
Data logged but no data transmitted to ground station	Partial science mission failure	test transmitter and receiver, ensure battery strength is adequate

Erratic data or inconsistent data	Science mission failure	check proper placement, wiring and calibration of sensor, ensure battery strength is adequate. Ensure adequate access to outside atmosphere. Faulty sensor.
No data logged or transmitted to ground station	Science mission failure	conduct proper ground testing, ensure battery strength is adequate
Damage during transportation or deployment	Science mission failure	pack carefully and ensure rugged construction techniques
Relative Humidity Sensor		
No data logged but data transmitted to ground station	Partial science mission failure	test data logger, ensure battery strength is adequate
Data logged but no data transmitted to ground station	Partial science mission failure	test transmitter and receiver, ensure battery strength is adequate
Erratic data or inconsistent data	Science mission failure	check proper placement, wiring and calibration of sensor, ensure battery strength is adequate. Ensure adequate access to outside atmosphere. Faulty sensor.
No data logged or transmitted to ground station	Science mission failure	conduct proper ground testing, ensure battery strength is adequate
Damage during transportation or deployment	Science mission failure	pack carefully and ensure rugged construction techniques
Temperature Sensor		
No data logged but data transmitted to ground station	Partial science mission failure	test data logger, ensure battery strength is adequate
Data logged but no data transmitted to ground station	Partial science mission failure	test transmitter and receiver, ensure battery strength is adequate
Erratic data or inconsistent data	Science mission failure	check proper placement, wiring and calibration of sensor, ensure battery strength is adequate. Ensure adequate access to outside atmosphere. Faulty sensor.
No data logged or transmitted to ground station	Science mission failure	conduct proper ground testing, ensure battery strength is adequate
Damage during transportation or deployment	Science mission failure	pack carefully and ensure rugged construction techniques
Solar Irradiance Sensor		
No data logged but data transmitted to ground station	Partial science mission failure	test data logger, ensure battery strength is adequate
Data logged but no data transmitted to ground station	Partial science mission failure	test transmitter and receiver, ensure battery strength is adequate
Erratic data or inconsistent data	Science mission failure	check proper placement, wiring and calibration of sensor,

		ensure battery strength is adequate. Faulty sensor.
No data logged or transmitted to ground station	Science mission failure	conduct proper ground testing, ensure battery strength is adequate
Damage during transportation or deployment	Science mission failure	pack carefully and ensure rugged construction techniques

Recovery Failures	***Potential Effects of Failure***	***Failure Prevention***
Drogue and main parachute bays experience separation during flight.	Parachutes will deploy early, causing the rocket to miss the target altitude. A zippering effect may also occur.	Ground test shear pins and ensure proper pressure equalization in parachute bays.
Shock cords snap upon parachute deployment.	Rocket will experience an uncontrolled descent.	Test shock cords to ensure that they are sufficiently strong and long enough to withstand expected loads.
Altimeter fails to deploy the drogue and main parachutes.	Rocket will experience an uncontrolled descent.	Ensure that the altimeter is functioning properly prior to launch. A double-redundant ejection system will be used.
Drogue and main parachutes are packed too tightly to release.	Rocket experiences uncontrolled descent.	Ground test efficiency of the packing technique before launch.
Parachute melts or chars due to ejection charge heat.	Parachute becomes partially or entirely ineffective, causing an uncontrolled descent.	Use flame/heat retardant material between the parachute/shock cord and the ejection charge.
Parachute lines tangle upon deployment.	Parachutes will be ineffective, causing an uncontrolled descent.	Test deployment prior to launch and use a parachute/shock cord packing procedure that minimizes tangling.

Propulsion Failures	***Potential Effects of Failure***	***Failure Prevention***
Propellant fails on the launch pad.	Launch will be unsuccessful.	Test the ignition system and ensure that the connection points and the installation of the igniters are correct.
Igniter fails on the launch pad.	Motor of the rocket will fail to ignite.	Ensure that the igniter is secure before attempting ignition.
Motor centering rings fail.	Thrust vector is will not be aligned with the axis of symmetry, causing erratic and unpredictable flight.	Use strong centering rings that are well mounted and have holes in the true center.

Motor mount fails.	Rocket and the payload might be destroyed by the motor traveling up through the rocket body.	Test the motor mount system for correct construction. The team shall also conduct an inspection of the mounting system prior to launch.
Motor retention system fails.	Free-falling ballistic objects could be produced, possibly harming people around the launch site.	Use an adequate motor retention system to ensure that the motor will remain in the rocket.
Motor explodes on the launch pad.	Rocket will explode and the mission will be a failure.	Use appropriate casings for motors and stand an appropriate distance away from the launch pad at the time of ignition.

Launch Operation Failures	***Potential Effects of Failure***	***Failure Prevention***
Power supply for the ignition fails.	Rocket will fail to launch, and the mission will be a failure.	Ensure that the power supply is fully charged.
Launch rail buttons malfunction.	Launch will be unsafe, and the rocket could have an unpredictable trajectory.	Ensure that the rail buttons are securely attached to the rocket body and that they are correctly aligned with one another.
Fault igniter.	Motor will not ignite and the rocket will not launch.	Bring extra igniters to the launch site.
Rocket snags on the launch rail.	Launch buttons will strip off, causing the rocket to have an unpredictable trajectory.	Clean the launch rail and apply a lubricant, such as WD-40, prior to the launch.
Grass at the launch site catches on fire after launch.	Equipment will be destroyed and people at the launch site may be harmed.	Use a fire-retardant blanket if the grass near the launch site is not excessively dry. Have a fire extinguisher readily available.
Rocket is carried out of range by the wind.	Rocket will be lost.	Don’t fly in heavy winds. Use a GPS or other tracking device
Catastrophic motor malfunction on launch pad	Rocket is damaged, possibly destroyed.	Ensure proper fire safety devices are on hand to prevent any injuries to personnel.

III.2 Subscale Flight Results

III.2.a Subscale Verification Status

We have flown the rocket without the science payload and have tested and verified these:

Launch and recovery of scale rocket	successful
Check list verification for completeness	successful
Black Powder ejection test without altimeters	successful
Black Powder ejection test with altimeters	successful
Flight test of dual deployment recovery system	successful
Drogue deployment during flight test	successful
Main deployment during flight test	successful
Safe main parachute-to-ground descent rate	successful
Predicted altitude	94% successful
Launch rail and GSE equipment function	successful
Recovery team performance	successful
Range setup	successful
Safety implementation	successful

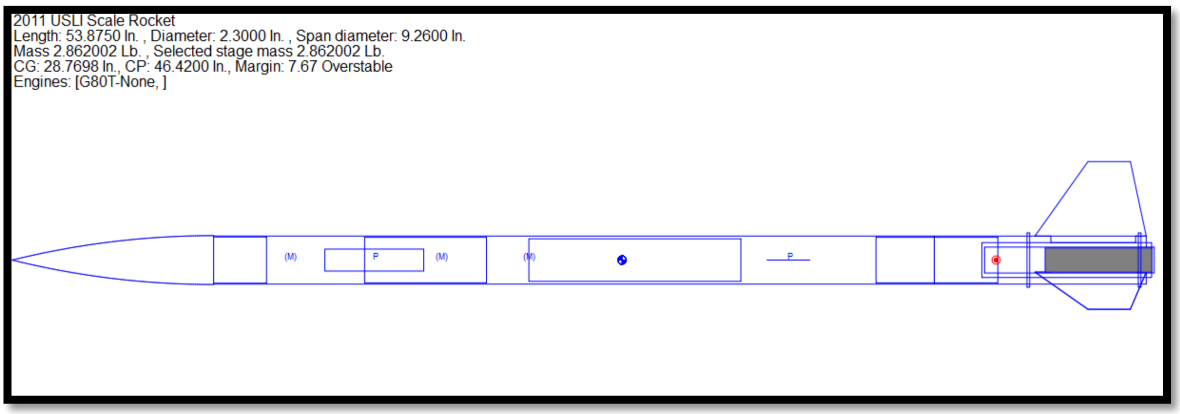


Figure 31 – Subscale Design Dimensions

The subscale rocket was powered by an Aerotech G80 with the ejection charge removed. We used a single PerfectFlight MAWD for dual deployment.

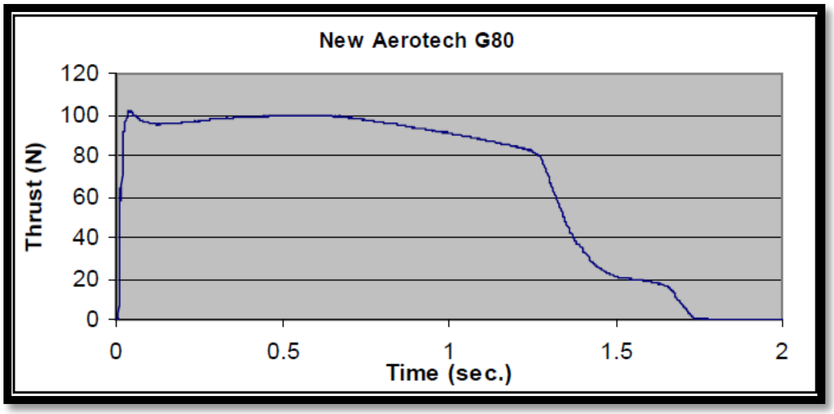


Figure 32 - Aerotech G80 Thrust Curve

Subscale Drogue and Main Parachute Black Powder Calculations

Black Powder Ejection Charge Calculator - Drogue

by Chuck Pierce

Volume =	64.2	in^3
Dia =	2.26	inch
Len =	16	inch

Calculation Mass of Black Powder for a desired Ejection Pressure

Desired Pressure =	15	psi	
mass BP =	0.50	grams	m=PV/R/T
Ejection F =	60.2	lbf	F=P*(pi/4)*d^2

Black Powder Ejection Charge Calculator - Main

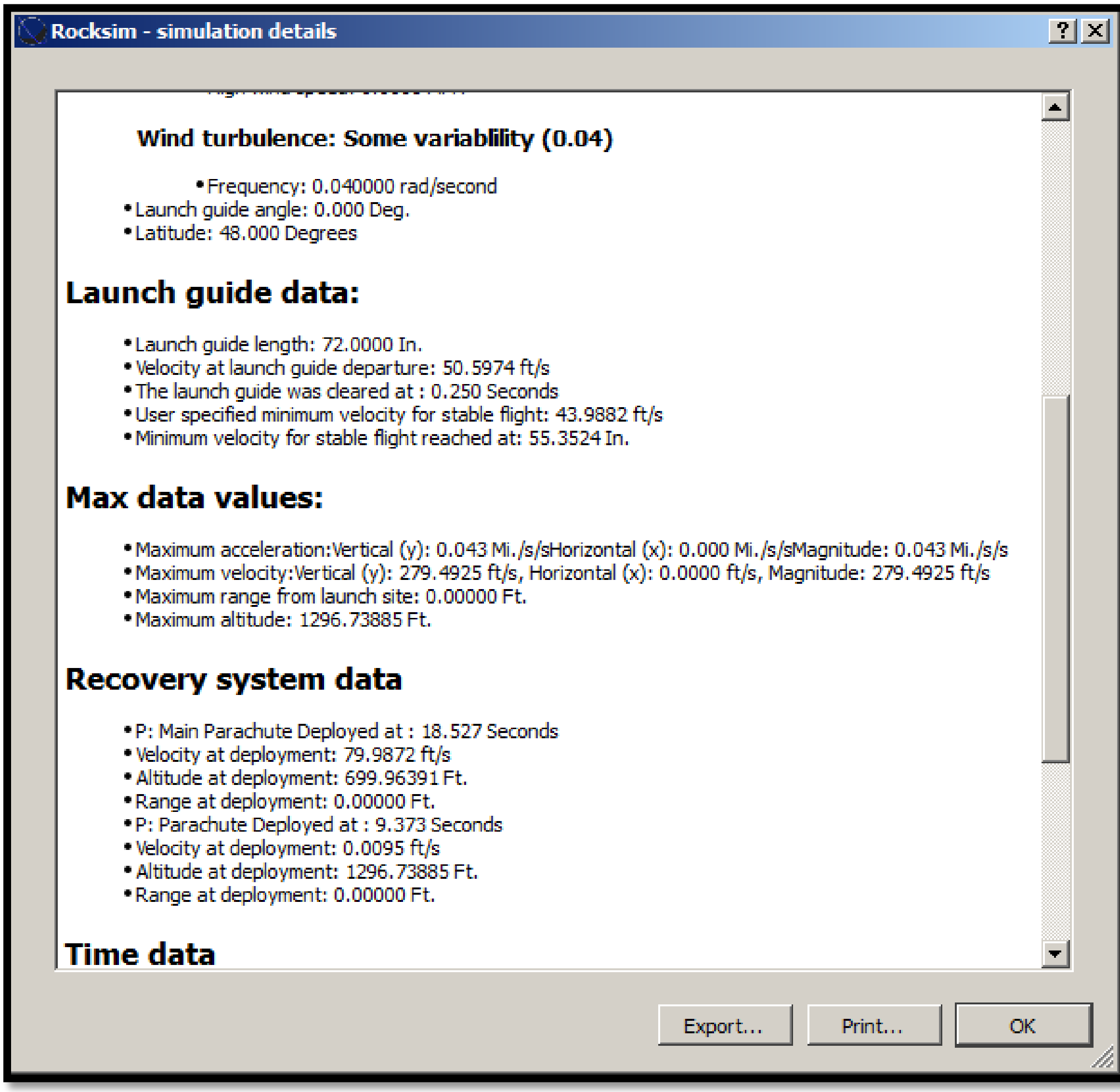
by Chuck Pierce

Volume =	72.2	in^3
Dia =	2.26	inch
Len =	18	inch

Calculation Mass of Black Powder for a desired Ejection Pressure

Desired Pressure =	15	psi	
mass BP =	0.56	grams	m=PV/R/T
Ejection F =	60.2	lbf	F=P*(pi/4)*d^2

III.2.b Flight Data


Rocksim - simulation details

Wind turbulence: Some variablility (0.04)

- Frequency: 0.040000 rad/second
- Launch guide angle: 0.000 Deg.
- Latitude: 48.000 Degrees

Launch guide data:

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 50.5974 ft/s
- The launch guide was cleared at : 0.250 Seconds
- User specified minimum velocity for stable flight: 43.9882 ft/s
- Minimum velocity for stable flight reached at: 55.3524 In.

Max data values:

- Maximum acceleration:Vertical (y): 0.043 Mi./s/sHorizontal (x): 0.000 Mi./s/sMagnitude: 0.043 Mi./s/s
- Maximum velocity:Vertical (y): 279.4925 ft/s, Horizontal (x): 0.0000 ft/s, Magnitude: 279.4925 ft/s
- Maximum range from launch site: 0.00000 Ft.
- Maximum altitude: 1296.73885 Ft.

Recovery system data

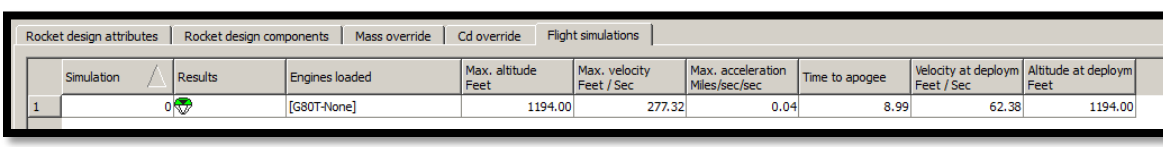
- P: Main Parachute Deployed at : 18.527 Seconds
- Velocity at deployment: 79.9872 ft/s
- Altitude at deployment: 699.96391 Ft.
- Range at deployment: 0.00000 Ft.
- P: Parachute Deployed at : 9.373 Seconds
- Velocity at deployment: 0.0095 ft/s
- Altitude at deployment: 1296.73885 Ft.
- Range at deployment: 0.00000 Ft.

Time data

Export... Print... OK

Figure 33 – Flight Data from Rocksim

The Rocksim data for the subscale model indicates that all desirable parameters are well within requirements. Launch conditions in Rocksim were set to match the conditions at the time of launch.


Rocket design attributes | Rocket design components | Mass override | Cd override | Flight simulations

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Miles/sec/sec	Time to apogee	Velocity at deploym Feet / Sec	Altitude at deploym Feet
1	0		[G80T-None]	1194.00	277.32	0.04	8.99	62.38	1194.00

Figure 34 - Rocksim Altitude Prediction

Predicted altitude was 1,194 feet.

The altitude data from the PerfectFlite MAWD below matches with the predicted altitude at 94% of the predicted altitude, 1194 feet predicted, 1128 reported.

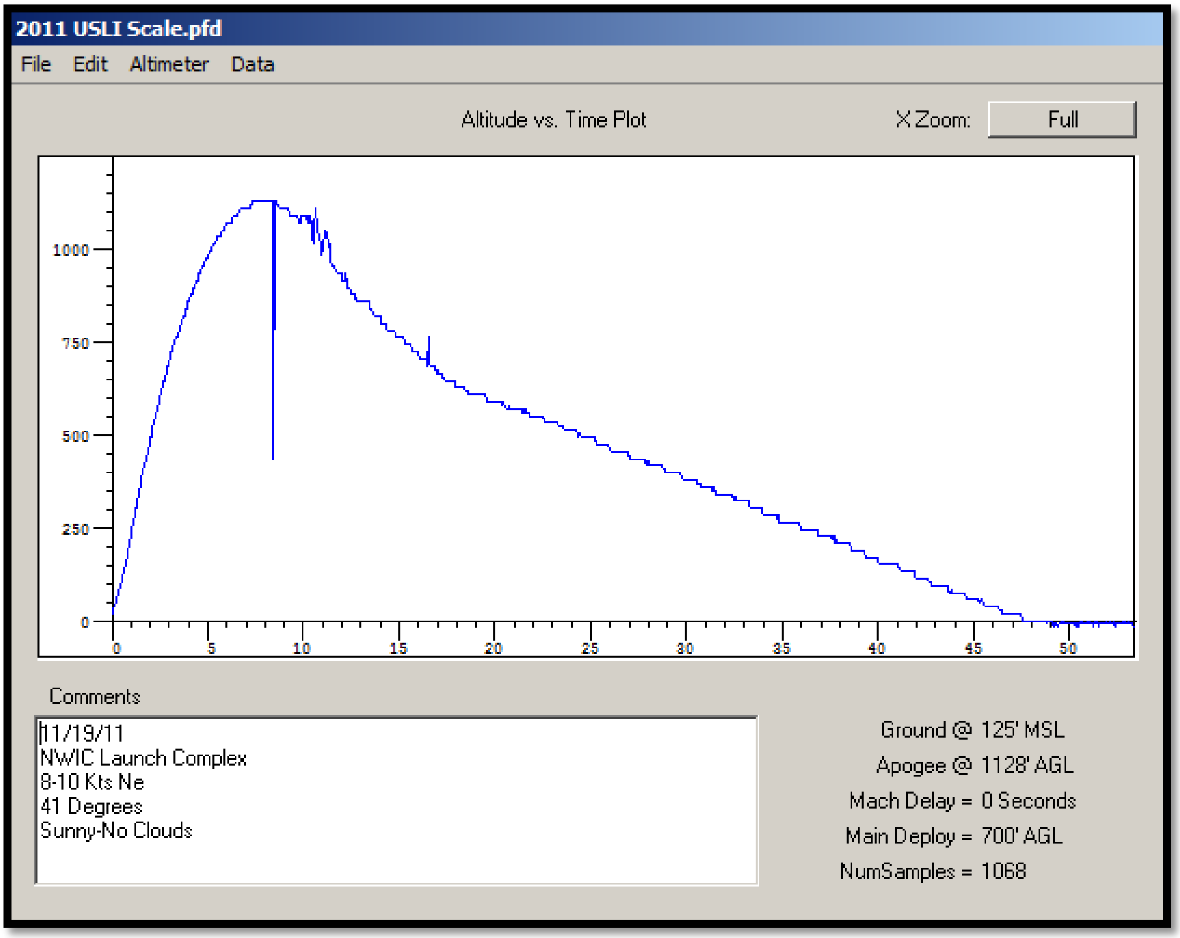


Figure 35 - Altitude Data from PerfectFlite MAWD

III.2.c Predicted vs. Actual Flight Data

The altitude data from the PerfectFlite MAWD below matches with the predicted altitude at 94% of the predicted altitude, 1194 feet predicted, 1128 reported.

III.2.d Subscale Impact on Full-Scale Rocket

The subscale flight forced us to re-evaluate the concept of having the science payload descend horizontally rather than the “traditional” vertical position. Given the materials that we had to work with, too much emphasis was placed on determining how to balance the loads necessary to keep the payload section horizontal.

One other impact learned from the actual flight data is that there appears to be leak in the ebay which caused the spike shortly after apogee. We hypothesis that the spike was caused by the drogue ejection charge. A smaller spike about the time and altitude of the main ejection charge is possibly also from a small leak where the ejection gasses enter the electronic bay.

Both leaks may be the result of our design. In our scale rocket the ebay did not separate from the airframe as is traditional. The ebay was fastened near the middle of the airframe and the parachutes were ejected from either end of the airframe with the desired result that the parachutes would support the airframe horizontally. Having the ebay exposed to the ejection charge in a confined space may have made the necessity for air tightness more prominent.

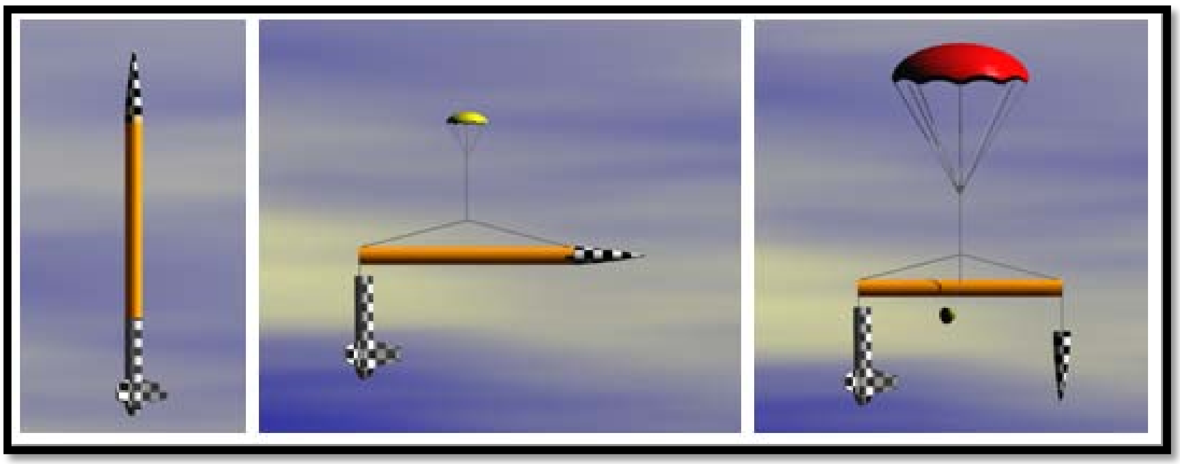


Figure 36 – Initial Recovery Scheme

III.3 Recovery Subsystem

III.3.a Parachutes, Harnesses, Bulkheads, and Attachment Hardware

III.3.a.1 Parachutes

Rocksim calculated the weight for the rocket at 27 pounds. USLI requires a maximum of 75 lb/ft^3 Kinetic Energy impact for the rocket. We used Excel and these formulas to calculate a main parachute size of 76 square feet which translates to a 60 inch or slightly over 78 square feet, parachute.

KE=Kinetic Energy
m=mass in pounds
V=velocity in feet per second
S=surface area of parachute in square feet
ρ=air density
C_d = Coefficient of drag

$$KE=\frac{1}{2}mV^2$$

$$S = \frac{2m}{\rho V^2 C_d}$$

	Section 1	Section 2	Section 3
	Nose/Main	Ebay	Science/Fin Can
Wgt	6.44	2.26	13.37
V	78.82	78.82	78.82
v^2	40009.10	14040.46	83062.36
1/2	20004.55	7020.23	41531.18
KE	621.26	218.02	1289.79

KE with Drogue

	Section 1	Section 2	Section 3
	Nose/Main	Ebay	Science/Fin Can
Wgt	6.44	2.26	13.37
V	17.39	17.39	17.39
v^2	1947.53	683.45	4043.25
1/2	973.77	341.73	2021.62
KE	30.24	10.61	62.78

KE with Main - Landing

Table 5 –Sectional Kinetic Energy Calculations

Drogue parachute size was calculated based upon descent speed. We select a descent speed between 70 and 80 fps and calculated a drogue size of 24 inches.

The Main parachute was determined by the descent speed and the KE upon landing. The Sky Angle Classic 52 and the Sky Angle Cert-3 Drogue satisfies the parachute requirements. We had initially contemplated using a Cert-3 XL; however, we had made an error in calculating the KE, thus the change to a Sky Angle Classic 52.

III.3.a.2 Recovery Harness

The two recovery harnesses, main and drogue, are 9/16' tubular nylon. The drogue harness is 20 feet long and the main harness is 30 feet long. Each harness is secured to its respective end of the ebay with stainless steel quick links. The other end of each harness is connected to its respective airframe component, drogue bay or main bay and their respective 3/8" closed eyebolt with quick links.

III.3.a.3 Bulkheads and Centering Rings

The bulkheads provide recovery harness mounts, confine the different components, and protect the components and electronics from black powder charges ignited during recovery system deployment. Eye-bolts are used on the bulkheads to provide a connection point for the recovery harnesses. The material for all bulkheads is 3/16 inch G10 fiberglass. This material was chosen because of its high strength, durability, it's relatively easy to shape with woodworking tools. It is suitable for protecting the instruments in the payload and the altimeters from the black powder charges used in the recovery system. The bulkheads are secured in place using West System epoxy resin.

III.3.a.4 Attachment hardware - Connecting the Components

Three different connection methods are used:

4. Permanent connections use West System epoxy.
5. Those that need intermittent access use #6, #8, or #10 T-nuts and screws.
6. Temporary connections between the ebay and the two parachute compartments use nylon shear pins. The shear pins prevent the rocket from premature separation due a combination of drag, inertia, and momentum. The shear pins are, however, designed to fail when the black powder ejection charge is ignited.

III.3.b Ebay

This subsystem consists of the parachute bays and the ebay that contains the avionics that control the parachute deployment. The parachute bays are connected to the ebay using frictional fitting and are secured with nylon #2-56 machine screws that act as shear pins. These screws prevent dynamic separation, premature deployment, of the recovery system. Each screw has an average shear strength of 25 pounds which means the black powder charge needs at least 50 pounds force to shear the screws. Two 3/8" closed eyebolts, are fastened each end of the ebay. These are the fastening points for the recovery harness.

III.3.c Drawings

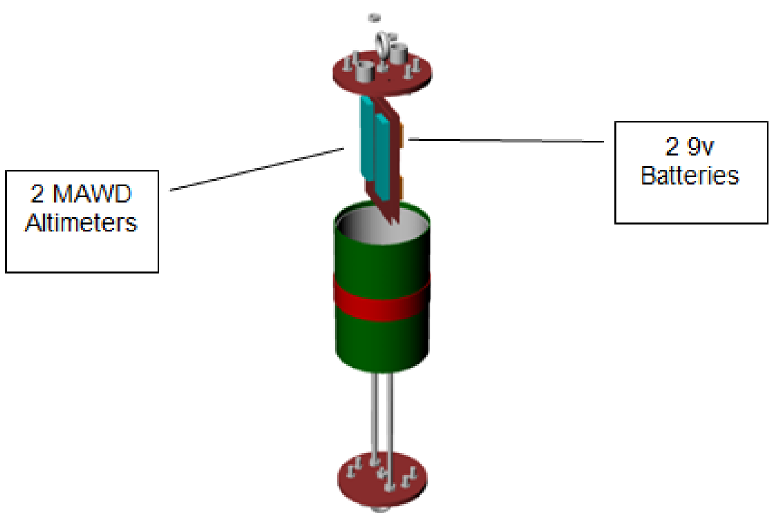


Figure 37 - Competition Rocket Ebay

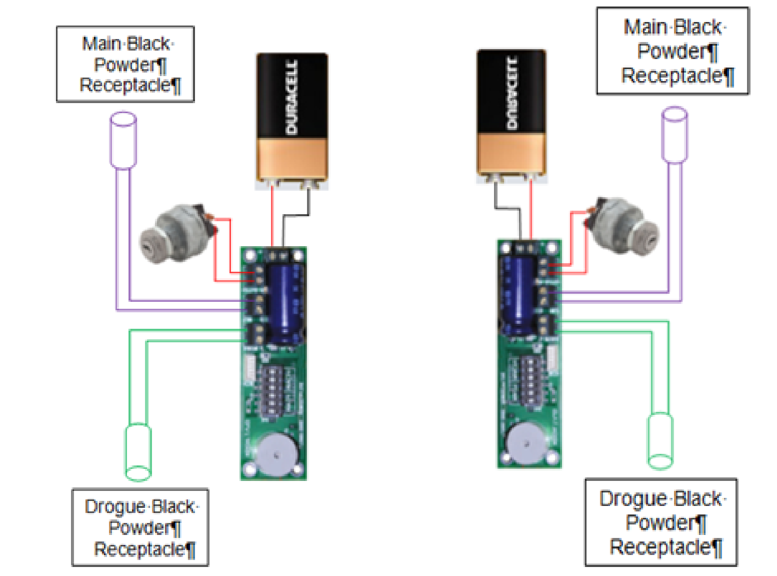


Figure 38 - Recovery Avionics, redundant dual deploy

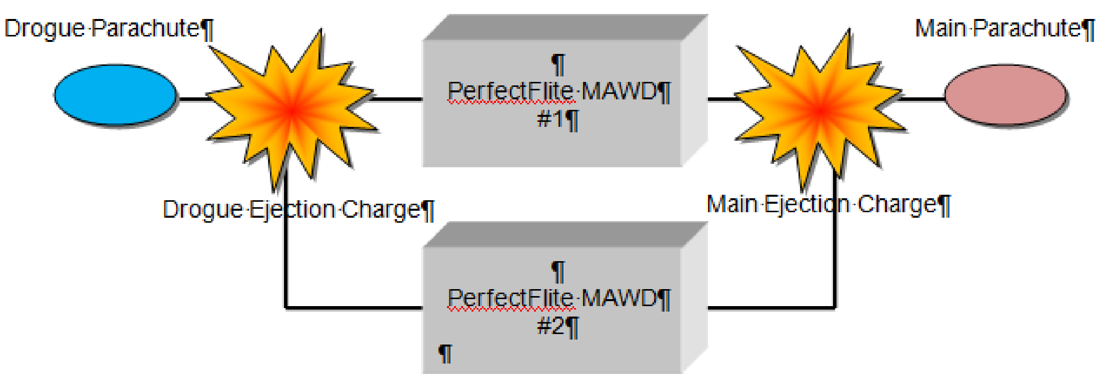


Figure 39 - Redundant Dual Deployment System Schematic

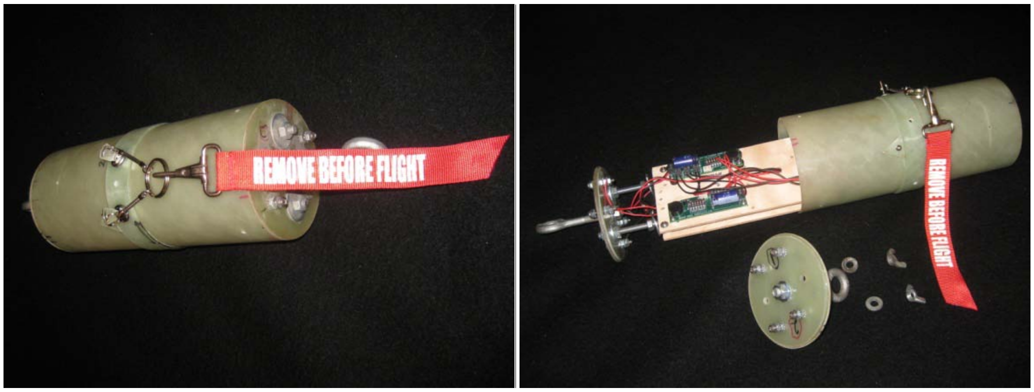


Figure 40 - Ebay

III.3.d Test Results

We need to calculate the stopping forces for our main parachute and the size of the recovery harness. We choose 9/16" tubular nylon which has a tensile strength of 1500 pounds. The mass of Skybolt would be 22.65 pounds and it would be travelling at 73.27 fps. If Skybolt slowed to a speed of 19 fps within 0.5 seconds, it exerts a force of approximately 300 pounds on the recovery harness, well with the tensile strength of 1500 pounds.

III.3.e Recovery Data from Rocksim

III.3.e.1 Launch conditions

- Altitude: 827 Ft.
- Relative humidity: 77.000 %
- Temperature: 65.000 Deg. F
- Pressure: 30.2683 In.

III.3.e.2 Wind speed model: Slightly breezy (8-14 MPH)

- Low wind speed: 8.0000 MPH
- High wind speed: 14.9000 MPH

III.3.e.3 Recovery system data

- P: Drogue Parachute Deployed at : 19.276 Seconds
- Velocity at deployment: 34.5027 ft/s
- Altitude at deployment: 5530.27686 Ft.
- Range at deployment: -563.35928 Ft.
- P: Main Deployed at : 87.069 Seconds
- Velocity at deployment: 72.4160 ft/s
- Altitude at deployment: 699.98324 Ft.
- Range at deployment: 570.39224 Ft.

III.3.e.4 Landing data

- Successful landing
- Time to landing: 130.614 Sec.
- Range at landing: 791.76922
- Velocity at landing: Vertical: -12.1141 ft/s , Horizontal: 11.9474 ft/s , Magnitude: 17.0145 ft/s

III.3.e.5 Launch guide data:

- Launch guide length: 72.0000 In.
- Velocity at launch guide departure: 55.1189 ft/s
- The launch guide was cleared at : 0.218 Seconds
- User specified minimum velocity for stable flight: 43.9882 ft/s
- Minimum velocity for stable flight reached at: 45.9310 In.

III.3.e.6 Drift Calculations

Latitude: 34° 38' 50" N
Longitude: 86° 33' 11" W
Elevation: 827 feet
Location: Braggs Farm, Toney, AL

Relative humidity: 77 %
Temperature: 65 Deg. F
Pressure: 30.27 In.

Drift Distance in Various Wind Speeds and Guide Rail Angle

	Wind Speed (Kts)				
Guide Rail Angle	0	5	10	15	20
0	0	295	1022	1517	2918
5	-1068	-756	257	917	2398
10	-2086	-1278	-1193	250	1592
15	-3014	-2167	-2157	-618	-868
20	-3819	-3108	-2870	-1287	-269

Table 6 – Drift Calculations

III.3.f Safety and Failure Analysis

Recovery Failures	*Potential Effects of Failure*	*Failure Prevention*
Drogue and main parachute bays experience separation during flight.	Parachutes will deploy early, causing the rocket to miss the target altitude. A zippering effect may also occur.	Ground test shear pins and ensure proper pressure equalization in parachute bays.
Harness breaks upon parachute deployment.	Rocket will experience an uncontrolled descent.	Test harnesses to ensure that they are sufficiently strong and long enough to withstand expected loads. Check for proper protection from the ejection charges
Altimeter fails to deploy the drogue and main parachutes.	Rocket will experience an uncontrolled descent.	Ensure that the altimeter is functioning properly prior to launch. A double-redundant ejection system will be used.
Drogue and main parachutes are packed too tightly to release.	Rocket experiences uncontrolled descent.	Ground test efficiency of the packing technique before launch.
Parachute melts or chars due to ejection charge heat.	Parachute becomes partially or entirely ineffective, causing an uncontrolled descent.	Use flame/heat retardant material between the parachute/shock cord and the ejection charge.
Parachute lines tangle upon deployment.	Parachutes will be ineffective, causing an uncontrolled descent.	Test deployment prior to launch and use a parachute/shock cord packing procedure that minimizes tangling.
Quick Link connecter fails	Rocket sections will become disconnected and a portion of the rocket will have an uncontrolled descent.	Visually check the soundness and the security of the quick links.

Table 7 – Recovery Safety/Failure Analysis

III.4 Mission Performance Prediction

III.4.a Mission Performance Criteria

The goals of Team Skywalker's rocket, Skybolt, is to safely deliver the payload to 5280 feet (AGL) conduct the science experiments and then safely descend to the earth using the redundant dual deploy recovery system. The following graphs illustrate Rocksim's flight simulations using the launch conditions given in III.3.e above.

III.4.b Flight Simulations from Rocksim 9

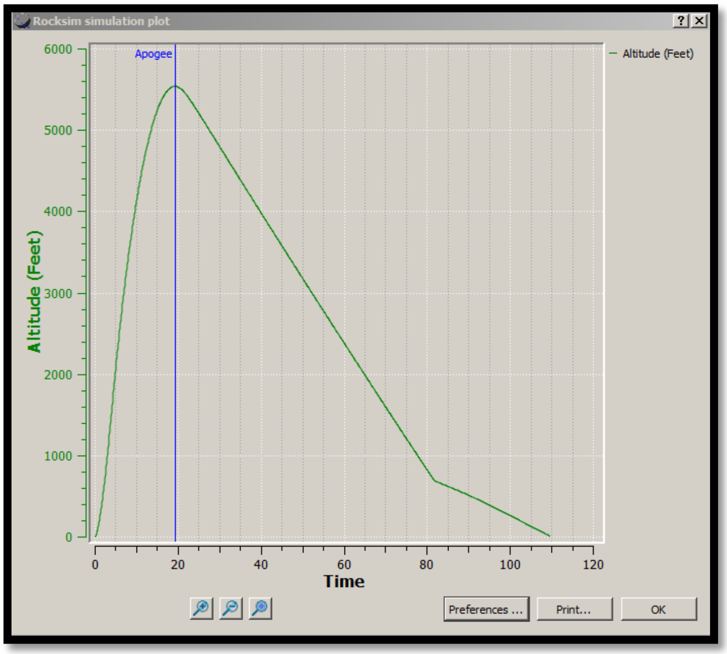


Figure 40 - Altitude

The altitude plot shows a steady increase in altitude until apogee is reached whereupon the altitude decreases while under the drogue parachute. At the preconfigured 700 foot altitude, the main parachute is deployed.

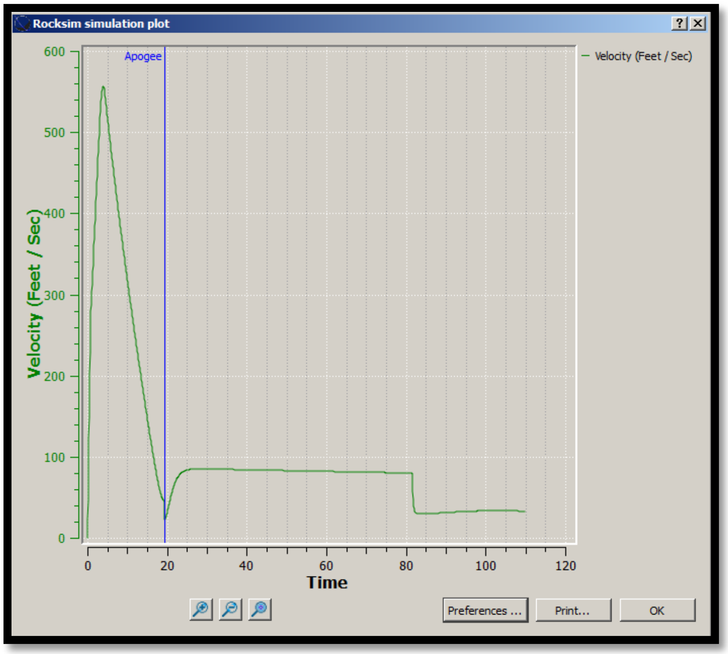


Figure 41 - Velocity

This velocity plot shows the change resulting from the thrust phase through the coast phase. After apogee is reached, the rocket descends momentarily while the drogue is deployed. At 700 feet the main is deployed and the rocket descends at a much slower speed until it lands.

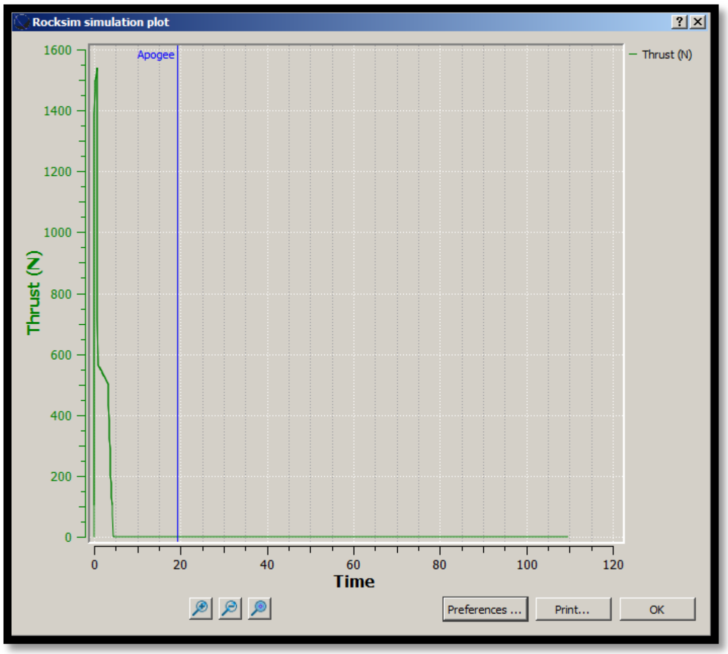


Figure 42 - Simulated CTI L640-DT Motor Thrust Curve

III.4.c Stability Data

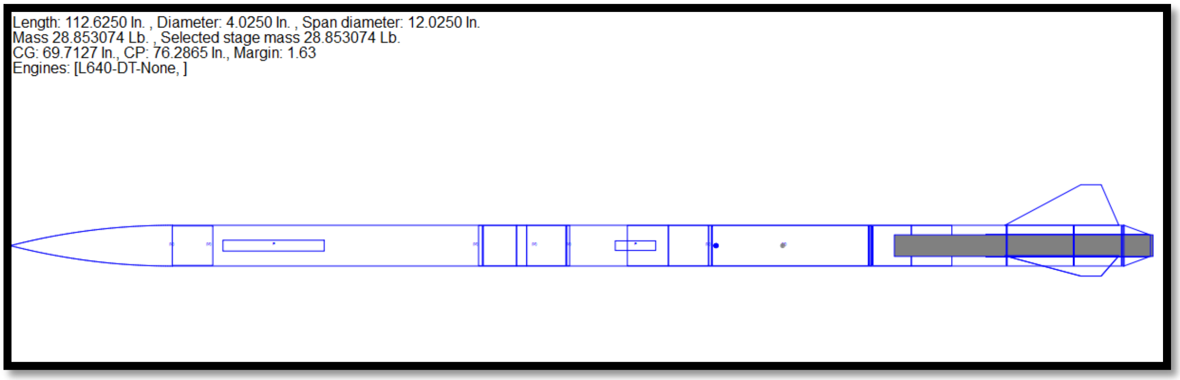


Figure 43 - Rocksim CP=76.3, CG=69.7, and Stability Margin at 1.91 with motor loaded

Center of Gravity	69.713	Center of Pressure	76.287
Static Stability	1.91 w/CTI L640 motor		

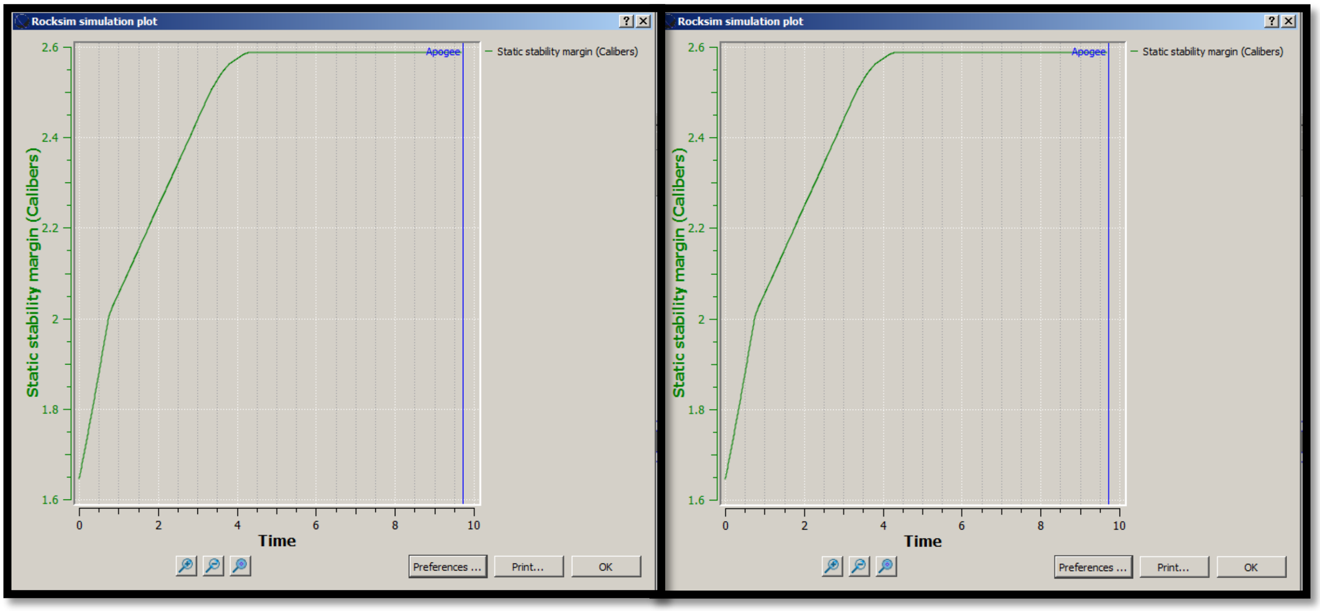


Figure 44 - Path of Static Stability Margin from liftoff to 1 second after apogee

The static stability does not change with the air dams extended or retracted.

III.3.4 Kinetic Energy

Rocksim calculated the weight for the rocket at 23 pounds. USLI requires a 75 lb/ft^3 Kinetic Energy impact for the rocket. We used Excel and these formulas to calculate a main parachute size of 76 square feet.

KE=Kinetic Energy
m=mass in pounds
V=velocity in feet per second
S=surface area of parachute in square feet
ρ=air density
C_d = Coefficient of drag

$$KE=\frac{1}{2}mV^2$$

$$S = {}^{2m}/_{\rho V^2 C_d}$$

Drogue parachute size was calculated based upon descent speed. We selected a descent speed between 70 and 80 fps and calculated a drogue size of 24 inches.

A descent speed of 19 fps for the main parachute resulted in parachute with a diameter of 72 inches.

The Sky Angle Classic 52 and the Sky Angle Cert 3 Drogue satisfy the parachute requirements.

	Section 1	Section 2	Section 3
	Nose/Main	Ebay	Science/Fin Can
Wgt	6.44	2.26	13.37
V	78.82	78.82	78.82
KE	621.26	218.02	1289.79
V	17.39	17.39	17.39
KE	30.24	10.61	62.78

Figure 45 – Kinetic Energy Calculations

III.3.5 Drift Calculations

All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.

Latitude: 34° 38' 50" N
Longitude: 86° 33' 11" W
Elevation: 827 feet
Location: Braggs Farm, Toney, AL

Relative humidity: 77 %
Temperature: 65 Deg. F
Pressure: 30.27 In.

Drift Distance in Various Wind Speeds and Guide Rail Angle

	Wind Speed (Kts)				
Guide Rail Angle	0	5	10	15	20
0	0	295	1022	1517	2918
5	-1068	-756	257	917	2398
10	-2086	-1278	-1193	250	1592
15	-3014	-2167	-2157	-618	-868
20	-3819	-3108	-2870	-1287	-269

Figure 46 - Drift Distance in Various Wind Speeds and Guide Rail Angles

III.5 Payload Integration

The payload is designed to be easily integrated with the other subsystems. The payload team, the airframe team and the recovery team have been working closely together in order to determine the weight of the payload within the rocket. The weight is a crucial parameter to optimize because this determines what size motor and parachutes are needed to reach the target altitude, bring the rocket and its payload safely to the ground as well as perform the science experiments.

Each experiment is self-contained and independent of any other experiment. We designed them in this fashion to give more students an opportunity to be involved in our project and to make the installation more flexible and it is easier to inspect and install several smaller devices rather than a larger one.

The payload is designed so that all of the components can be assembled before launch day and then the instrument package can easily be installed into the rocket science payload bay at any time. On launch day fresh batteries will be checked and installed, and then the payload will be installed into the rocket.

The science payload will fit into the science payload bay which is an integral part of the airframe. It is connected to the fin can and the ebay with a 9 inch G10 coupler. The coupler is bolted to the science payload bay with 10-24 T-nuts and screws.

The power management system slides into the lower portion of the science payload bay and is connected to the fin can with 10-24 T-nuts and screws.

III.5.a Airframe Internal Interfaces

Each section of the rocket is connected to each other section with a 9" G10 fiberglass tube coupler. This allows for a 4.5" insert for each connecting section.

1. Permanent connections use West System epoxy.
2. Those that need intermittent access use 10-24 T-nuts and screws.
3. Temporary connections between the ebay and the two parachute compartments use shear pins. The shear pins prevent the rocket from premature separation due a combination of drag, inertia, and momentum. The shear pins are, however, designed to fail when the black powder ejection charge is ignited.

III.5.b Launch Vehicle and Ground Facilities Interface

The science payload sensors will be connected to the RDAS-Tiny transmitter which will transmit the data to the ground station. Altitude data is recorded through several altimeters and will be collected and analyzed after ground operations cease. Photos and videos are collected during the flight and also after landing and will be collected and analyzed after ground operations cease. Photos and videos will be taken of the rocket after it has landed and prior to retrieval to help analyze any data anomalies. Furthermore, data will be stored on board and can be analyzed after ground operations cease.

III.5.c Rocket and Launch Rail Interface

Two 0.5 inch rail guide buttons are bolted and fiber glassed to the fin can. These serve to guide the rocket up the 72 inch long T-Slotted Aluminum Extrusion Framing, 70 inches which are available for rocket guidance.

III.6 Launch Concerns and Operation Procedures

All of our operations follow detailed check lists. Please see appendices E-I for the checklists.

III.6.a Launch System and Platform

Our launch controller has a continuity check light and switch, a key-locked power switch, and two independent normally-open push buttons to close the circuit to the igniters. We have two sets of launch cables; one set is 100 feet long and the other is 200 feet long.

III.6.b Ground Support Equipment

Our launch pad base is constructed of 1 inch black pipe. The base has three 36" long legs that are connected to a manifold that supports a 72 inch long T-Slotted Aluminum Extrusion Framing, 70 inches which are available for rocket guidance. The blast shield is a 1/16 x 18 x 12 inch steel plate mounted between the launch rail and the launch pad legs. See photos and drawing below. The legs of the launch pad are chained together to help prevent the legs from spreading and tilting the guide rail.

Launch Stand with Blast Deflector

Launch Control Box

Figure 47 – Ground Support Equipment

First Aid kits, a fire extinguisher, a portable sound system, 4 foot rebar stakes and "Do Not Cross" tape, and round out our ground support equipment. The recovery crew is equipped with cell phones as is the Range Safety Officer who has to contact Bellingham International Airport, USA and Victoria International Airport, Canada prior to the launch and at the cessation of the day's operations.

III.6.c Final Assembly and Launch Procedures

Launch operations follow a very strict policy with safety being paramount. This is accomplished by following a set routine which involves using a series of check lists. Each launch begins with a safety review meeting and is followed by meticulously using supporting documents and the checklists which are in the appendices. A summary of the routine is as follows:

1. Prepare and install the ground support equipment
2. Prepare the electronics
3. Prepare the motor
4. Assemble the rocket
5. Pre-launch check list
6. Final launch check list
7. Launch
8. Recover
9. Post recovery
10. Clean up

<u>III.6.c.1 Documents On Hand at Each Launch</u>

- FAA/CAA Contact Schedule
- Liability Waiver
- HPR Safety Rules
- Flight Card

Checklists

- Ground Support Equipment
- Final Assembly Check List
- Pre-Launch Preparation
- Final Launch Preparation
- Post Recovery

III.7 Vehicle Safety and Environment

III.7.a Safety Officer

Justin is the safety officer for the team. He is responsible for ensuring that all safety procedures, regulations, and risk assessments are followed. Justin is a member of the National Association of Rocketry and holds his Level 1 certification.

The Northwest Indian College Space Center has a 5000 foot waiver from the US and the Canadian aviation agencies. We launch our rockets from 8:00am to 12:00pm on Saturday's and Sundays.

<u>III.7.a.1 Safety Rules and Regulations</u>

1. All members of the team shall adhere to the NAR High Powered Safety Code. The NAR HPSC is attached as Appendix J
2. All members of the team shall adhere to the National Fire Protection Association (NFPA) 1127: “Code for High Powered Rocket Motors”.
3. All members of the team shall be aware of Federal Aviation Regulations 14 CFR, Subchapter F Subpart C “Amateur Rockets”.
4. 4. All team members shall read and sign the "Range Safety Regulations" (RSR) statement. The RSR is attached as Appendix K.

All team members will have been briefed on the NAR High Power Rocket Safety Code and the risks involved with high power rocket launches. These briefings have taken place prior to submitting the USLI proposal and are repeated prior to each launch.

III.7.b Potential Failure Modes and Mitigation

Structural Failures	***Potential Effects of Failure***	***Failure Mitigation***
Fins fail during flight due to shear forces or inadequate use of adhesive.	Rocket will experience an unstable and unpredictable flight trajectory.	Use suitable building materials, through-the-wall fin mounting, and ample application of adhesive and fillets.
Rocket experiences drag separation during flight.	Rocket will prematurely separate, leading to early parachute deployment and a mission failure.	Ensure that all joints are secure and drill a hole in the body tube to equalize pressure between the interior of the rocket and the atmosphere.
Rocket joints do not separate at parachute deployment.	Parachute bay will experience over-pressurization from the ejection charge but will not deploy the parachute.	Conduct pre-launch separation testing.
Parachute deploys too early or too late in flight.	High-speed deployment causes the shock cord to produce a “zippering" effect.	Test the altimeter for drogue deployment at apogee and the correct deployment altitude for the main is set..
Rocket components are lost or damaged during transport to launch site.	Team risks not launching the rocket unless repairs can be made.	Pack components safely and securely for transport and have replacement components and needed tools available at the launch site.
Rocket structure is crushed due to in-flight forces.	Rocket will have a ballistic trajectory, and the mission is a failure.	Test, evaluate, test again
Center of gravity is too high or too low.	Rocket will be unstable or over stable.	Adjust weight so that center of gravity is 1-2 calibers ahead of center of pressure.
Center of pressure is too high or too low.	Rocket will be unstable or over stable.	Adjust fin sizing and position so that the center of pressure is 1-2 calibers behind the center of gravity.
Payload Failures	***Potential Effects of Failure***	***Failure Mitigation***
Altimeter and/or science payload battery power supply fails	Avionics will fail to record data, resulting in the inability of the altimeter to eject the parachutes.	Check batteries prior to launch and have extra batteries located at the launch site. The team shall also use separate power supplies for each section containing electronic devices

		to prevent the failure of all electronics.
Wire connections in the rocket loosen during transport or flight.	Data will not be complete, causing a payload objective failure. Ejection electronics may not deploy parachutes, causing a ballistic recovery.	Secure wires with wiring loom and ensure that all wires are properly connected prior to launch.
Altimeter fails to record data during flight.	Altitude may not be properly measured resulting in parachute deployment failure.	Test the altimeter for functionality prior to launch. Calibrate the altimeter before launch.
GPS system fails to record the position of the rocket.	Recovery of the rocket will become more difficult. The rocket may possibly be lost.	Test the GPS before launch and use a secondary tracking system.
Avionics are broken during the transport, storage, or flight.	Data will not be collected, and the payload objective will be considered a failure.	Store equipment in a safe, dry place during both storage and transport.
Static discharge to electronics.	Electronic instruments are damaged.	Team members should properly ground themselves before handling electronics.
Recovery Failures	***Potential Effects of Failure***	***Failure Mitigation***
Drogue and main parachute bays experience separation during flight.	Parachutes will deploy early, causing the rocket to miss the target altitude. A zippering effect may also occur.	Ground test shear pins and ensure proper pressure equalization in parachute bays.
Shock cords snap upon parachute deployment.	Rocket will experience an uncontrolled descent.	Test shock cords to ensure that they are sufficiently strong and long enough to withstand expected loads.
Altimeter fails to deploy the drogue and main parachutes.	Rocket will experience an uncontrolled descent.	Ensure that the altimeter is functioning properly prior to launch. A double-redundant ejection system will be used.
Parachute melts or chars due to ejection charge heat.	Parachute becomes partially or entirely ineffective, causing an uncontrolled descent.	Use flame/heat retardant material between the parachute/shock cord and the ejection charge.
Drogue and main parachutes are packed too tightly to release.	Rocket experiences uncontrolled descent.	Ground test efficiency of the packing technique before launch.
Parachute melts or chars due to ejection charge heat.	Parachute becomes partially or entirely ineffective, causing an uncontrolled descent.	Use flame/heat retardant material between the parachute/shock cord and the ejection charge.
Parachute lines tangle upon deployment.	Parachutes will be ineffective, causing an uncontrolled descent.	Test deployment prior to launch and use a parachute/shock cord packing procedure that minimizes tangling.

III.7.c Personnel Hazards and Hazard Mitigations

III.7.c.1 Construction

The Airframe Lead has the final say while constructing any designs, subsystems, or sections of the rocket.

The safety officer is responsible for having all MSDS for hazardous materials. Also, the safety officer shall inform the team of any material or substance hazards before use. A sample MSDS sheet and hyperlinks to the MSDS sheets are located on our website: http://blogs.nwic.edu/rocketteam

All team members are required to wear appropriate Personal Protective Equipment (PPE). The equipment includes, but is not limited to, safety glasses, gloves, ear plugs, and breathing masks. The safety officer will notify team members when materials that require PPE are being used. If additional PPE is required, it is the safety officer's responsibility to obtain the additional equipment.

Figure 48 – Working Safely

1. Safety glasses shall be worn when any member is using a tool that may create fragments of a material (Dremmel tool, hammer, band saw, etc.)
2. Power tool use requires at least two members be present. All team members shall wear the appropriate PPE.
3. Safety is the responsibility of all team members. The safety officer shall make all team members aware of any hazards, but individual team members shall be responsible for following all regulations and guidelines set forth by the safety officer.

III.7.c.2 Payload

Proper static grounding shall be utilized while handling sensor modules. Soldering requires adequate ventilation and safety glasses. None of the payload modules use electrical power greater than 9 volts.

A summary of safety hazards include adequate fastening together the science payload bay halves and the science payload bay itself to the rocket airframe. Details of the steps for safely working with the science payload bay and its contents are in Appendix F.

III.7.c.3 Motors and Black Powder

1. All explosive materials shall be kept in the appropriate storage magazine located off-site on the property of Gary Brandt, the Team Official.
2. All extra black powder, e-matches, igniters, and any unused ejection charges will be stored in the magazine.
3. Any explosives being handled during launch day will be monitored by the safety officer.

III.7.c.4 Launch Operations

1. The area surrounding the launch pod shall be cleared of all flammable materials, such as dry vegetation, for a radius of at least 50 feet. The launch control box will be located at least 100 feet from the launch stand.
2. The launch rail shall not be inclined greater than 30 degrees from the vertical position.
3. An amplified audio system will be employed during launches.
4. Once everyone is a safe distance from the launch stand, the Range Safety Officer (RSO) will permit the Launch Control Officer (LCO) to connect the launch control system to the power source.
5. The RSO shall contact the appropriate aviation agencies 5-10 minutes prior to launch for clearance to launch.
6. After the RSO has received clearance and agrees that conditions are safe for launch, the system will be checked for continuity and then armed by the LCO.
7. The LCO shall check for aircraft and any other potential hazards and then commence counting down from 5 seconds.
8. The LCO shall activate the launch system when the countdown reaches zero.

III.7.c.5 Recognition of Tribal, Federal, State, and Local Laws

The Northwest Indian College Space Center USLI team recognizes and adheres to all Tribal, state, federal, and local laws relating to the use of high power rockets. Each team member is required to sign a Range Safety Regulations (Appendix K) form acknowledging that they are aware of these laws and regulations. All team members are briefed on safety hazards and risks that will be present at any build sessions or rocket launches. The RSO shall conduct a safety meeting before any launch day. This meeting will include information about predicted risks, weather conditions, minimum distances from launch pad, and any changes in the launch waiver.

The RSO or her designee shall contact the proper authorities at the appropriate times to activate the waiver for launching. Appendix L lists the time frame and contacts for waiver activation.

Each team member understands and fully complies with the following safety regulations. These regulations will be enforced by the Safety Officer.

- FAA- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- NAR High Powered Rocketry Safety Code
- NFPA 1127 "Code for High Power Rocket Motors"
- NAR High Powered Safety Code
- CFR Title 27 "Commerce in Explosives"

III.7.c.6 Interaction with Rocket Motors

Motors will be purchased by either Bill Munds or one of the appropriately certified officers. After motors are received they will be placed in the team's motor magazine which is located off-site on the property of the Team Official, Gary Brandt. This magazine is an ATF-approved Type 4 container. A second, smaller magazine box is an ATF-approved Type 3 container and will be used to transport motors to and from the launch.

Arrangements for purchase, delivery, and storage of our motors for the USLI launch in April at Huntsville, AL will be performed by our NAR Mentor, Bill Munds.

III.7.d Environmental Safety at the Northwest Indian College Launch Complex

1. All hazardous materials, such as black powder and epoxy, brought onto the field must be removed.
2. All trash will be removed prior to leaving the launch complex.
3. Motor remains must be disposed of properly.
4. All rockets shall be recovered. If a rocket is lost, the team will work with the appropriate Tribal office for further assistance.
5. The launch complex will be left as clean, or cleaner than it was prior to launching.

IV) Payload Criteria

IV.1 Selection, Design, and Verification of Payload Experiment

We are going to do the NASA Science Mission Directorate's scientific payload that monitors several weather and atmospheric phenomena. The measurements that we'll be monitoring are:

- Barometric pressure
- Atmospheric temperature,
- Relative humidity
- Solar irradiance
- Ultraviolet radiation

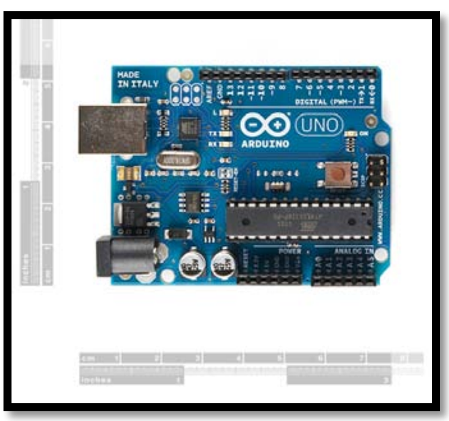
The measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Furthermore, surface data collection operations will terminate 10 minutes after landing. Data from the payload shall be stored onboard and transmitted to the ground station after completion of surface operations. We are going to transmit some of the data during the descent.

The secondary mission requires recording at least two pictures during descent and three after landing. The pictures need to portray the sky toward the top of the frame and the ground toward the bottom of the frame.

We will use a microcontroller, power supply and data logger controlling the sensors and recording and transmitting the data. We will have a second microcontroller, power supply and data logger acting as backup and providing system redundancy. Having a redundant system ensures that some data will be collected in the event of a microcontroller malfunction. A totally catastrophic failure is the only reason that we wouldn't be able to collect meaningful data.

The main part of the payload will be the Arduino Uno. The Arduino Uno will be tasked with collecting data from all of the sensors and sending the data to the Adafruit Data Logger and to the 900 MHz transmitter. The Adafruit Data Logger will in turn store the data in an SD card, which will be easily accessible upon landing.

The software used for the payload will be developed using the Arduino Development Environment. The two primary purposes of the software aspect of the payload will be data acquisition and servo control for the power management system. The Arduino software will also tag all of the data and video with time data. In doing this, all sensor data can be related to other data taken at the same time. The sensor data will be saved as a comma delimited text file for easy parsing.



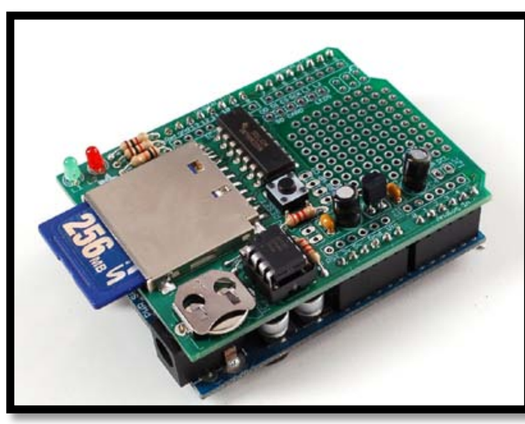
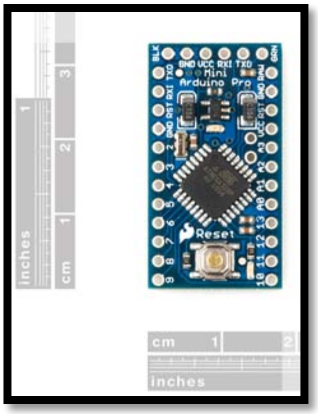


Figure 49 - Arduino Uno   Adafruit Data Logger installed on Uno



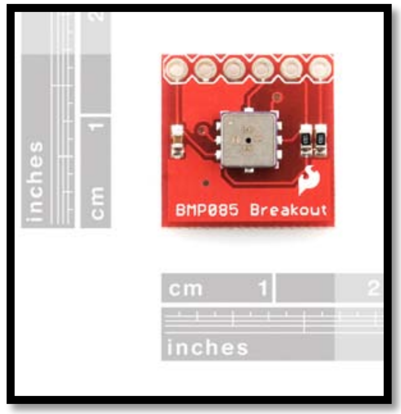


Figure 50 - Arduino Pro Mini *Barometric Pressure Sensor for Power Management System*

The payload system will easily fit into our 4" science payload bay. The UV and IR sensors will be located on a horizontal bulkhead that will maintain a vertical orientation during descent. Vents will allow atmospheric equilibrium for the barometric pressure sensor as well as allow atmospheric access for the humidity and temperature sensors.

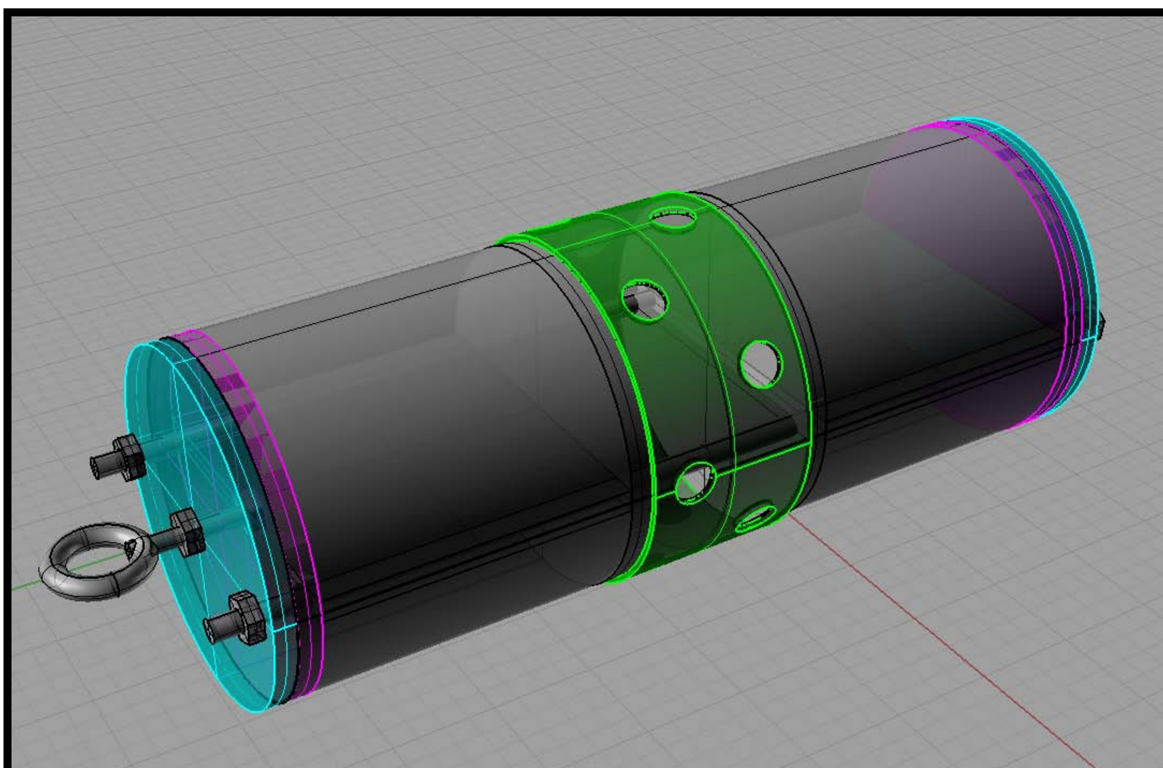


Figure 51 - Science Payload Bay

The green cover represents the transparent cover over the probe section of the science payload bay. Here the light dependent probes will be located.

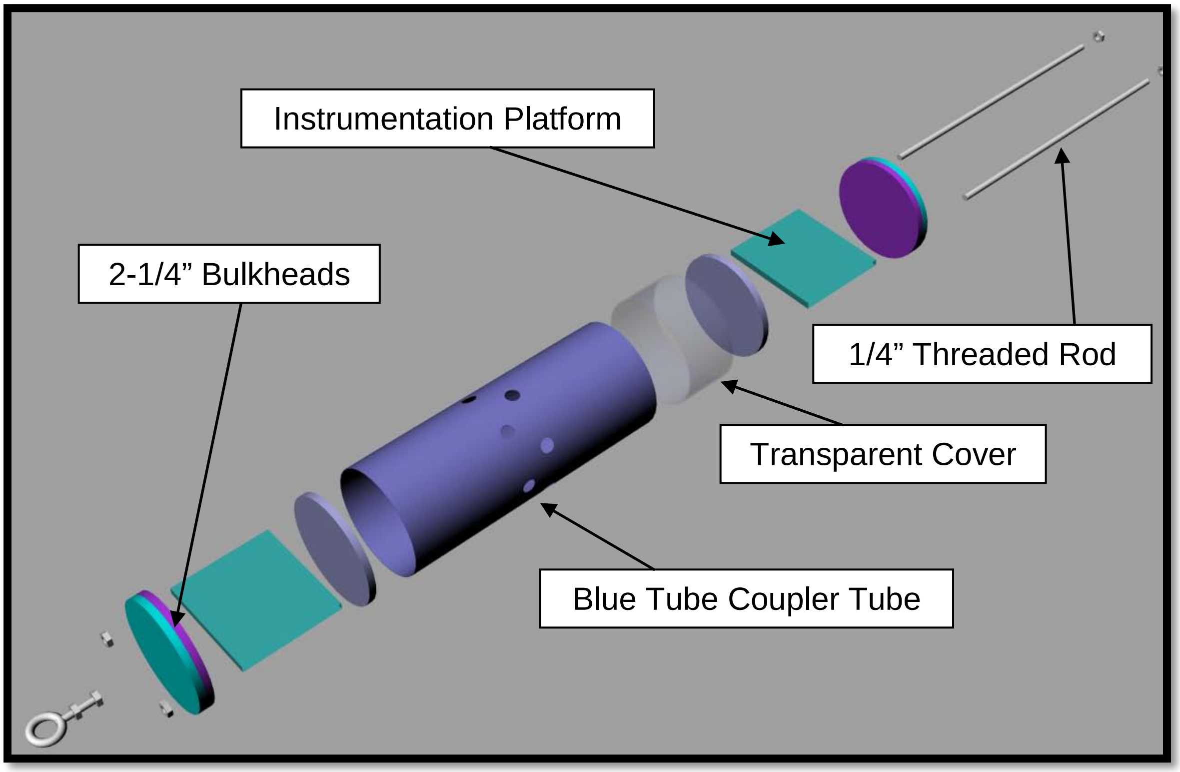


Figure 52 - Science Payload Bay – exploded

We are exploring the possibility of installing a 2" Plexiglas section for the UV and IR sensors. If this proves feasible, we will be extensively ground testing with the sensors both in and out of the science payload bay in order to calculate and data compensation and offsets.

IV.1.a System's Function

IV.1.a.1 Barometric Pressure

The barometric pressure will be logged and transmitted with the BMP 085 barometric pressure sensor.

IV.1.a.2 Atmospheric Temperature

The TR-74U will measure the temperature with one of it probes. Its probe will be mounted in the probe section of the science payload bay.

IV.1.a.3 Relative Humidity

The TR-74U will measure the relative humidity with one of it probes. Its probe will be mounted in the probe section of the science payload bay.

IV.1.a.4 Solar Irradiance

The solar irradiance unit determines how much available sunlight (solar insolation) there is at a location. The silicon pyranometer is based on a PIC16F88-I/P microcontroller and will have its own data logger and power supply. Its probe will be mounted in the probe section of the science payload bay. The irradiance range it from 0 to 1520 watts per meter squared (W/m^2). The resolution is 1.5 W/m^2. Readings are taken every 10 seconds. Data collection will start five seconds after liftoff which is triggered by an accelerometer.

IV.1.a.5 Ultraviolet Radiation

The TR-74U will measure Ultraviolet Radiation with one of its probes. Its probe will be mounted in the probe section of the science payload bay. The UV range is from 0 to 30 milliwatts per square centimeter (mW/cm^2). The recording level is one reading per second. Data collection will start five seconds after liftoff which is triggered by an accelerometer.

IV.1.a.6 Photography

The camera, 0.5 x 0.75 x 2.75 inches will be mounted on the airframe near the nose cone. It will be mounted in an inverted position so that it will record with the sky at the top of the picture frame after the drogue parachute has deployed and is descending. Three cameras that are mounted in line with the fins will ensure that at least one of them will record with the proper orientation. Each of the cameras will be powered by a battery pack that will record for at least two hours. The cameras will start recording when the altimeters are armed.

IV.1.a.7 Data Recovery

Data retrieval will take place during descent, while on the ground for 10 minutes, and after recovery. The data will be transmitted to our ground station during descent and while on the ground during the 10 minute competition parameters. Data will also be stored on the Adafruit Data Logger's USB drive. The USB data storage drive will be removed and the data downloaded to the team's laptop computer. The data will be downloaded to at least two computers for data safety. Camera data will be treated the same.

Figure 53 - TAND TR74UI

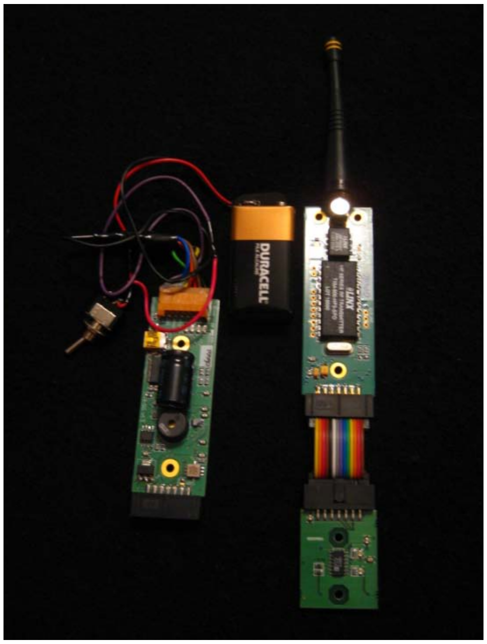


Figure 54 - RDAS Altimeter & Data Collector, 900MHz Transmitter & 3-axis accelerometer

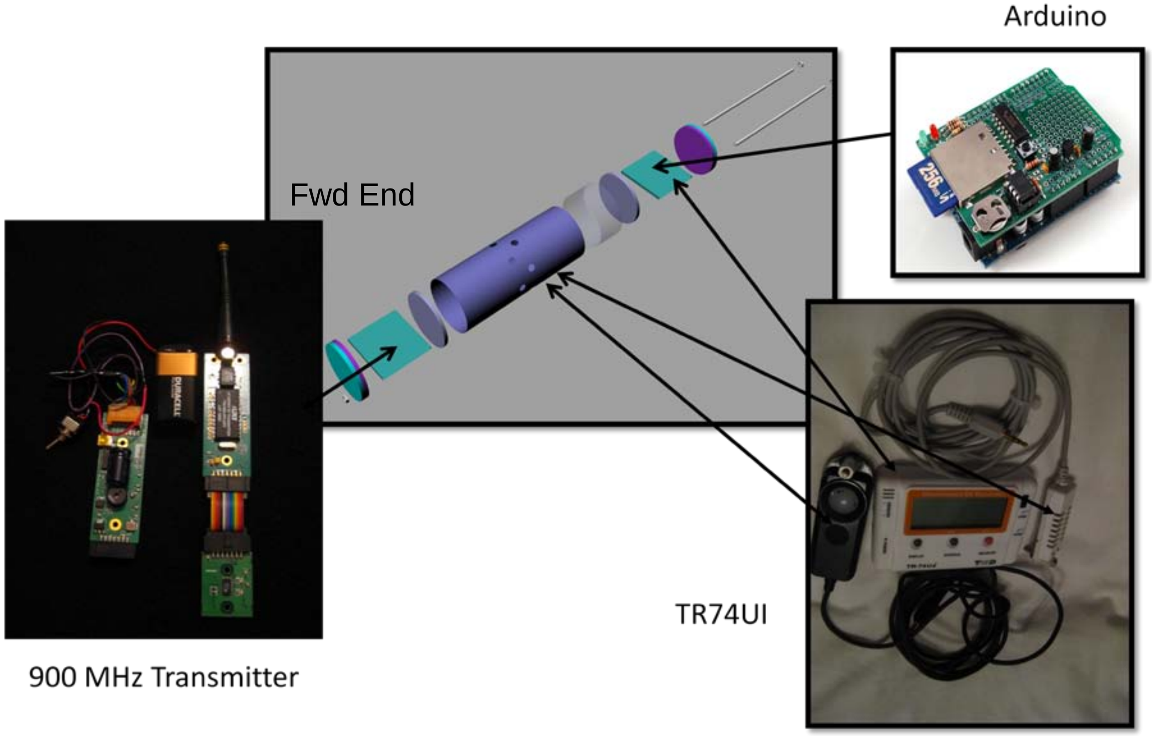


Figure 55 - Instrumentation Layout

IV.1.b Payload Subsystems

Payload Subsystem Description		
Sensors	silicon photo detector	These will be used to take readings on descent and after landing.
	temperature sensor	
	humidity sensor	
	UV sensor	
	pressure sensor	
Controllers	Arduino Uno Microcontroller	This will be used to activate the devices and integrate the data collected.
Data Logger	Adafruit Data Logger	The data logger collects the data directed through the micro controller from the sensors. It stores this data for retrieval after landing.

Power Management	Arduino Pro Mini	This takes the readings from the barometric sensor and velocity and calculates when to deploy the velocity reduction system flaps.
	HiTec HS 645MG Ultra Torque Servo	This controls the velocity reduction dams.
	BMP 085 Barometric Sensor	

IV.1.c Performance Characteristics

We cannot at this time provide data for this section. We need to build and test our payload system and see what the limitations and specifications for each sensor.

Extensive testing of the individual sensors as well as the integrated package will be done. Data transmission testing will be done throughout the construction and testing phases.

IV.1.d Verification Plan and Status

Requirement	Design Feature	Verification	Status
The payload shall gather data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation. Measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Surface data collection operations will terminate 10 minutes after landing.	Arduino microcontroller-based sensors	Test	Work in Progress
The payload shall take at least 2 pictures during descent and 3 after landing.	Multiple Cameras oriented appropriately	Test	Cameras purchased
The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.			Work in Progress
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.	900 MHz transmitter &receiver	Test	Work in Progress

IV.1.e Preliminary Integration Plan

The Arduino UNO will be the primary data collection center .It will collect data from the SDL-1 Solar Data Logger, the TR-74UI unit, and the BMP085 barometric pressure sensor. The UNO will transfer its data to the 900 MHz transmitter which is powered by the RDAS Tiny altimeter. Data will be transmitted to a receiver that is connected to a laptop computer. Data is also stored on board the computer via the Adafruit Data Logger.

IV.1.f Instrumentation Precision, Repeatability and Data Recovery

Instrument	Sensor	Capability
AED Electronics	Temp	Temperature measurement: -40 to 85 deg C, resolution 0.22 deg C (-40 to +185 deg F, resolution 0.39 deg F)
	2-Axis Accelerometer	Configurable range: +/- 50g, +/- 25g, +/- 10g and +/-5g (each axis can have a different scale)
TR-74UI	Temp	0-55 C
	Humidity	10-95% RH
	Illuminance	0-130,000 lx
	UV Intensity	0-30 mW/cm^2
SDL-1 Solar Data Logger	Irradiance	Range 1520 W/m^2
Barometric Pressure Sensor - BMP085 Breakout	Barometric pressure	300-1100hPa (+9000m to -500m)

Table 8 - Instrument Precision

Precision will be determined by extensive testing and comparing the results to standard laboratory instruments. Assuming that our construction and testing are robust, we should be able to repeat our results throughout the duration of this project and beyond.

IV.1.g Science Payload Schematics

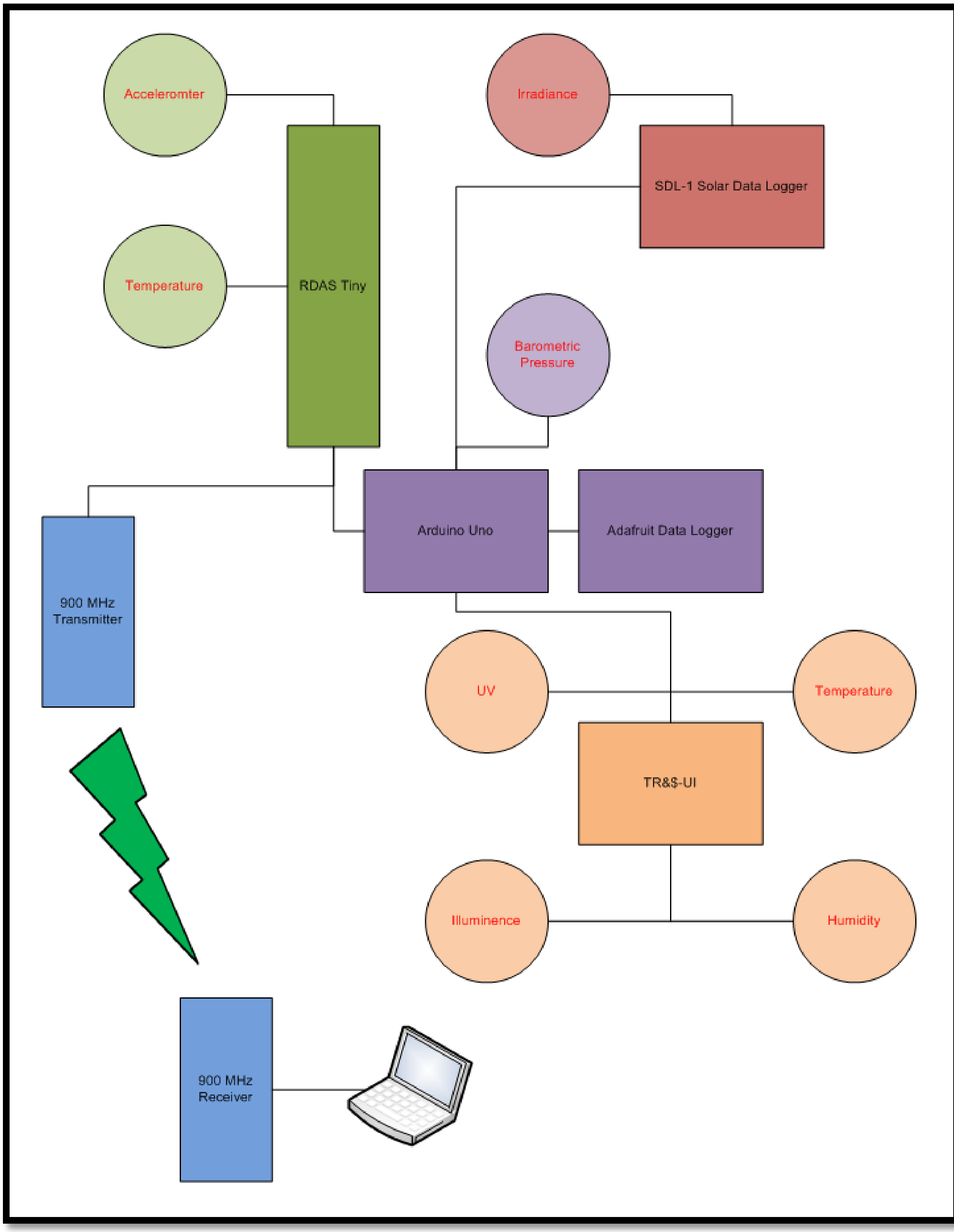


Figure 56 - Instrumentation Block Diagram

IV.1.h Payload Key Components Interaction to Achieve Desired Results

The sensors will collect information based upon the programming of the Arduino Uno. The data will be stored in the data logger as well as passed onto the 900 MHz transmitter. The transmitter will transmit the data to the receiver that is connected to a laptop.

IV.2 Payload Concept Features and Definition

IV.2.a Creativity and Originality

Only two team members have any electronic or microcontroller programming experience. This learning experience is taking place because the students believe that they can learn enough in a timely manner to construct and test the sensors and to install them in the rocket in such a fashion that the data collected will be meaningful to them as well as to the USLI panel of scientists and engineers.

IV.2.b Uniqueness or Significance

Our payload will essentially create a vertical profile of the atmosphere from ground level to 1 mile AGL. This data will be analyzed by the rocket team and students from the NWIC Native Environmental Science program. This payload is significant because it will capture data about the atmosphere, and this data can be analyzed and perhaps used by students in the Native Environmental program of study when we do our own launches on the Lummi Nation Reservation.

IV.2.c Suitable Level of Challenge

This is a totally new process for most of the students. We’ve had a little experience since January 2010 in building, and flying high powered rockets. We’ve had little to no experience in developing electronic experiments except for last year’s USLI project. We’ve had little to no experience working on a project of this magnitude. That being said, Sky Walkers are confident that we can complete this project successfully. Our advisors, Gary and Dave, are totally supportive and help us find answers, figure out how to find solutions to our challenges. This is true of our mentor, Bill, as well.

IV.3 Science Value

The objective of the science payload is to collect data and learn to analyze that data and report it in a meaningful way. We will be working with the Native Environmental Science students and the math instructor to analyze this data.

IV.3.a Payload Objectives

Team Skywalker’s intention is two faceted: 1) gather atmospheric data and present it in a meaningful format; and, 2) see if we can develop a power management system so that we can achieve a predicted altitude.

The first objective involves building sensor and probe modules to sample atmospheric temperature, humidity, and pressure. Also we will be building an ultraviolet radiation sensor and a solar irradiance sensor.

The second objective will develop our analytical, programming, engineering, and construction skills.

Our major reasons for doing this are to not only satisfy the SMD goals, but to enhance the learning and knowledge of our team members. All of the team members want to be challenged and to build upon last year's team success. *(Advisor's note: several administrators and faculty members have likened the Space Center's activities to a major university's successful athletic team. This project has brought pride to both the college and the Space Center's team members.)*

IV.3.b Payload Success Criteria

1. Sensors need to make successful readings during the entire descent of the rocket and while on the ground.
2. Cameras need to successfully record during the descent of the rocket and while on the ground.
3. Microcontroller needs to store all of the data it collects in an SD card without any loss or corruption of data
4. Data needs to be successfully transmitted to the laptop
5. Data needs to be transferred to a laptop without any loss or corruption

Power Management Success Criteria

1. Velocity Reduction System deploys at the appropriate time and speed
2. Microcontroller performs as programmed
3. Mechanical system works as designed
4. Target altitude reached

IV.3.c Experimental Logic, Approach, and Investigation Method

Sky Walkers' logic and approach is to meticulously build everything, provide a thoughtful approach to reaching our goals, be acutely aware of safety, put the rocket into the air and analyze the data that we retrieve.

IV.3.d Test and Measurement, Variables, and Controls

We will be evaluating our atmospheric sensor modules by comparing the sensor results with standard scientific measuring tools such as laboratory quality thermometers, barometers, and hygrometers. Prior to the competition flight, we will have a baseline for each of the sensors that we have developed from a controlled environment.

IV.3.e Relevance of Expected Data and Accuracy/Error Analysis

Since the sensor modules are under programming logic, we should be able to programmatically correct any consistent discrepancies between our sensors and standard scientific measurement tools. What will be interesting is how much, if any, the data collected through actual flights differs from static data collection. If there are significant differences, that will be a challenging task to evaluate the differences and to be able to compensate for accuracy.

IV.3.f Preliminary Experimental Procedures

After having built and tested the prototype sensor modules, we will be building robust modules that will be able to withstand the rigors of a high powered rocket flight. The competition modules will then be mounted in the science payload bay and a series of static tests will be developed and carried out for each of the sensors. Data collection and analysis will allow us to make any programming changes or other modifications necessary to obtain consistent and accurate results. Test, evaluate, modify, and repeat as necessary.

A typical test session follows this order:

1. Test battery voltages
2. Power up the system
3. Gather data for a set amount of time
4. Power down the system
5. Analyze the data
6. Trouble shoot mechanical, electrical and/or programming issues.

IV.4 Payload Safety and Environment

IV.4.a Safety Officer

Justin is the safety officer.

IV.4.b Failure Modes

Payload failure modes can be hazardous or nonhazardous. Hazardous failures may result injury to personnel or damage to property. Non-hazardous failures are failures affecting the success of the mission, but not resulting in injury to personnel or damage to property (other than that of the team). See page 20 for more details.

IV.4.c Personnel Hazards

Personnel hazards have discussed elsewhere. Please see section, III.7.c Personnel Hazards and Hazard Mitigations.

IV.4.d Payload Environmental Concerns

Nothing in the payload constitutes an environmental hazard.

V) *Activity Plan*

V.1 Budget Plan

Qty	Description		Total Price
Scale Model Rocket			
1	LOC Precision Vulcanite Kit	$69.95	$69.95
1	48" 54mm Airframe	$7.30	$7.30
3	Tube Couplers - 54mm	$2.05	$6.15
1	1/4" Plywood	$6.99	$6.99
2	Aerotech G80	$26.99	$53.98
			$144.37
Full Scale Rocket			
1	Performance Rocketry MadDog DD	$179.55	$179.55
1	4" G10 Airframe - 48"	$83.60	$83.60
1	4" Tail Cone	$28.50	$28.50
2	G10 Sheet, 3/32 x 12 x12	$13.30	$26.60
2	4" Coupler	$20.90	$41.80
1	1/4" Plywood	$6.99	$6.99
1	Aero Pack tail cone	$54.99	$54.99
1	G10 Sheet, 1/8 x 12 x12	$17.10	$17.10
			$439.13
Motors for Full Scale Rocket			
2	CTI 54mm 6 grain reload	$182.95	$365.90
1	CTI 54 mm 6XL grain motor casing	$106.95	$106.95
2	Aerotech 54mm 5 grain reload	$119.66	$239.32
1	RMS-54/2560 MOTOR	$199.80	$199.80
			$911.97
Miscellaneous Parts			
1	Misc Construction Supplies - paint, glue	$100.00	$100.00
1	Misc hardware - bolts, nuts, links	$100.00	$100.00
			$200.00
Recovery System			
1	Recovery materials, nomex, nylon, kevlar	$60.00	$60.00
1	Black Powder	$40.00	$40.00
1	60" Parachute	$79.95	$79.95
1	24" Parachute	$16.75	$16.75
1	RDAS-Tiny altimeter	$300.00	$300.00
2	MAWD Altimeter	$99.95	$199.90
			$696.60
Payload and Tracking System			
1	GPS Unit	$295.00	$295.00
1	Payload camera	$9.95	$9.95

1	Science Payload	$2,100.00	$2,100.00
1	Arduino Uno	$19.95	
1	Arduino Pro Mini	$29.95	
1	Adafruit Data Logger	$29.95	
1	Power Management System	$200.00	$200.00
3	HiTec HS 645MG Ultra Torque Servo	$31.99	
1	Arduino Uno	$19.95	
			$2,604.95
		Total	**$4,997.02**
	Travel		
12	Huntsville Travel	$575.00	$6,900.00
4	Huntsville Lodging	$200.00	$800.00
			$7,700.00
	Project Income		
	NASA SMD		$3,000.00
	Outreach		$3,000.00
	Washington State Space Grant		$2,000.00
	Tribal Support		$5,000.00
			$13,000.00

Budget Summary	
Scale Rocket	$144.37
Competition Rocket	$439.13
Propulsion	$911.97
Construction Supplies	$200.00
Recovery	$696.60
Electronics & Payload	$2,604.95
	$4,997.02
Travel & Lodging	$7,700.00
Project Income	
	$13,000.00

V.2 Timeline

Please see Appendix B

V.3 Educational Engagement

As of the report submittal, Team SkyWalkers have participated in the following educational engagement activities:

- AISES National Conference
- Windward Discovery Academy (Special Education Students)
- AISES Presentation at Northwest Indian College
- NASA's Future Forum at Museum of Flight, Seattle, WA

Additionally, we are published monthly in the Lummi Nation paper, “Squol Quol”. See Appendix N

We’ve also been recognized by the “Tribal College Journal” and will have an article in February’s “Indian Country Today”.

http://www.tribalcollegejournal.org/archives/7918

and we have a NASA webpage devoted to us.

http://www.nasa.gov/audience/foreducators/postsecondary/features/inexperience-stop-flying.html

We are in communication with the school districts in Whatcom County, Washington. We are working with the middle schools to setup time lines to work with their science students.

Our outreach is focused on middle school aged students. However, we recognize the importance of a successful Native American science endeavor. We need to take this and reach as many people as possible. It is a vast contradiction to how many view Native Americans.

VI) Conclusion

The Sky Walkers are confident in the design that we have created to meet the overall mission requirements in the USLI competition. The complete design be tested in the very near future. Any design flaws or improvements, subtle or otherwise, will be addressed well before the final launch in April; this will ensure that the mission safe as well as successful.

The payload presents many challenges to the Sky Walkers. The team involvement in such a challenging environment can’t help but make us better students.

Safety is our greatest priority. We insure this by creating and following rigorous launch checklists. Testing, testing, and more testing add to the safety margin. Our mentor plays an important role in following our course of action and stepping in where necessary to challenge our assumptions.

The overall success of the Sky Walkers is dependent upon dedication, hard work, and the excitement of doing something that few of us have previously done.

Appendix A – Launch Vehicle Fly Sheet

Milestone Review Flysheet

CDR

Institution Name	Northwest Indian College	**Milestone**	CDR

Vehicle Properties	
Diameter (in)	4
Length (in)	112.625
Gross Liftoff Weight (lb)	23.9
Launch Lug/button Size	0.5
Motor Retention	Aero Pack Tail Cone/Retention

Motor Properties	
Motor Manufacturer	CTI
Motor Designation	L640
Max/Average Thrust (N/lb)	1590/630.4
Total Impulse (N-sec/lb-sec)	2772.2
Mass pre/post Burn (lb)	4.95/2.85

Stability Analysis	
Center of Pressure (in from nose)	76.29
Center of Gravity (in from nose)	63.42 w/motor
Static Stability Margin	1.91
Thrust-to-Weight Ratio	13:1
Rail Size (in) / Length (in)	1 in/72 in

Ascent Analysis	
Rail Exit Velocity (ft/s)	55.12
Max Velocity (ft/s)	558
Max Mach Number	0.50
Max Acceleration (ft/s^2)	367.51
Peak Altitude (ft)	5,566/5,280

Recovery System Properties				
Drogue Parachute				
Manufacturer/Model	Sky Angle Cert3			
Size	24"			
Altitude at Deployment (ft)	5,280			
Velocity at Deployment (ft/s)	0.03			
Terminal Velocity (ft/s)	78.82			
Recovery Harness Material	Tubular Nylon			
Harness Size/Thickness (in)	9/16"			
Recovery Harness Length (ft)	20			
Harness/Airframe Interfaces	3/8' closed steel eyebolt			
Kinetic Energy During Descent (ft-lb)	Section 1	Section 2	Section 3	Section 4
	621	218	1290	

Recovery System Properties				
Main Parachute				
Manufacturer/Model	Sky Angle Classic 52			
Size	89 sq ft			
Altitude at Deployment (ft)	700			
Velocity at Deployment (ft/s)	78.82			
Landing Velocity (ft/s)	17.39			
Recovery Harness Material	Tubular Nylon			
Harness Size/Thickness (in)	9/16"			
Recovery Harness Length (ft)	30			
Harness/Airframe Interfaces	3/8" closed steel eyebolt			
Kinetic Energy Upon Landing (ft-lb)	Section 1	Section 2	Section 3	Section 4
	30	11	63	

Recovery System Properties	
Electronics/Ejection	
Altimeter(s) Make/Model	PerfectFlite MAWD
Redundancy Plan	2nd PefectFlite MAWD
Pad Stay Time (Launch Configuration)	2 hours

Recovery System Properties	
Electronics/Ejection	
Rocket Locators (Make, Model)	Garmin Astro 200, DC 20
Transmitting Frequencies	151.82, 151.88, 151.94, 154.57, 154.60 MHZ for GPS
Black Powder Mass Drogue Parachute (gram)	2.36 upped to 3
Black Powder Mass Main Parachute (gram)	3.15 upped to 4

Milestone Review Flysheet

CDR

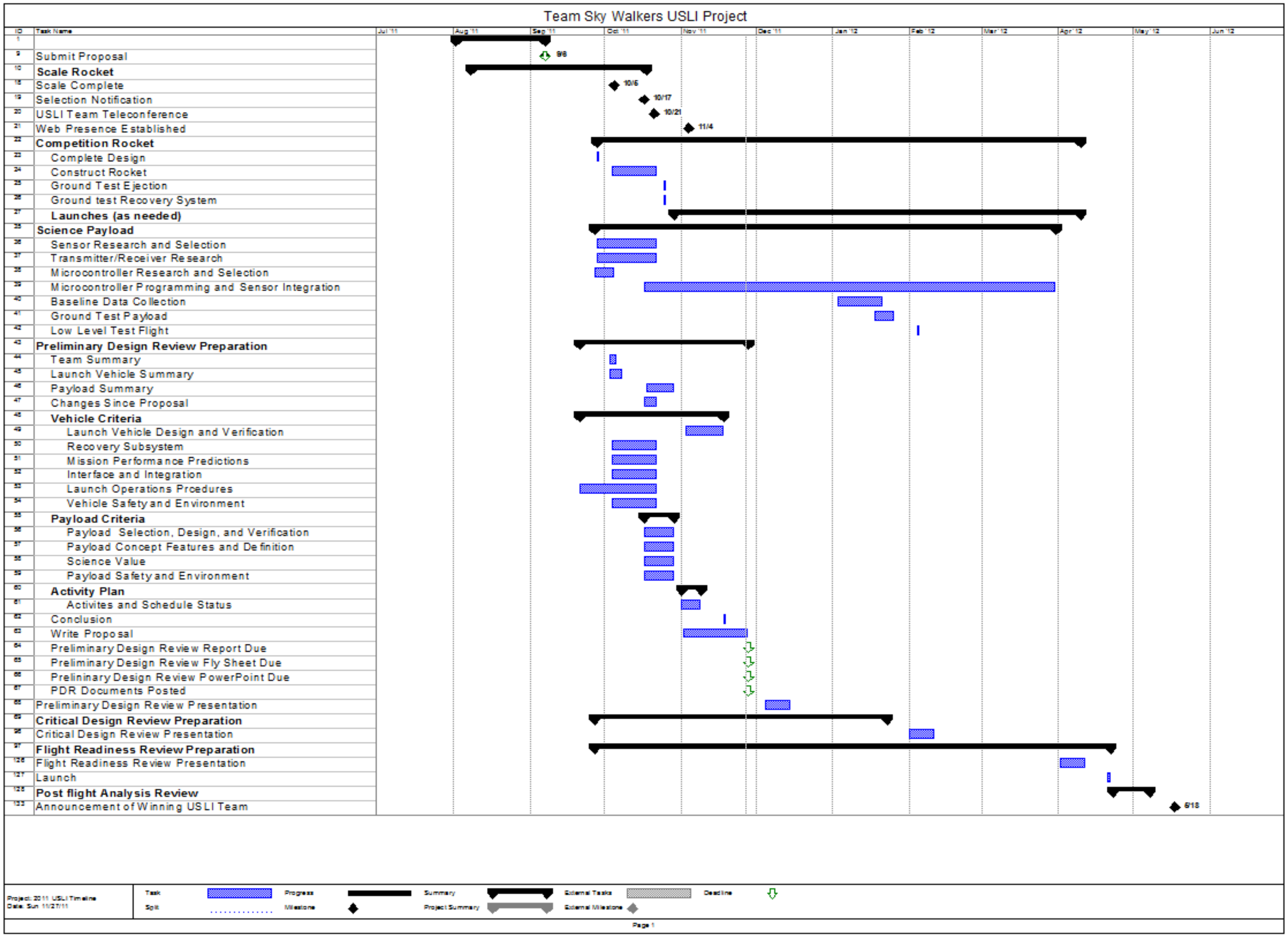
Institution Name	Northwest Indian College	Milestone	CDR

Payload/Science	
Succinct Overview of Payload/Science Experiment	SMD atmospheric measuring and photography Power Management system
Identify Major Components	Nose cone, main parachute bay, ebay, drogue parachute bay, science/power management bay, fin can, propulsion system, recovery system
Mass of Payload/Science	6.4 pounds

Test Plan Schedule/Status	
Ejection Charge Test(s)	Tested for subscale - complete Scheduled for competition rocket -
Sub-scale Test Flights	Complete 11/12/11
Full-scale Test Flights	Scheduled: 1/28, 1/29, 2/18/12, 3/12/12, 4/9/12

Additional Comments	

Appendix B – Time Line



Appendix C – Competition Rocket Verification Plan

Requirement	Design Feature	Verification	Status
1. Option 2: The Science Mission Directorate (SMD) at NASA HQ will provide a $3,000 sponsorship to any team that chooses to build and fly a deployable science payload meeting the following criteria:	SMD Payload	Inspection	Work in Progress
The payload shall gather data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet radiation. Measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Surface data collection operations will terminate 10 minutes after landing.	Arduino microcontroller-based sensors	Test	Work in Progress
The payload shall take at least 2 pictures during descent and 3 after landing.	Multiple Cameras oriented appropriately	Test	Cameras purchased
The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.			Work in Progress
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.	RDAS-Tiny transmitter & receiver	Test	Work in Progress
Separation of payload components at apogee will be allowed, but not advised. Separating at apogee increases the risk of drifting outside of the recovery area. The payload shall carry a GPS tracking unit. Minimum separation altitude shall be 2,500 ft.	Not Applicable	Not Applicable	Not Applicable
2. The launch vehicle shall deliver the science or engineering payload to, but not exceeding, an altitude of 5,280 feet. above ground level (AGL). One point will be deducted for each foot achieved below the target altitude. Two points will be deducted for each foot achieved above the target altitude. Any team whose vehicle travels over 5,600 ft. according to their competition altimeter will be disqualified from being able to receive the overall competition award and will receive a score of zero for the altitude portion of their total score.	Design through Rocksim 9, Power Management System	Test	Work in Progress
3. The vehicle shall carry one Perfect Flight MAWD or ALT15 altimeter for recording of the official altitude used in the competition scoring. Teams may have additional altimeters to control vehicle electronics and payload experiments. At the flight hardware and safety check, a NASA official will mark the altimeter which will be used for the official scoring. At the launch field, a NASA official will also obtain the altitude by listening to the audible beeps reported by the altimeter. The following circumstances will warrant a score of zero for the altitude portion of the competition:	Two PerfectFlite MAWD altimeters	Inspection	Complete
a. The official, marked altimeter is damaged and/or does not report an altitude after the team's competition flight.	Safe Recovery will preclude this	Inspection	Work in Progress
b. The team does not report to the NASA official designated to record the altitude with their official marked altimeter by 5:00 pm on the day of the launch.	Check list will preclude this	Inspection	Work in Progress
4. The recovery system electronics shall have the			

following characteristics:			
a. The recovery system shall be designed to be armed on the pad.	Locking key switches installed	Inspection	Work in Progress
b. The recovery system electronics shall be completely independent of the payload electronics.	Payload electronics in separate science by		
c. The recovery system shall contain redundant altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Designed with two independent systems		
d. Each altimeter shall be armed by a dedicated arming switch.	Locking Key Switches		
e. Each altimeter shall have a dedicated battery.	Designed with two independent systems including batteries		
f. Each arming switch shall be accessible from the exterior of the rocket airframe.	Locking switches located on ebay ring		
g. Each arming switch shall be capable of being locked in the ON position for launch.	Switches that lock with a key are installed		
h. Each arming switch shall be a maximum of six (6) feet above the base of the launch vehicle.	Switches located 64 inches from base of rocket		
5. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system by the transmitting device(s).	Ebay lined with aluminum foil	Inspection	Work in Progress
6. The launch vehicle and science or engineering payload shall remain subsonic from launch until landing.	Designed with Rocksim 9 to stay subsonic	Simulation	Work in Progress
7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Simulation	Work in Progress
8. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery from apogee to main parachute deployment is permissible, provided that the kinetic energy is reasonable.	Designed with Rocksim 9, using drogue at apogee and main at 700 feet	Simulation	Work in Progress
9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	2 - #2-56 nylon screws will be shear pins	Ground Testing	Work in Progress
10. The launch vehicle shall have a maximum of four (4) independent or tethered sections.	Designed with three	Inspection	Work in Progress
a. At landing, each independent or tethered sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Designed via calculations	Simulation	Complete
b. All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.	Designed with Rocksim 9	Simulation analysis	Complete
11. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the waiver opens.	Designed as required	Check lists	Work in Progress

12. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any onboard component.	Battery power calculated to last at least 2 hrs for each device using a battery	Simulation analysis	Work in Progress
13. The launch vehicle shall be launched from a standard firing system (provided by the Range) using a standard 10 - second countdown	Designed as required	Test	Work in Progress
14. The launch vehicle shall require no external circuitry or special ground support equipment to initiate the launch (other than what is provided by the Range).	None are necessary as designed	Inspection	Work in Progress
15. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	Data analysis will be examined post flight	Testing will follow payload completion prior to the competition flight	Work in Progress
16. An electronic tracking device shall be installed in each independent section of the launch vehicle and shall junction with an electronic, transmitting device, but shall not replace the transmitting tracking device.	Garmin GPS unit in nose cone	Ground tested complete. Flight test to follow	Work in Progress
17. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA) and/or the Canadian Association of Rocketry (CAR).	Designed to use CTI/Aerotech reloadable motor	Inspection	Work in Progress
18. The total impulse provided by the launch vehicle shall not exceed 5,120 Newton-seconds (L-class). This total impulse constraint is applicable to any combination of one or more motors.	Designed as required, L motor largest permissible	Inspection	Work in Progress
19. All teams shall successfully launch and recover their full scale rocket prior to FRR in its final flight configuration.			
a. The purpose of the full scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight.	Test flights scheduled prior to FRR	Test flight	Work in Progress
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle	Test flight	Work in Progress
c. The payload does not have to be flown during the full-scale test flight.			
▪ If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Measured mass of actual payload will be either substituted or the payload will be flown	Test flight	Work in Progress
▪ If the payload changes the external surfaces of the launch vehicle (such as with camera housings and/or external probes), those devices must be flown during the full scale demonstration flight.	Test flight will be with rocket as its designed		Work in Progress
d. The full scale motor does not have to be flown during the full scale test flight. However, it is recommended that the full scale motor be used to demonstrate full flight readiness and altitude verification.	Both smaller and a full scale motor will be used in test flights	Test flight	Work in Progress

e. The success of the full scale demonstration flight shall be documented on the flight certification form, by a Level 2 NAR/TRA observer.	Our mentor and 3 other NAR L2 individuals are available		Work in Progress
f. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer.	No changes will be made.		Work in Progress
20. The following items are prohibited from use in the launch vehicle:			
a. Flashbulbs. The recovery system must use commercially available low-current electric matches.	None of these have been included in the rocket design	Inspection	Complete
b. Forward canards.			
c. Forward firing motors.			
d. Rear ejection parachute designs.			
e. Motors which expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).			
f. Hybrid motors.			
21. Each team shall use a launch and safety checklist. The final checklist shall be included in the FRR report and used during the flight hardware and safety inspection and launch day.	Check lists are designed	Inspection and actual testing	Complete
22. Students on the team shall do 100% of the work on the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder charges.	Implemented as required	Inspection	Work in Progress
23. The rocketry mentor supporting the team shall have been certified by NAR or TRA for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 15 flights in this or a higher impulse class, prior to PDR.	Implemented as required	Inspection	Complete
24. The maximum amount teams may spend on the rocket and payload is $5000 total. The cost is for the competition rocket as it sits on the pad, including all purchased components and materials and the fair market value of all donated components and materials. The following items may be omitted from the total cost of the vehicle:			
a. Shipping costs.	Implemented as required	Inspection	Complete
b. Ground Support Equipment.			
c. Team labor.			

Appendix D - Northwest Indian College Space Center (NWIC-SC) Release Form for Rocket Launches

As consideration for the opportunity to participate in NWIC-SC launches, I hereby release and forever discharge the National Association of Rocketry (NAR), the Tripoli Rocketry Association (TRA) and their officers, members, administrators, agents and assigns; Northwest Indian College Space Center and its officers, members and agents; the launch site's landowners, administrators and caretakers including the state of Washington and all other persons attending NWIC-SC launches from suits of any kind or nature whatsoever resulting from attending NWIC-SC events. This release and discharge includes but is not limited to suits involving injury and/or property loss or damage resulting from accidents which might happen to me and/or to those who accompany me to Northwest Indian College Space Center launches.

When attending NWIC-SC launch events, I hereby agree to fly high power rocket motors of "H" impulse and above only if I possess a valid NAR or TRA High Power Certification. I affirm that I possess valid copies of all permits and paperwork required to legally fly high power rocket motors. Further more, I will never fly rocket motors more powerful than my certification will allow except when engaged in a formally supervised NAR or TRA certification flight attempt. I also agree that I will fly only commercially manufactured rocket motors that are certified for use by NAR and/or TRA.

I am fully aware of the risks involved in traveling to and participating in rocketry events and hereby assume all of those risks. I agree further that I have completely read, fully understood the terms of and voluntarily accept this agreement. Furthermore, I agree to follow the NAR and TRA Safety Codes as well as all local, state and federal laws, regulations and rules that apply to NWIC-SC launches.

Name (Please print)____

Signature & Date ____

Parent/Guardian (17 and younger) ________________________________

Address ____

City State Zip____

Email address ____

Phone (   )____

NAR Membership ____________________Cert Level ________ Expires ____

TRA Membership ____________________Cert Level ________ Expires_____

Appendix E - GSE Check List

- ❑ Fire Extinguisher
- ❑ 1st Aid Kit
- ❑ Launch Legs
- ❑ Launch Rail
- ❑ Launch Leg Connector
- ❑ Launch Blast Shield
- ❑ Control Box
- ❑ Igniter Cables
- ❑ Launch Batteries
- ❑ Igniter Clips
- ❑ Weather Station
- ❑ Compass/Direction Recorder
- ❑ Cell Phone
- ❑ Phone Numbers
- ❑ Fireproof Blanket
- ❑ Writing Pad
- ❑ Pencils/Pens
- ❑ Sandpaper
- ❑ Flight Card
- ❑ Liability Waiver
- ❑ Flight Data Sheets
- ❑ Portable Weather Station
- ❑ Mosquito Repellant (seasonal)
- ❑ FSR Radios w/fresh batteries
- ❑ Video/Still Camera
- ❑ Clipboard

Appendix F – Ebay and Recovery System Check List

Recovery System Preparation

Recovery System, Drogue Chute:

- *Check all connections. Insure all devices are in good condition and properly secured:*
  - ❑ Aft bay recovery harness to drogue
  - ❑ Booster recovery harness to drogue
  - ❑ Fold drogue chute per manufacturer's instructions.
  - ❑ Insure shroud lines are free from tangles.
  - ❑ Insure all quick links are secure.
  - ❑ Insert ejection charge protection (dog barf).
  - ❑ Insert folded and protected chute into drogue recovery compartment.

Recovery System, Main Chute

- *Check all connections. Insure all devices are in good condition and properly secured:*
  - ❑ Forward bay recovery harness to shock cord mount
  - ❑ Forward bay recovery harness to main
  - ❑ Fold main chute per manufacturer's instructions.
  - ❑ Insure shroud lines are free from tangles.
  - ❑ Insure all quick links are secure.
  - ❑ Insert ejection charge protection.
  - ❑ Insert folded and protected chute into forward recovery compartment

EBay & Black Powder Ejection Charges

Wear eye protection whenever working with Black Powder!

Prepare avionics #1

- ❑ Be sure all arming switches are off.
- ❑ Install battery in altimeter.
- ❑ Secure battery in place with positive battery retention system.
- ❑ Altimeter properly programmed and verified.
- ❑ Connect aft pyrotechnic leads to electronic deployment device.
- ❑ Connect forward pyrotechnic leads to electronic deployment device

Prepare avionics #2

- ❑ Be sure all arming switches are off.
- ❑ Install batteries in altimeter.
- ❑ Secure batteries in place with wire ties and tape.
- ❑ Flight computer properly programmed and verified.
- ❑ Connect aft pyrotechnic leads to electronic deployment device.
- ❑ Connect forward pyrotechnic leads to electronic deployment device

Black Powder, drogue

- ❑ Trim electric match to an appropriate length.
- ❑ Remove at least an inch of insulation from each lead
- ❑ Short electric match leads
- ❑ Insert electric match into BP container

- ❑ Pour measured amount of BP into BP container
- ❑ Fill remaining space with dog barf
- ❑ Tape over the BP container with tape to make certain that no BP escapes while filling the other cups.
- ❑ Repeat for the secondary BP container
- ❑ Insert external disarming mechanisms to insure all electronically discharged pyrotechnics are disabled until final launch readiness.
- ❑ Connect electric match leads to appropriate connecting posts for each altimeter

Black Powder, main

- ❑ Trim electric match to an appropriate length.
- ❑ Remove at least an inch of insulation from each lead
- ❑ Short electric match leads
- ❑ Insert electric match into BP container
- ❑ Pour measured amount of BP into BP container
- ❑ Fill remaining space with dog barf
- ❑ Tape over the BP container with tape to make certain that no BP escapes while filling the other containers.
- ❑ Repeat for the secondary BP container
- ❑ Insert external disarming mechanisms to insure all electronically discharged pyrotechnics are disabled until final launch readiness.
- ❑ Connect electric match leads to appropriate connecting posts for each altimeter

Mount ebay into rocket, checking external disarming mechanisms are in place.

<u>Insure all black powder electronic devices are in disarmed mode during EBay final installation.</u>

<u>Note: All pyrotechnic devices must remain in an unarmed mode until rocket is on pad ready to launch.</u>

Appendix G - Motor and Launch Preparation Checklist

Motor preparation

- ❑ Be sure that motor is clean
- ❑ Open reload package
- ❑ Read the instructions
- ❑ Identify all of the parts to make certain that they are all there. If not, contact the Safety Officer
- ❑ Grease motor liner
- ❑ Insert propellant grains
- ❑ Tighten nozzle
- ❑ Remove black powder from (CTI motor) forward end of reload
- ❑ Seal ejection charge hole with grease
- ❑ Insert reload into motor
- ❑ Fasten retaining tail cone
- ❑ Tape igniter to rocket airframe
- ❑ Discard trash properly

Launch team transports rocket to assigned launch pad

Appendix H - Final Launch Preparation Checklist

Tools to launch pad

- ❑ Multi bit screwdriver
- ❑ Sandpaper
- ❑ Wire strippers
- ❑ Masking tape
- ❑ Small screwdriver
- ❑ Razor knife

Setup on launcher

- ❑ Verify pad power is OFF
- ❑ Slide rocket on to rail guide
- ❑ Raise rail guide and position vertically as desired
- ❑ Remove both safety restraints from altimeter switches
- ❑ Altimeters – beeping
- ❑ Cameras on

Igniter installation

After rocket is on the launch rail and after the altimeters are turned on then,

- ❑ Strip at least an inch of insulation from the igniter leads
- ❑ Make certain that igniter leads are shorted out to prevent accidental ignition
- ❑ Straighten igniter leads
- ❑ Insert igniter through the nozzle to the top of the motor
- ❑ Retain with plastic nozzle cap
- ❑ Short alligator clips to check for unpowered igniter wires
- ❑ Clamp clip of igniter lead and wrap excess igniter lead wire around alligator clip
- ❑ Repeat for second igniter lead.
- ❑ Make certain that there is no tension on the igniter leads that might cause it to fall from the rocket.
- ❑ Check continuity
- ❑ Fasten igniter into position
- ❑ Dispose of trash properly

Final Launch Sequence

- ❑ Insure Flight Witnesses are in place and ready for launch.
- ❑ Arm all devices for launch.
- ❑ Return to Safe Area
- ❑ Ready cameras
- ❑ Signal LCO & RSO that rocket is ready for launch.
- ❑ Countdown and launch

Misfire Procedures

- ❑ Wait 60 seconds per NAR
- ❑ Safe all pyrotechnics to pre-launch mode.
- ❑ Remove failed igniter
- ❑ Resume checklist at "Final Launch Preparations/Prepare Igniter."

Appendix I - Post-Recovery Checklist

Normal Post Flight Recovery

- ❑ Take at least five photographs of the rocket and its components BEFORE touching it
- ❑ Check for non-discharged pyrotechnics.
- ❑ Safe all ejection circuits.
- ❑ Remove any non-discharged pyrotechnics.

Flight Failure Checklist

- ❑ Take at least five photographs of the rocket and its components BEFORE touching it
- ❑ Disarm all non-fired pyrotechnic devices.
- ❑ Continue Normal Post Flight Recovery procedures.
- ❑ Carry the pieces back to the staging area with great solemnity and respect.

Appendix J - High Power Rocket Safety Code

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. If my rocket has onboard ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.
5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.
7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.
8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater.
11. **Launcher Location.** My launcher will be 1500 feet from any inhabited building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE				
Installed Total Impulse (Newton-Seconds)	**Equivalent High Power Motor Type**	**Minimum Diameter of Cleared Area (ft.)**	**Minimum Personnel Distance (ft.)**	**Minimum Personnel Distance (Complex Rocket) (ft.)**

0 -- 320.00	H or smaller	50	100	200
320.01 -- 640.00	I	50	100	200
640.01 -- 1,280.00	J	50	100	200
1,280.01 -- 2,560.00	K	75	200	300
2,560.01 -- 5,120.00	L	100	300	500
5,120.01 -- 10,240.00	M	125	500	1000
10,240.01 -- 20,480.00	N	125	1000	1500
20,480.01 -- 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Appendix K - Range Safety Regulations

I , ____________________________________, have fully read and fully understand the following regulations relating to operating high powered rockets:

1. The National Association of Rocketry High Powered Rocketry Safety Code
2. The National Fire Protection Association (NFPA) 1127: “Code for High Powered Rocket Motors".
3. The Federal Aviation Regulations 14 CFR, Subchapter F Subpart C “Amateur Rockets”.

Also, I understand that the Range Safety Officer has the right to deny any rocket from launch. Before launch I will check with the RSO about:

1. Safety inspection of my rocket
2. Checking the stability of my rocket (center of pressure and center of gravity locations).
3. Weather conditions at the launch pad and predicted altitude
4. Electronics such as altimeters, timers, flight computers, etc.
5. Best recovery options including: Descent rates, launch pad inclination, etc.

Safety is the number one priority for the NWIC Space Center. I hereby reaffirm my commitment to keeping myself, my teammates, launch participants, and the environment safe from risk, harm, and damage.

Signed:

____

Appendix L - Launch Wavier Activation

Date	Time	Initials	Agency	Phone	Timing
			NOTAM	877-487-6867	24-72 hrs
			BLI ATC	360-734-2745	24-48 hrs
			Vancouver ACC	604-586-4560	24-48 hrs
			BLI ATC	360-734-2745	30-45 min
			Vancouver ACC	604-586-4560	5-10 min
			NOTAM	**877-487-6867**	**Operations Concluded**
			BLI ATC	**360-734-2745**	
			Vancouver ACC	**604-586-4560**	

½ nm radius of the Whatcom VOR (HUH), 175 degree radial at 9 nm
Latitude 48°47’38.44”N. Longitude 122°38’26.09”W

Appendix M - HPR Flight Card

High Power Flight Card

Northwest Indian College Space Center

Date: ____________

RSO Initials ________

Rod/Rail # ________

Section Break (Continuous)

Rocketeer's Name: ____________________ Launching on: Rod ☐ Rail ☐

Tripoli / NAR# __________ Current Cert Level: ___ Motor(s): ☐ Single ☐ Clustered ☐ Staged ☐ Air Starts

Rocket Manufacturer: ____________________ Main Motor: ____________________

Rocket Name: ____________________ More than one motor? If YES, see back: __________

Source: ☐ Kit ☐ Custom Color: __________ Recovery: ☐ Motor Eject ☐ Electronics ☐ Dual Deploy

Length: __________ Diameter: __________ Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Weight: __________ First Flight of Rocket?: ___ Electronics: ____________________

Modifications: ____________________ Other Payload: ____________________

I certify that the assembly and installation of this motor is per the manufacturer's printed instructions and that the construction, deployment and recovery system of this rocket is per the NAR/Tripoli Safety Code. I certify that I have a current, signed NWIC Space Center Liability Waiver and Participation Agreement on file for this launch date.

Signed: ______________________________

☐ Certification Flight: ☐ L1 ☐ L2 ☐ L3 Certifier: ______________________________

☐ Special Flight Info: ______________________________

Good Flight ☐

Failed Flight Reason

☐ Cato ☐ Hard Impact

☐ Shred ☐ Recovery Failed

High Power Flight Card

Northwest Indian College Space Center

Date: ____________

RSO Initials ________

Rod/Rail # ________

Section Break (Continuous)

Rocketeer's Name: ____________________ Launching on: Rod ☐ Rail ☐

Tripoli / NAR# __________ Current Cert Level: ___ Motor(s): ☐ Single ☐ Clustered ☐ Staged ☐ Air Starts

Rocket Manufacturer: ____________________ Main Motor: ____________________

Rocket Name: ____________________ More than one motor? If YES, see back: __________

Source: ☐ Kit ☐ Custom Color: __________ Recovery: ☐ Motor Eject ☐ Electronics ☐ Dual Deploy

Length: __________ Diameter: __________ Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Weight: __________ First Flight of Rocket?: ___ Electronics: ____________________

Modifications: ____________________ Other Payload: ____________________

I certify that the assembly and installation of this motor is per the manufacturer's printed instructions and that the construction, deployment and recovery system of this rocket is per the NAR/Tripoli Safety Code. I certify that I have a current, signed NWIC Space Center Liability Waiver and Participation Agreement on file for this launch date.

Signed: ______________________________

☐ Certification Flight: ☐ L1 ☐ L2 ☐ L3 Certifier: ______________________________

☐ Special Flight Info: ______________________________

Good Flight ☐

Failed Flight Reason

☐ Cato ☐ Hard Impact

☐ Shred ☐ Recovery Failed

Appendix N- November 2012 __Squol Quol__ Article

NWIC Space Center joins 2012 NASA competition

Northwest Indian College (NWIC) Space Center students will go toe to toe with students in colleges and universities across the nation in NASA's University Student Launch Initiative (USLI) competition.

On Oct. 17, Space Center advisor Gary Brandt was notified that NWIC's proposal was accepted and his students will again get to participate in NASA's student rocket building competition against top universities such as MIT, Vanderbilt University, Purdue University and the University of Washington.

NWIC was the second tribal college to join the national competition, and this year Haskell Indian Nations University will also participate.

Last year was NWIC's first as a USLI competitor — NWIC students came in 17th out of 33 teams. The students' experience in last year's competition will be hugely beneficial going into the competition this year, Brandt said.

"Experience is priceless," Brandt said. "We know what is supposed to happen and how to better prepare ourselves."

That experience will be especially helpful this year — competition requirements this year are more challenging than last year.

The student teams will need to create a rocket that can fly to 5,280 feet into the air. For every foot short of that height, teams will lose one point, but they have to be careful not to go over too— for every foot exceeding 5,280 feet, teams will lose two points.

In addition to building and launching their rocket, NWIC's team, Team Sky Walkers, will launch devices that collect atmospheric data, UV, solar irradiance, humidity, barometric pressure and temperature, and transmit that data to their ground station. Their rocket must also be equipped with a camera that can take properly oriented— sky on top, ground on the bottom— photos while in the air and on the ground.

The eight-month-long project includes delivering three presentations to NASA representatives, as well as writing and compiling four reports, which are typically greater than 125 pages in length.

In addition to building a rocket for the NASA competition, the NWIC Space Center was also awarded a grant by NASA's Exploration Systems Mission Directorate for $4,000 to build and fly a rocket with a system that can stop it at a predetermined altitude.

"We are off to a busy year," Brandt said.

You can follow the NWIC Space Team's progress at blogs.nwic.edu/rocketteam.

Northwest Indian College Space Center

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Appendix O – HS-645MG High Torque Metal Gear Servo

The powerful HS-645MG is one of Hitec's most popular servos. It's the perfect choice for those larger sport planes or monster trucks and buggies requiring a durable high torque servo. Featuring our unique M/P and metal gear train technology, the HS-645MG offers one of the strongest gear trains available in any servo.

Specifications

Motor Type:	3 Pole
Bearing Type:	Dual Ball Bearing
Speed (4.8V/6.0V):	0.24 / 0.20
Torque oz./in. (4.8V/6.0V):	107 / 133
Torque kg./cm. (4.8V/6.0V):	8.0 / 10.0
Size in Inches:	1.59 x 0.77 x 1.48
Size in Millimeters:	40.39 x 19.56 x 37.59
Weight ounces:	1.94
Weight grams:	55

Appendix P – Responses to PDR Questions and Comments

NASA Student Launch Projects

Feedback Form **School/Institution**	NW Indian College
Milestone	PDR
Review Panel Decision	**PDR Passed**

Feedback
An abbreviated transcript from the PDR discussion is listed below. Additional comments from off-line reviewers are included. 1. Good job on PDR package. 2. Cert 3XL may be a little too big for a 4" airframe. Be sure that it can be deployed reliably. 3. 9/16 Kevlar may be a bit small for a rocket this heavy. May want to look at something closer to ½" 4. Good diagrams of power management system. 5. Good risk/mitigation charts. 6. 75 lbf is a little on the low side for an ejection force. Try using 200 lbf to ensure a good recovery. 7. Great verification matrix. 8. How much is the team planning on overshooting without any input from the power management system. 9. How is the static stability margin affected by the flaps opening and closing? 10. If one flap opens and one stays closed, are there any concerns with stability? 11. Are the altimeters that control the power management system completely independent from the altimeters that control the recovery events? They have to be. 12. 12. How will the flaps be actuated? Pneumatics? Electric?
Actions
1. At CDR, be sure to include intricate design details concerning the power management system.

1. Non required
2. Rocket's weight has been measured with actual components and a smaller parachute will suffice.(B2 Rocketry does say that a Cert 3XL will fit in a 25"x4" airframe).
3. This might be a typo because 9/16" is larger than ½" (8/16")
4. Non required
5. Non required
6. Data copied incorrectly from worksheet. Correctly entered this report
7. Non required
8. Rocksim indicates 5,500 feet without having the power management system activated.
9. Rocksim indicates no variation in stability with the dams retracted or extended.
10. System is constructed so that it is not possible for one side to open without the other side opening.
11. The altimeter that provides data to the power management system is completely independent of the altimeters that control the recovery events.
12. The flaps have been replaced by air dams that will be extended and retracted by two 1 pound torque servos. Both servos are connected to each of the two dams and in effect, act as a backup for each other.

Action
Design details included in report