NORTHWEST INDIAN COLLEGE
Xwlemi Elh>Tal>Nexw Squl

2011

Northwest Indian College Space Center
Team SkyWalkers
USLI Flight Readiness Review

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Flight Readiness Review Report

I) *Summary of Flight Readiness Review Report*

I.1 Team Summary

I.1.a Team Name

Northwest Indian College Space Center – Team SkyWalkers
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	23.95 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 L640

I.2.c Recovery System

Our rocket is equipped with a redundant recovery system consisting of two PerfectFlite StratoLogger altimeters that are electrically independent of each other. Recovery harnesses of suitable length and strength maintain connection between the recovery subsystems and the rocket. Landing will have a maximum kinetic energy of 75 ft-lbf.

I.2.d Rail Size

Two 0.630” x 0.680” (large) rail guide buttons are bolted and fiber glassed to the fin can that will guide the rocket up the 96 inch long 80/20 15 Series 1515 1.5" X 1.5" T-Slotted extrusion.

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 Critical Design Review Report

II.1 Changes made to Vehicle Criteria

One change is we had two failures of our number 2 PerfectFlite STRATOLOGGER altimeter. During the test launches of 1/28/12 and 2/4/12, the #2 altimeter deployed the main parachute at 1500 feet instead of the 700 feet programmed via the dip switch. We have replaced both PerfectFlite STRATOLOGGERs with PerfectFlite StratoLoggers The other change is that we opted to not use the Plexiglas section. It was too complicated to machine to the correct size.

The rocket's overall weight has been reduced with smaller payload components, a more efficiently designed power management system, and elimination of the Plexiglas section.

II.2 Changes made to Payload Criteria

No changes have been made to the payload

II.3 Changes made to Activity Plan

As in the previous reports, adverse weather conditions in the form of high winds, heavy rain, or low cloud ceilings have forced 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 Construction

The vehicle design and been stable since the PDR. We've used Rocksim 9 as the basic design software and have used it and Open Rocket for simulations.

III.1.a Design and Construction Features

<u>III.1.a.1 Structural Elements</u>

<u>III.1.a.1a Nosecone</u>

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, (, 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.

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

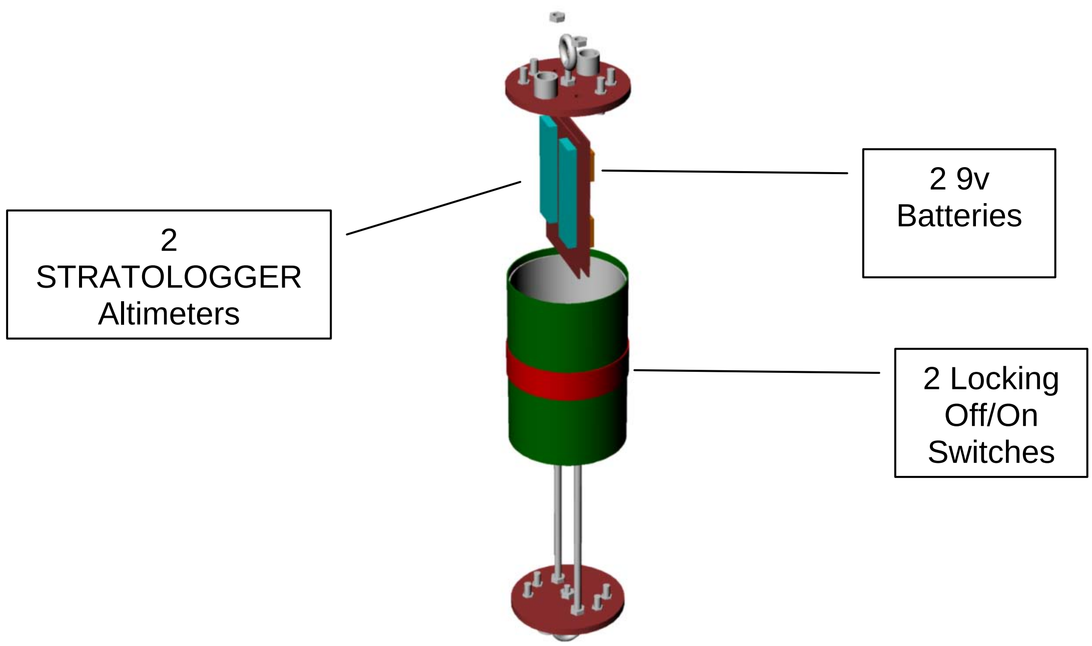
III.1.a.1b Main Parachute Recovery Bay

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.a.1c 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 StratoLogger 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 STRATOLOGGER 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 ebay altimeters will be shielded from stray RF signals with a layer of aluminum foil glued to the ebay's interior.



Ebay Concept

III.1.a.1d Drogue Parachute Recovery Bay

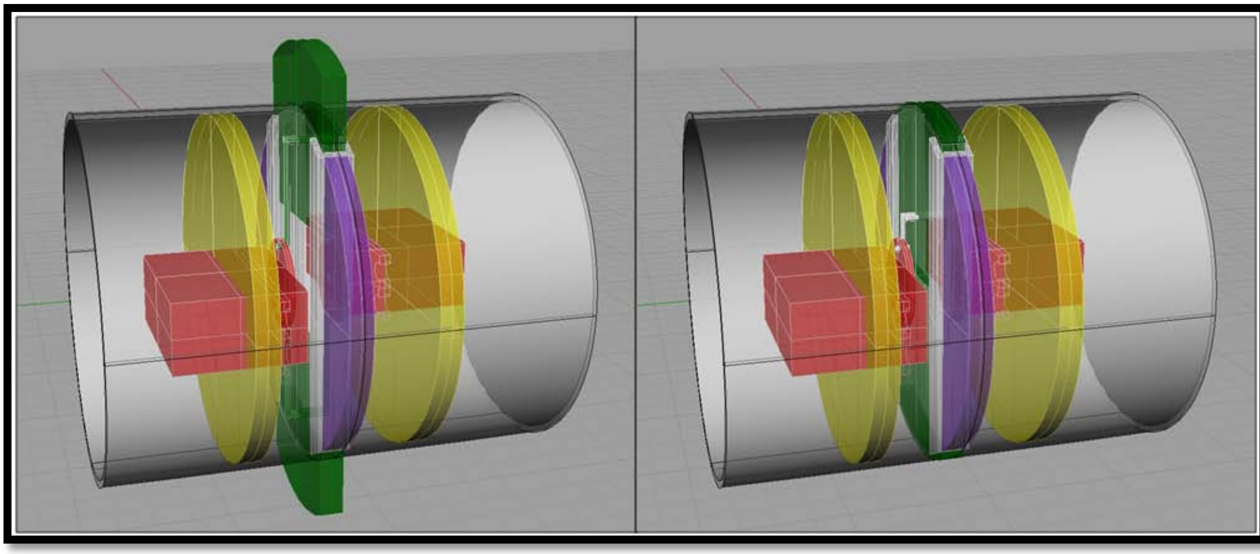
The drogue parachute recovery bay is 16 inches long, of which the upper 4 inches are allocated for the connection to the ebay. This leaves 12 useable inches. The bottom slides over the tube connector between it and the science payload bay. The tube remains hollow for the first 4 inches for recovery harness/drogue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

III.1.a.1e 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.a.1f 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.



Power Management System Concept

III.1.a.1h 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.a.1g 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.

Fin-to-Motor Tube Mounting

III.1.a.1i 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. a.11j 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.

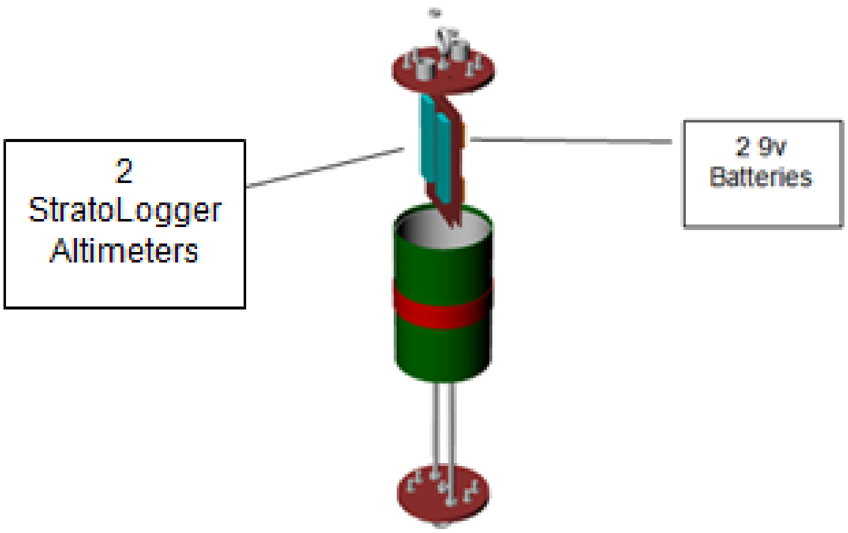
III.1.a.1k Connecting the Components

Four different connection methods are used:

- Permanent connections use West System epoxy.
- Those that need intermittent access use #6, #8, or #10 T-nuts and screws.
- Where T-nuts are not possible, #6 or #8 wood screws are used.

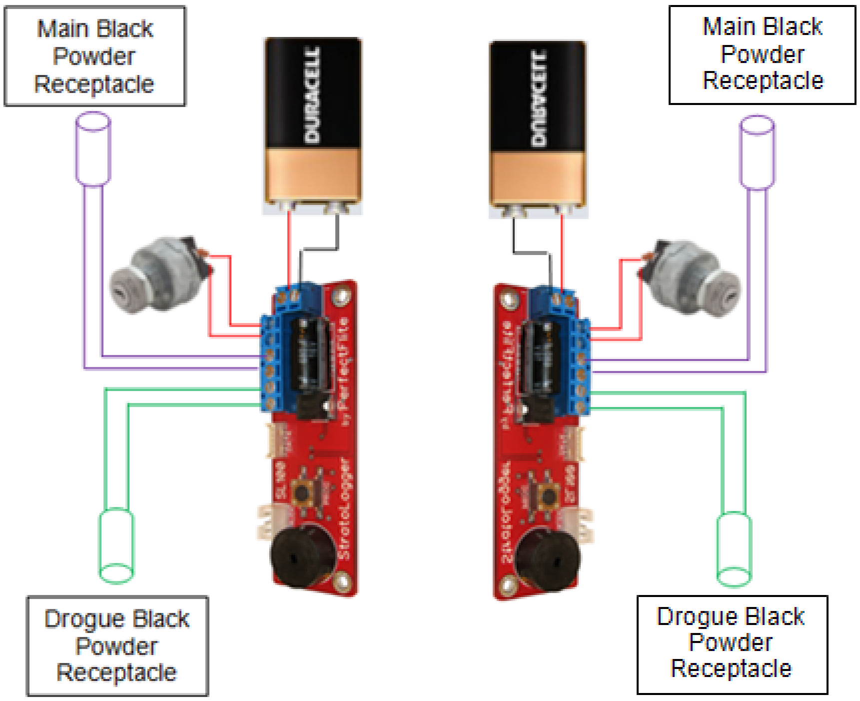
- Temporary connections between the ebay and the two parachute compartments use nylon shear pins. The shear pins prevent the rocket from premature separation due a combination of drag, inertia, and momentum. The shear pins are, however, designed to fail when the black powder ejection charge is ignited.
- Components that undergo extreme forces are connected with ¼” carriage bolts or ¼” threaded rod

III.1.a.2 Recovery System Schematics

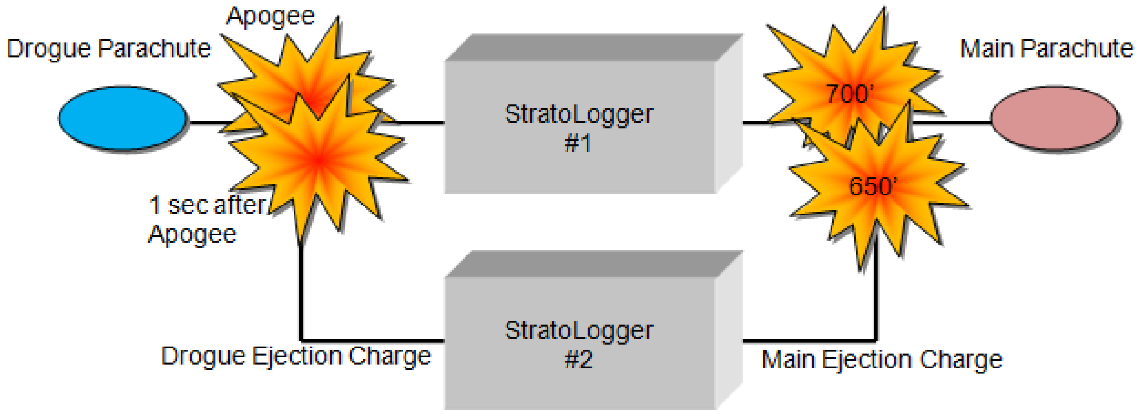


Ebay Layout

Ebay

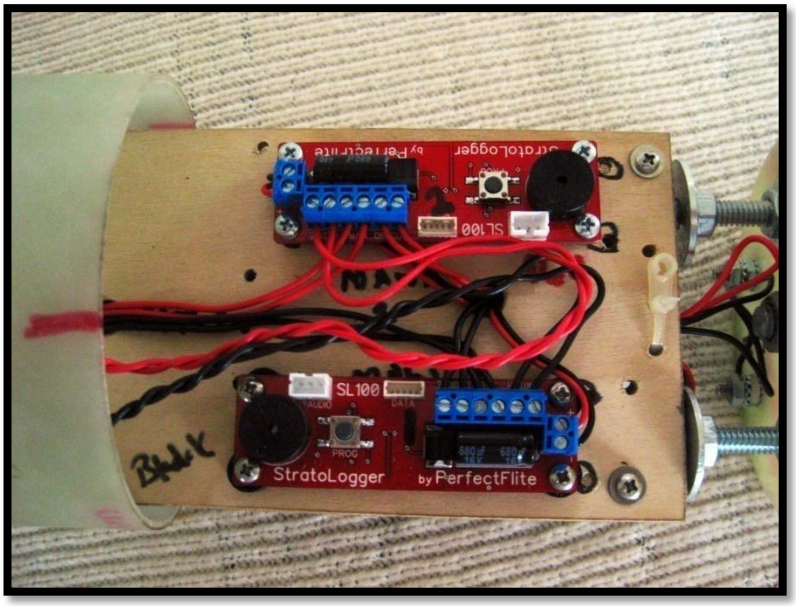


Redundant Altimeter Layout

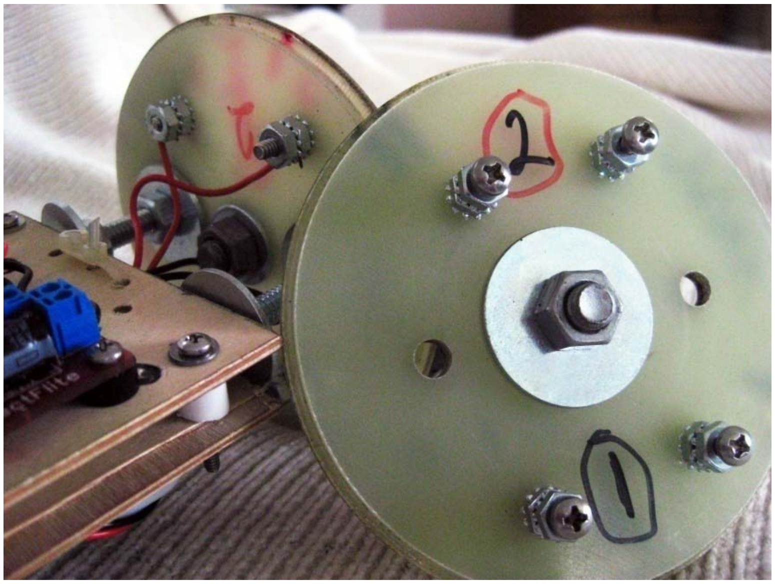


Redundant Dual Deployment Event Sequence

The altimeters are mounted on one side of the first 5-ply 1/8" plywood platform. The platform is mounted with epoxy resin onto two 3/8" tubes that slide over the ¼" threaded rod that holds the ebay ends onto the ebay tube. The batteries are mounted on a second 5-ply 1/8" plywood platform that is bolted with #4 bolts to the first platform. The interior of the ebay is lined with aluminum HVAC tape to shield the altimeters from extraneous RF.



Dual PerfectFlite Stratologger Altimeters



Underside of Ebay Lids showing ejection charge connectors

III.1.b Flight Reliability Confidence

III.1.b.1 Demonstrate that the design can meet 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	Verification Method	Date Verified
Rocket launches as designed	Successful Launches	1/28 2/4
Attain an altitude within .01% of 5280 feet with the power management system	Data analysis from altimeters	
Drogue parachute deploys at apogee	Successful Launches and altimeter data	1/28 2/4
Main parachute deploys at 700 feet above ground level	Data analysis from altimeters	1/28 2/4
Descent rates are within design parameters	Data analysis from altimeters	1/28 2/4
Rocket is recovered with minimal damage and able to be launched again within four hours	Post flight inspection	1/28 2/4
Rocket and electronics sustain no damage from a damp landing	Post flight inspection	1/28 2/4
Picture Success Criteria	**Verification Method**	**Date Verified**
Pictures are oriented within 95% of normal viewing orientation	Post flight inspection	2/4
Science Payload Success Criteria	**Verification Method**	**Date Verified**
85% of the measurement applications	Post flight data analysis	

function as designed		
100% of the data is collected from the functioning science applications	Post flight data analysis	
Power Management System (PMS) Success Criteria	**Verification Method**	**Date Verified**
PMS deploys as programmed	Post flight data analysis	

III.1.b.2 Discuss analysis, and component, functional, and/or static testing.

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.

Three flight tests have proven the ruggedness and reliability of the vehicle. It has survived landings in mud and shallow water. Our moisture mitigation system for the ebay has proven successful.

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	All sensors and microcontrollers function as designed
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.			Flight tested camera satsifactorly
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground	RDAS-Tiny transmitter & receiver	Test	Transmitter and receiver function as

station at the time of completion of all surface operations.			designed. Data successfully transmitted and stored
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 STRATOLOGGER 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 STRATOLOGGER altimeters	Inspection	Completed
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	Designed with Rocksim 9, using drogue at apogee and main at 700 feet	Simulation	Flight tests and post flight data analysis complete and successful

that the kinetic energy is reasonable.			
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	Completed
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	Completed
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	Completed
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	Garmin GPS unit in nose cone	Ground tested complete. Flight test to follow	Completed

tracking device.			
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	Completed
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle	Test flight	Completed
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	Completed
▪ 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		Completed
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	Completed

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

III.1.c Test Data and Analysis, and Component Functional and/or Static Testing

III.1.c.1 Airframe Subsystem

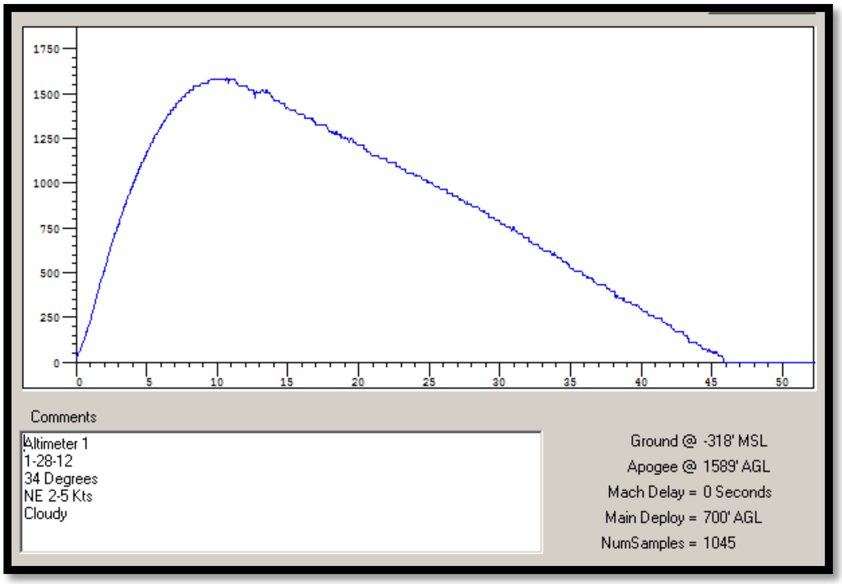
Skybolt has been flown three times, with a CTI J330, an Aerotech K1275 and a CTI J760. All flights were successful in that the launch and recovery were within design parameters.

Test Flight #1 – 1/28/12

Flight Duration: 46.00 seconds
Altitude: 1589 feet

This flight was to test the airframe integrity and the recovery system. The PerfectFlite MAWD #1 performed as programmed whereas MAWD #2 detonated the main charge at 1500’ rather than the 700’ it was programmed to do. Since this was a low power (CTI J330) flight, the drift was well within acceptable limits. Further testing of the #2 took place and we were reasonably certain that #2 would function as designed.

We modified the CD in Rocksim to have the simulation prediction match more closely with actual flight data.



MAWD Data

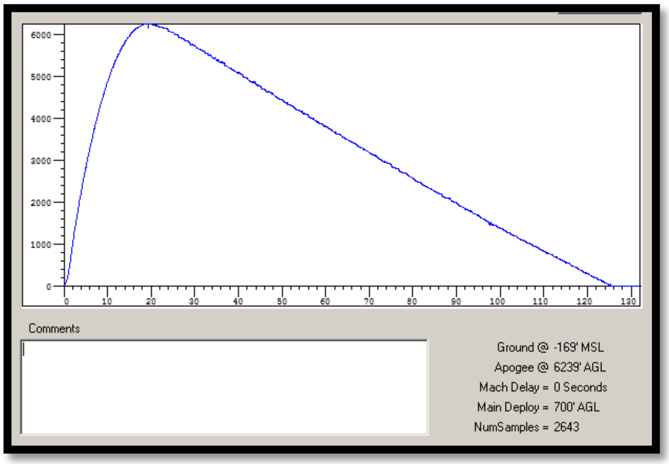
Test Flight #2 – 2/4/12

Flight Duration: 125.05 seconds
Altitude: 6239 feet

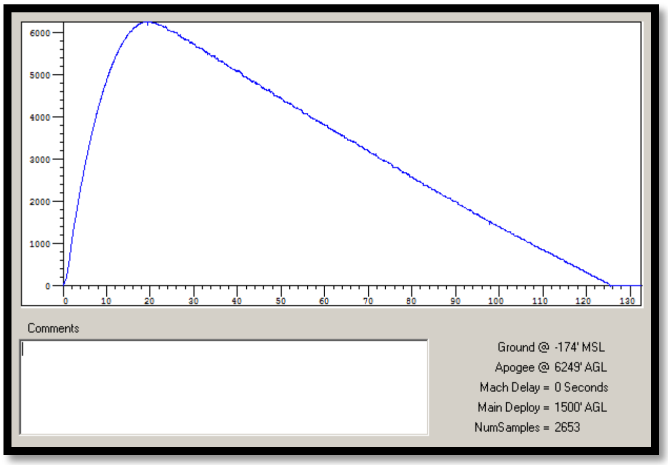
This was a high power test using an Aerotech K1275. This flight tested the airframe with simulated weights using a reload very close to what we'll fly in Huntsville. Again, altimeter #1 performed as programmed (apogee and 700') whereas Altimeter #2 fired its main ejection charge at 1500 feet rather than the 700' that it was programmed for. This resulted in a further than expected drift from the launch area. Both altimeters have been replaced with new PerfectFlite Stratologgers. The remainder of the launch, flight, and recovery went as planned.

After compensating for an interesting weighing error (we weighed the rocket with the loaded motor and then ran the simulation prior to the flight) where our altitude was much higher than predicted, we actually were within 0.05% of our pre-flight data.

As you can see from the above photo, building the rocket from fiberglass and having water resistant components is a necessity because of the amount of standing water and extensive drainage systems in our recovery area.



MAWD Altimeter 1



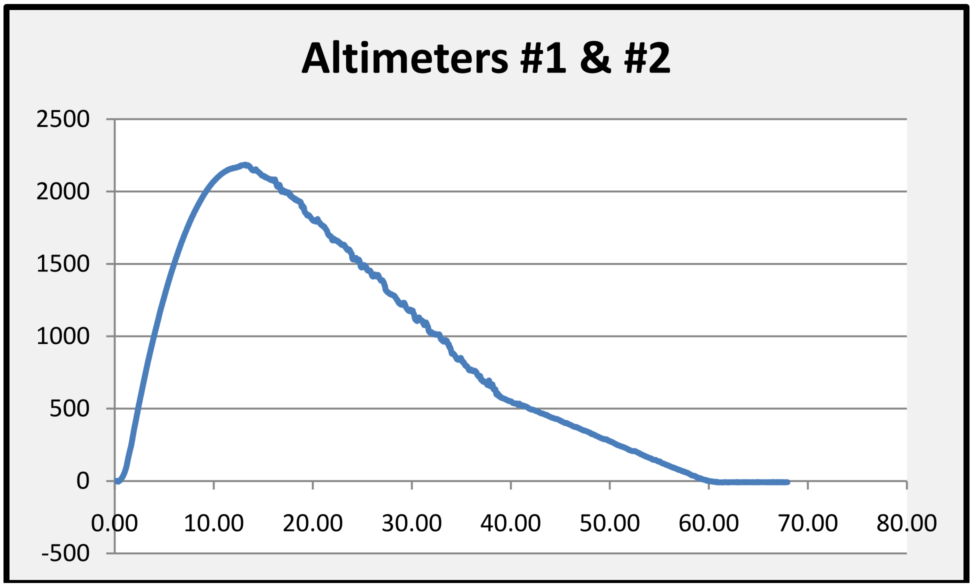
MAWD Altimeter 2

<u>Test Flight #3 – 3/18/12</u>

Flight Duration: 60.00 seconds
Altitude: 2184 feet

This flight was flown with all of the instruments and power management system installed. This was the “fly as built” launch in the configuration that will be flown at Huntsville. We tested the radio transmitter, the UV, the illuminance, the barometric and the temperature sensors, the GPS tracker, as well as the new altimeters. All performed as designed and provided good data to use as a baseline.

The adjusted CD from Test Flight #1 is within .05% of what Rocksim predicts as an altitude.



StratoLogger Data

III.1.c.2 Recovery Subsystem

Test Flight #1 – 1/28/12

The harnesses and parachutes performed as designed. MAWD Altimeter #1 data log showed that the drogue deployed at apogee and the main at 700 feet. MAWD Altimeter #2 data log showed that the drogue deployed at apogee and the main at 1500 feet. The low power flight kept the rocket well within our drift parameters even though it was under the main for the majority of the descent.

Test Flight #2 – 2/4/12

The harnesses and parachutes performed as designed. MAWD Altimeter #1 data log showed that the drogue deployed at apogee and the main at 700 feet. Again, even after testing, MAWD Altimeter #2 data log showed that the drogue deployed at apogee and the main at 1500 feet. The early main deployment at 1500 feet caused the rocket to drift out of our designed drift range. Altimeters have been replaced.

Test Flight #3 – 3/18/12

Everything worked as designed.

III.1.c.3 Science Payload

Radio Frequency Interference Tests

RF Interference Test Results	GPS	900 HMz Transmitter	UV	Illuminance	Barometric Pressure	Temperature	Humidity	Servo 1	Servo 2	Altimeter 1	Altimeter 2	Arduino 1	Arduino 2 w/datalogger
GPS		?	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
900 HMz Transmitter	OK		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
UV	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Illuminance	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Barometric Pressure	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Temperature	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Humidity	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Servo 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Servo 2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Altimeter 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Altimeter 2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Arduino 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Arduino 2 w/datalogger	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

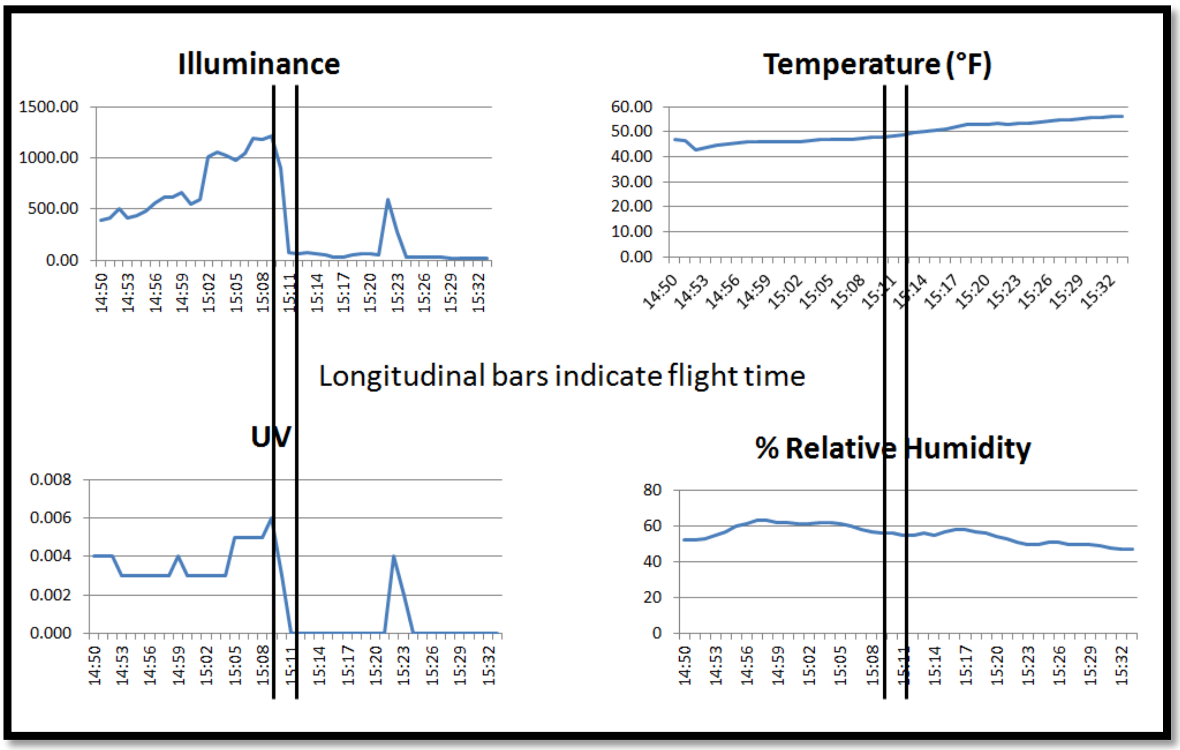
We did a wide variety of component combination testing to ensure there was no interference among the various electronic items, in particular interference with the altimeters and the ejection charge capabilities.

The one questionable area is the GPS tracker. Its response was very intermittent and we are performing additional testing to eliminate the transmitter as the cause of the intermittencies.

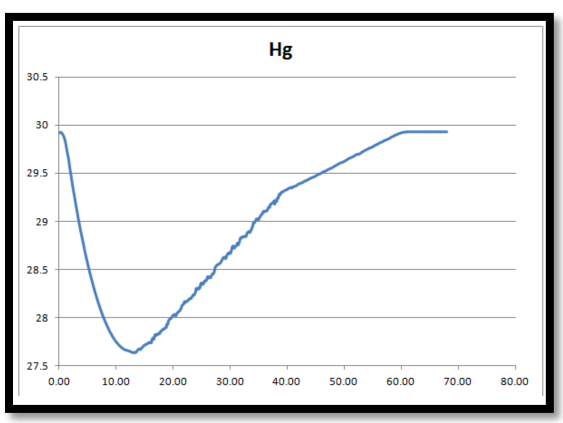
__Individual Components__

Illuminance
UV
Temperature
Humidity
Barometric Pressure

__Test results from Sensors after Test Flight #3__



__Illuminance, Temperature, UV, and Relative Humidity data from test flight__



Flight Success Criteria	Verification Method	Date Verified
Rocket launches as designed	Successful Launches	1/28 2/4 3/18
Attain an altitude within .01% of 5280 feet with the power management system	Data analysis from altimeters	WIP
Drogue parachute deploys at apogee	Successful Launches and altimeter data	1/28 2/4 3/18
Main parachute deploys at 700 feet above ground level	Data analysis from altimeters	1/28 2/4 3/18
Descent rates are within design parameters	Data analysis from altimeters	1/28 2/4 3/18
Rocket is recovered with minimal damage and able to be launched again within four hours	Post flight inspection	1/28 2/4 3/18
Rocket and electronics sustain no damage from a damp landing	Post flight inspection	1/28 2/4 3/18
Picture Success Criteria	**Verification Method**	**Date Verified**
Pictures are oriented within 95% of normal viewing orientation	Post flight inspection	2/4
Science Payload Success Criteria	**Verification Method**	**Date Verified**
85% of the measurement applications function as designed	Post flight data analysis	3/18
100% of the data is collected from the functioning science applications	Post flight data analysis	3/18
Power Management System (PMS) Success Criteria	**Verification Method**	**Date Verified**
PMS deploys as programmed	Post flight data analysis	WIP

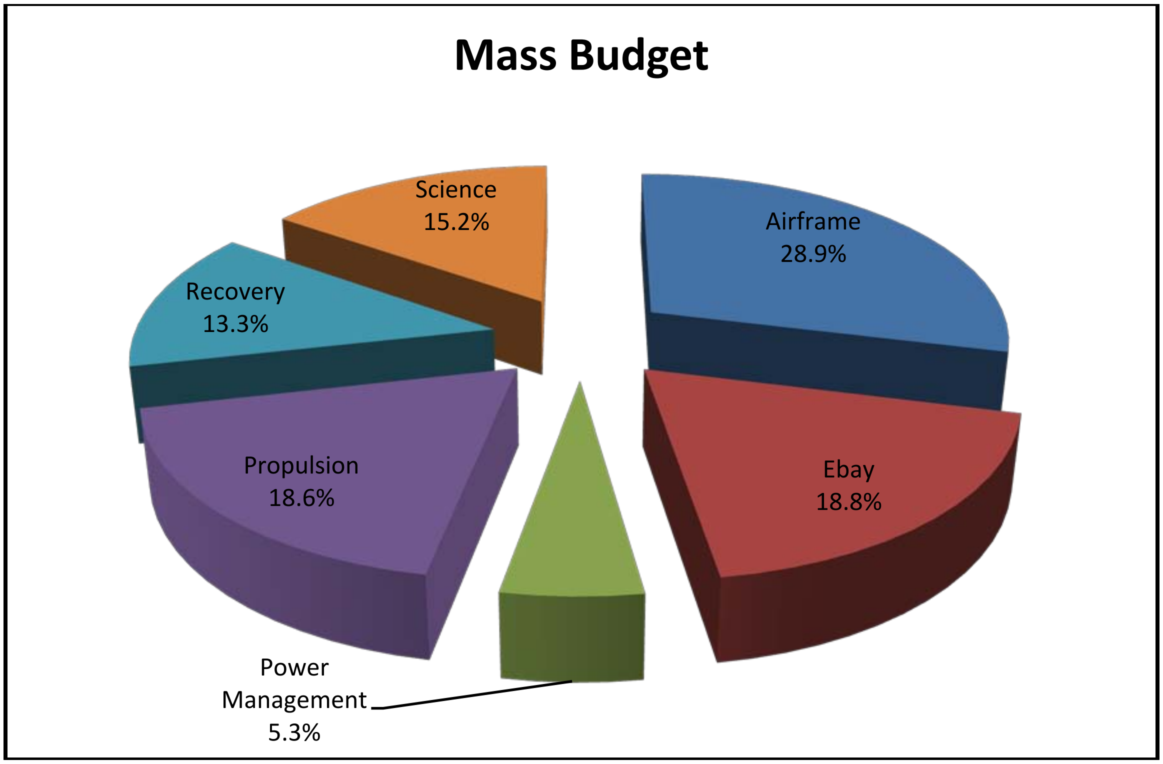
III.1.g Mass Statement

System	Component	Mass (lb)
Airframe	Aft Airframe	0.857
Ebay	Aft Ebay Bulkplate	0.077
Ebay	Aft Ebay Eyebolt	0.125
Propulsion	Aft Motor Mount Center Ring	0.075
Science	Fin Can Bulkplate	0.077
Science	Aft Science Bay Eyebolt	0.125

Ebay	Avionics (altimeters, batteries)	0.750
Recovery	Drogue Parachute	0.375
Recovery	Drogue Recovery Harness	0.980
Ebay	Ebay Coupler	0.478
Ebay	Ebay Ring	0.071
Airframe	Epoxy	0.250
Airframe	Fin Can	1.125
Airframe	Fin Can Eybolt	0.125
Airframe	Fin Can Tube Coupler	0.478
Airframe	Fin Set	0.902
Airframe	Fwd Airframe	1.714
Ebay	Fwd Ebay Bulkplate	0.077
Ebay	Fwd Ebay Eyebolt	0.125
Propulsion	Fwd Motor Mount Center Ring	0.075
Science	Fwd Science Bay Bulkplate	0.077
Science	Fwd Science Bay Eyebolt	0.125
Recovery	GPS Unit	1.000
Recovery	Main Parachute	1.880
Recovery	Main Recovery Harness	1.580
Propulsion	Mid Motor Mount Center Ring	0.075
Airframe	Nose Cone	0.823
Airframe	Nose Cone Bulkplate	0.077
Airframe	Nose Cone Eyebolt	0.125
Airframe	Paint	0.250
Power Management System	Power Management System	1.250
Airframe	Science Bay Tube Coupler	0.478
Science	Science Payload (sensors, transmitter, cameras	1.250
Airframe	Science Payload Bay	0.625
Airframe	Tailcone	0.170
Ebay	Threaded Rod	0.375
	Total Mass=	**19.021**

Mass Table

Each component was weight prior to construction, if it was part of the construction. The subsystems were weighed after construction and the component weights adjusted to account for epoxy and minor alteration due to sanding or shaving.



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 are estimates.

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.e 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 Recovery Subsystem

Two independent PerfectFlite Stratologger altimeters comprise the recovery electronics subsystem. Each altimeter will independently control ejection charges. Altimeter 1 will deploy the drogue at apogee and altimeter 2 will fire its charge 1 second after apogee. Altimeter 1 will deploy the main at 700 feet and altimeter 2 at 650 feet.

III.2a Describe and defend the robustness of as-built and as-tested recovery system.

III.2.a.1 Structural elements (such as bulkheads, harnesses, attachment hardware, etc.)

III.2.a.1a 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 or multiple layers of ¼" aircraft grade birch plywood. The fiberglass 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.

Ebay bulkhead with closed eye-bolt harness connector

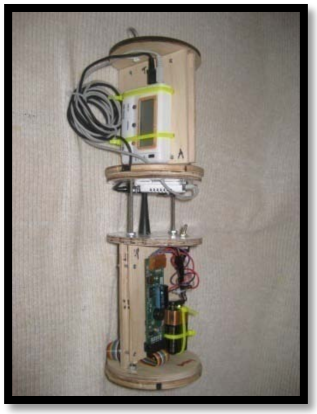
III.2.a.1b Attachment hardware - Connecting the Components

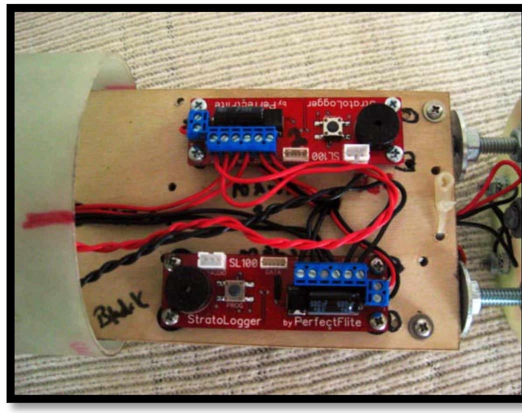
Three different connection methods are used:

- Permanent connections use West System epoxy.
- Those that need intermittent access use #6, #8, or #10 T-nuts and screws.
- 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.2.a.2 Electrical elements (such as altimeters/computers, switches, connectors).





Each electrical component is bolted to its respective 1/8 inch plywood platform. The platforms sandwich a ¼" tube that slides over a threaded rod which in turn, is fastened to one of the bulkheads.

III.2.a.3 Redundancy features

- Dual altimeters
- Three temperature sensors
- Two barometric pressure sensors

III.2.a.4 Parachutes

Rocksim calculated, and we verified by weighing, the weight for the rocket at 19 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. The Skyangle 52" parachute satisfies both the KE and the drift requirements.

Drogue parachute size was calculated based upon descent speed. We select a descent speed between 80 and 90 fps and calculated a drogue size of 18 inches which will keep the rocket within the 2500 foot landing range.

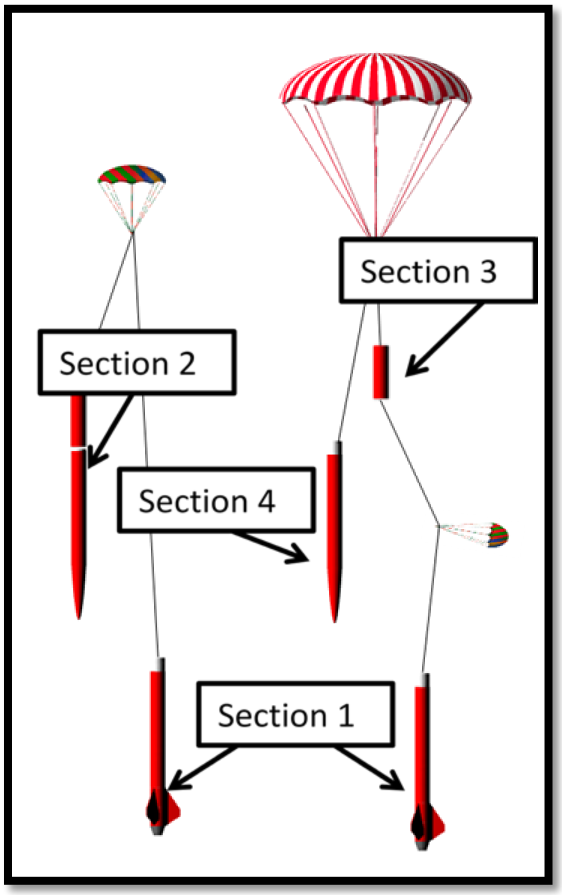
KE=Kinetic Energy
m=mass in pounds
V=velocity in feet per second
S=surface area of parachute in square feet
ρ=air density
C_d = Coefficient of drag

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

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

KE with Drogue

Skybolt has three physical segments; however, there are four combinations of the three sections that occur during the recovery phase.



Recovery Sections

Section	Component	KE
Section 1	Fin Can	1074
	Science Bay	
	Drogue Bay	
Section 2	Ebay	1324
	Main Bay	
	Nose Cone	
Section 3	Ebay	
Section 4	Main Bay	
	Nose Cone	

KE while descending with drogue parachute

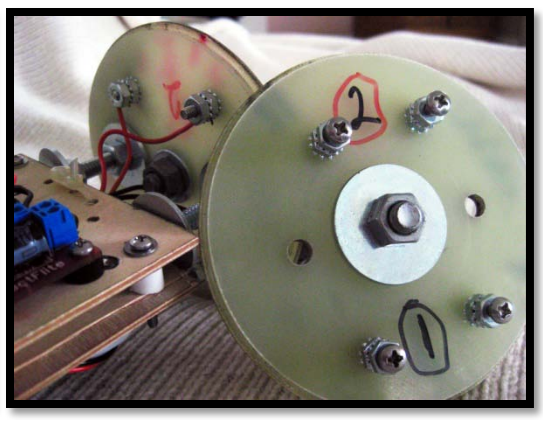
Section	Component	KE
Section 1	Fin Can	56
	Science Bay	
	Drogue Bay	
Section 2	Ebay	
	Main Bay	
	Nose Cone	
Section 3	Ebay	19
Section 4	Main Bay	50
	Nose Cone	

KE at landing under main parachute

The Main parachute was determined by the descent speed and the KE upon landing. The Sky Angle Classic 52 and the LOC 18" parachute satisfies the parachute requirements.

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.

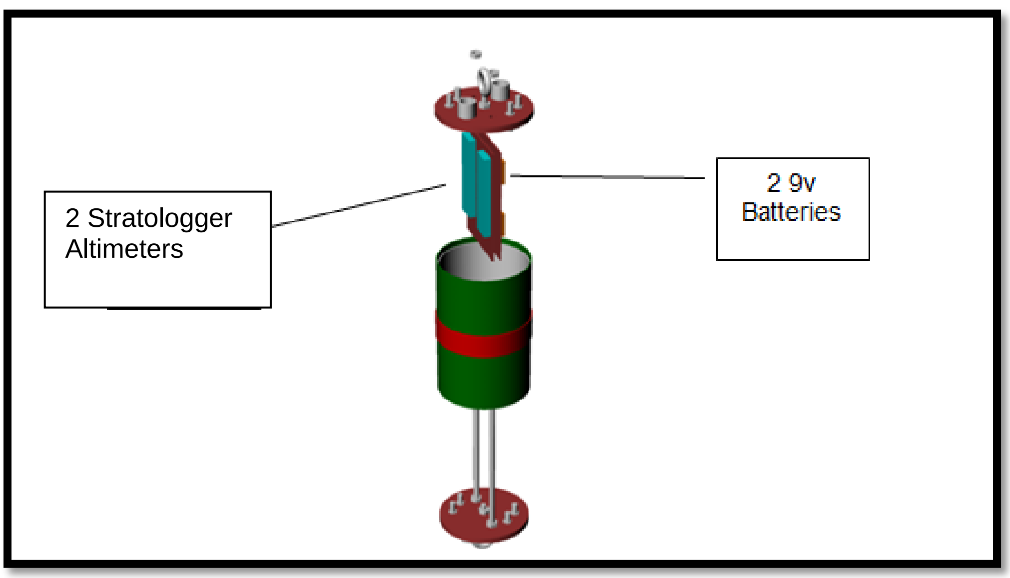
The bulkheads are connected to each other with two ¼" threaded rods.



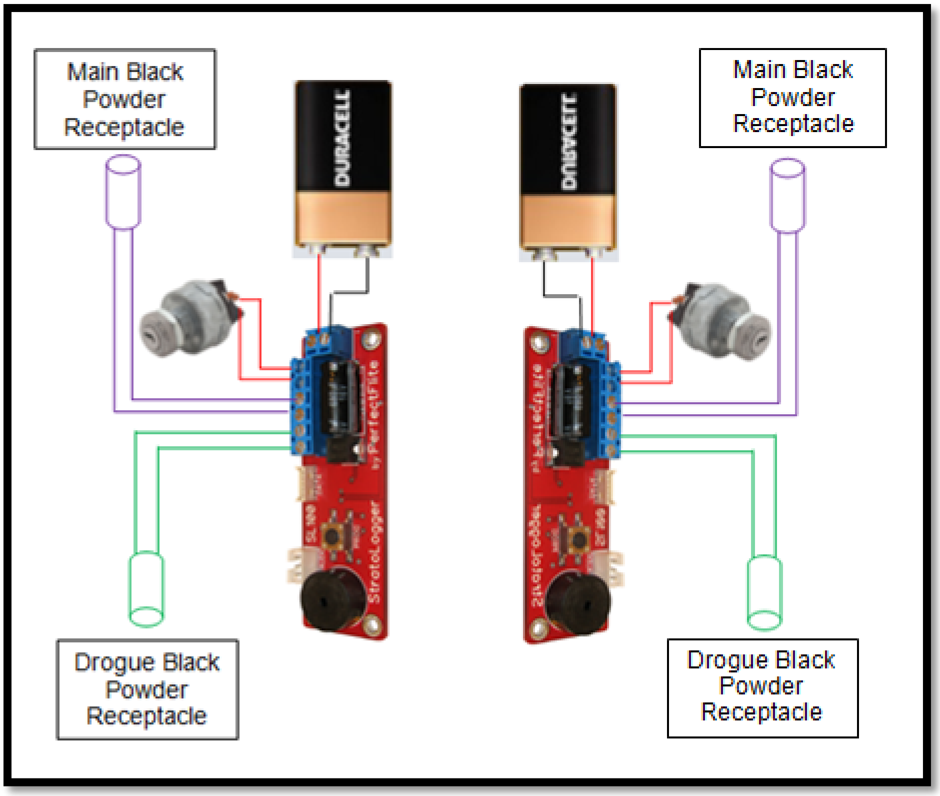
We calculated the stopping forces for our main parachute and the size of the recovery harness. We choose 9/16" tubular nylon which has a tensile strength of 1500 pounds. The mass of Skybolt would be 22.65 pounds and it would be travelling at 93 fps. If Skybolt slowed to a speed of 22 fps within 0.5 seconds, it exerts a force of approximately 400 pounds on the recovery harness, well with the tensile strength of 1500 pounds.

III.2.a.5 Drawings and schematics of the electrical and structural assemblies

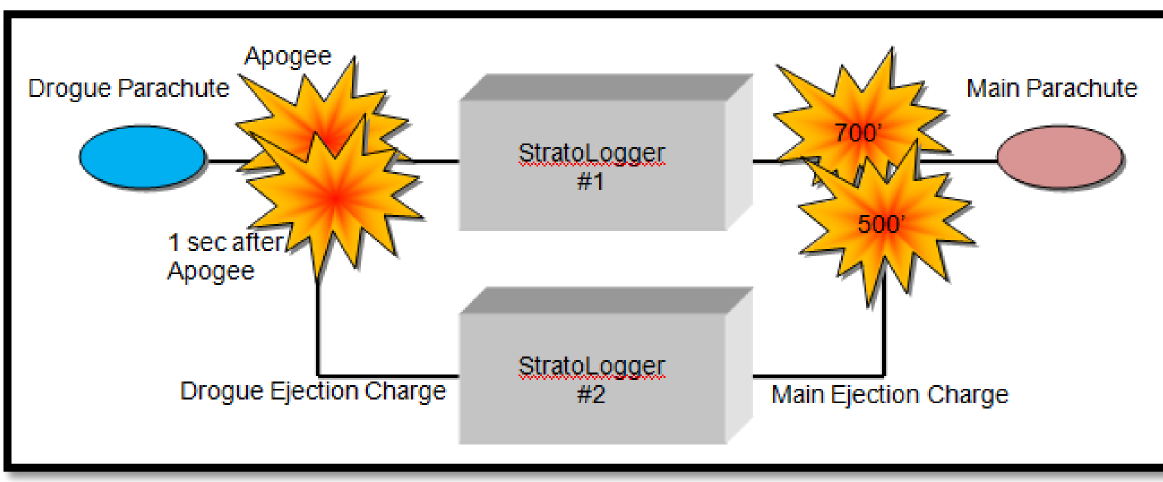
This subsystem consists of the parachute bays and the ebay that contains the avionics that control the parachute deployment. The parachute bays are connected to the ebay using frictional fitting and are secured with nylon #2-56 machine screws that act as shear pins. These screws prevent dynamic separation, 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.



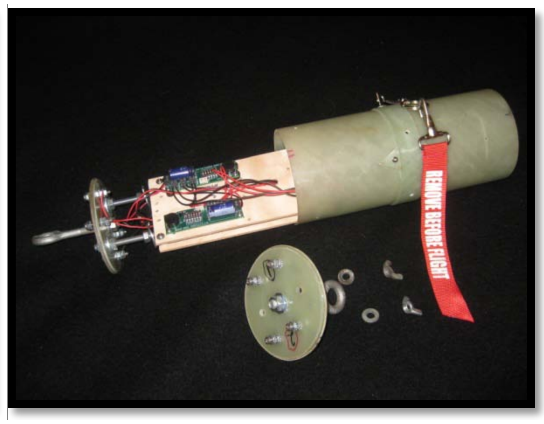
Competition Rocket Ebay



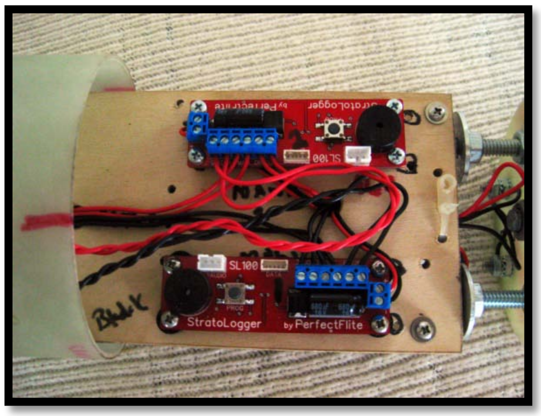
Recovery Avionics, redundant dual deploy

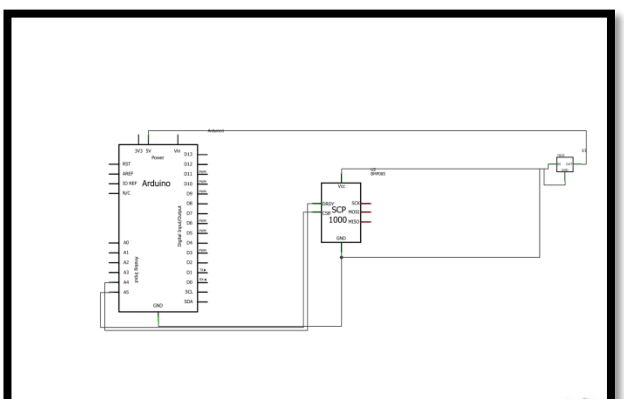


Redundant Dual Deployment System Schematic

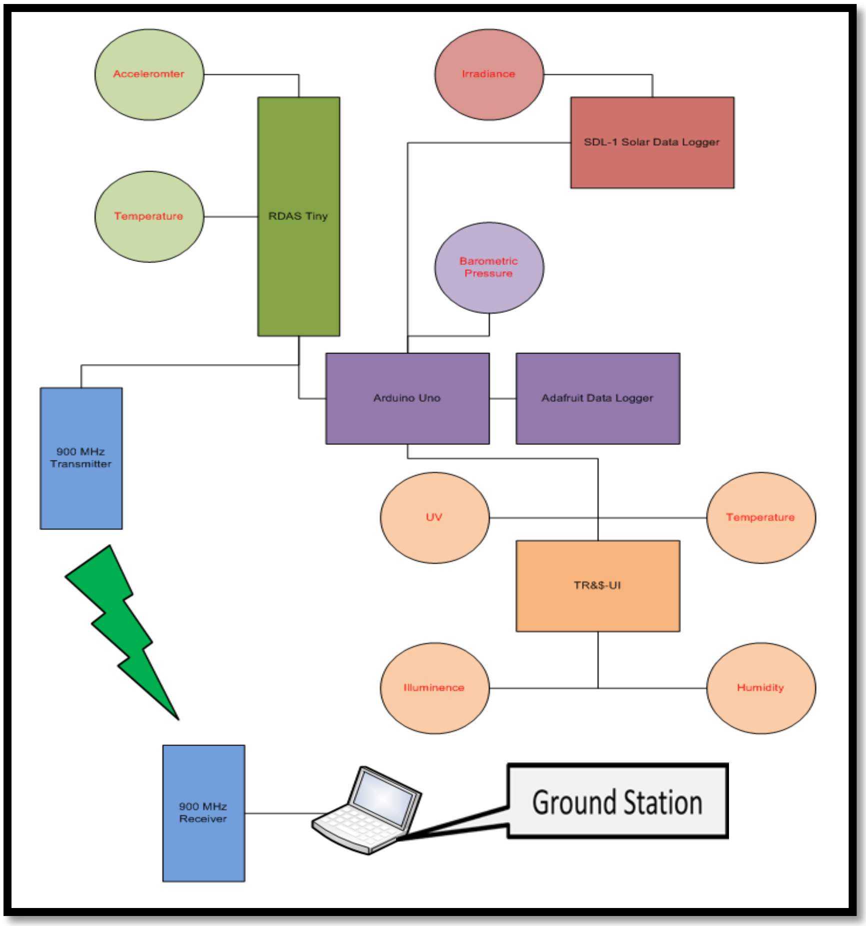


Ebay





Arduino, Barometric Pressure Sensor Schematic



Science Payload Block Diagram

III.2.a.6 Rocket-locating transmitters with a discussion of frequency, wattage, and range.

A Garmin Astro 200 dog tracker is located in the nose cone of Skybolt.

Radio
MURS (Multi-use Radio Service) Frequency:
151.82 MHz
151.88 MHz
151.94 MHz
154.57 MHz
154.60 MHz

Range: Up to 7 miles – line of sight
Output Power: 2 watts

RDAS Telemetry System
10 Hz data rate
8 channels

Range: 2-3 miles – line of sight
Output Power: 50 mW RF

<u>III.2.a.7 Discuss the sensitivity of the recovery system to onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis section.</u>

RF Interference Test Results	GPS	900 HMz Transmitter	UV	Illuminance	Barometric Pressure	Temperature	Humidity	Servo 1	Servo 2	Altimeter 1	Altimeter 2	Arduino 1	Arduino 2 w/datalogger
GPS		?	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
900 HMz Transmitter	OK		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
UV	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Illuminance	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Barometric Pressure	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Temperature	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Humidity	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Servo 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Servo 2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Altimeter 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Altimeter 2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Arduino 1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Arduino 2 w/datalogger	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

We did a wide variety of component combination testing to ensure there was no interference among the various electronic items, in particular interference with the altimeters and the ejection charge capabilities.

The one questionable area is the GPS tracker. Its response was very intermittent and we are performing additional testing to eliminate the transmitter as the cause of the intermittencies.

III.2.b Suitable parachute size for mass, attachment scheme, deployment process, test results with ejection charge and electronics

Black Powder Calculations for Drogue Parachute

Volume =	178.135	in^3
Dia =	4.025	inch
Len =	14	inch
Mass of BP =	3	grams
Pressure =	32.621	psi
Ejection F =	415.071	Lb/f

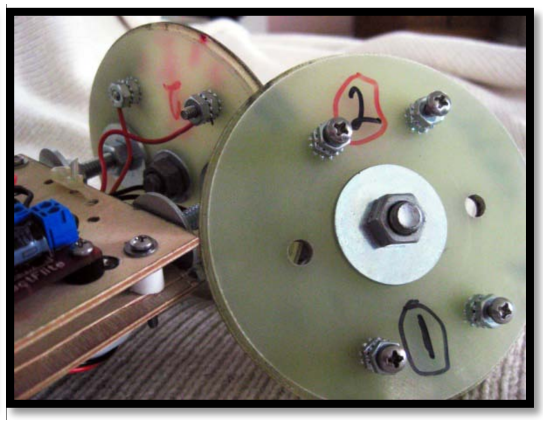
Black Powder Calculations for Main Parachute

Volume =	305.375	in^3
Dia =	4.025	inch
Len =	24	inch
Mass of BP =	5	grams
Pressure =	31.715	psi
Ejection F =	403.541	Lb/f

The Main parachute was determined by the descent speed and the KE upon landing. The Sky Angle Classic 52 and the LOC 18" parachute satisfies the parachute requirements.

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.

The bulkheads are connected to each other with two ¼" threaded rods.



We calculated 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 93 fps. If Skybolt slowed to a speed of 22 fps within 0.5 seconds, it exerts a force of approximately 400 pounds on the recovery harness, well with the tensile strength of 1500 pounds.

III.2.c Safety and failure analysis. Include table with failure modes, causes, effects, and risk mitigations.

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.

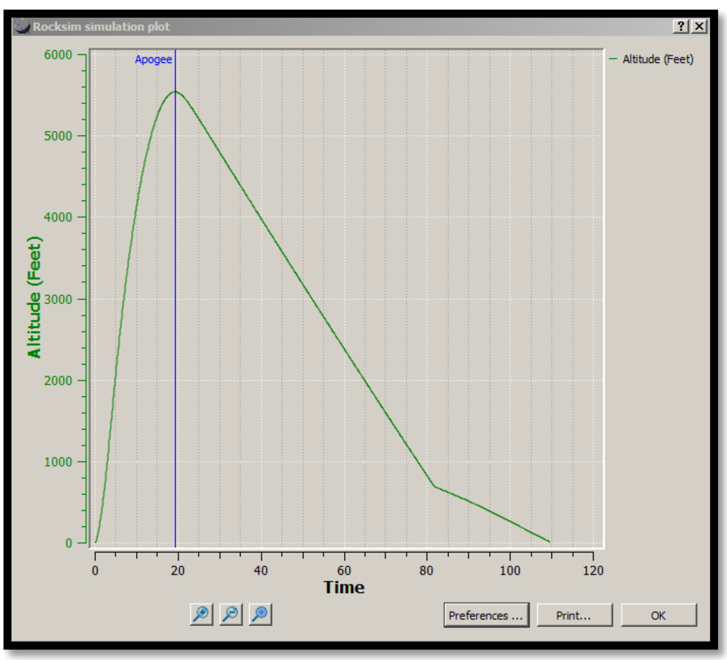
III.3 Mission Performance Prediction

III.3a 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.

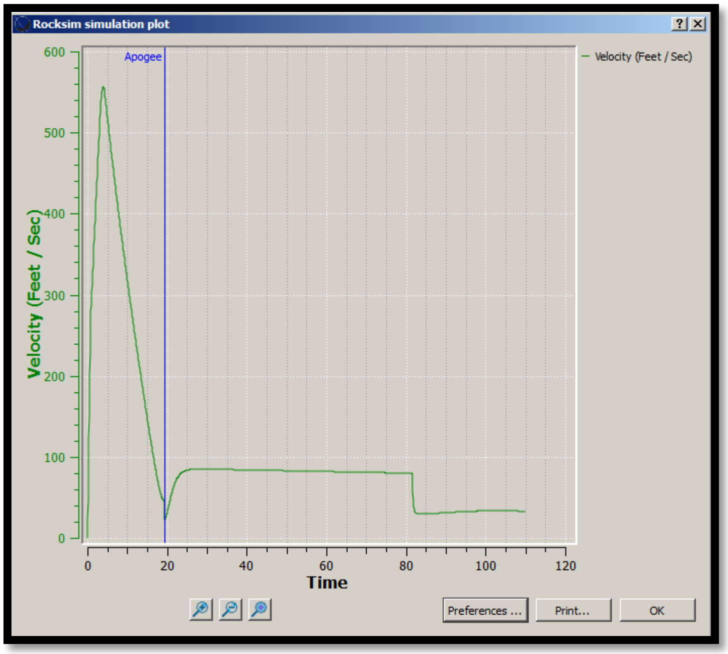
III.3.b Provide flight profile simulations, altitude predictions with real vehicle data, component weights, and actual motor thrust curve. Include real values with optimized design for altitude. Include sensitivities.

III.3.b.1 Flight Simulations from Rocksim 9



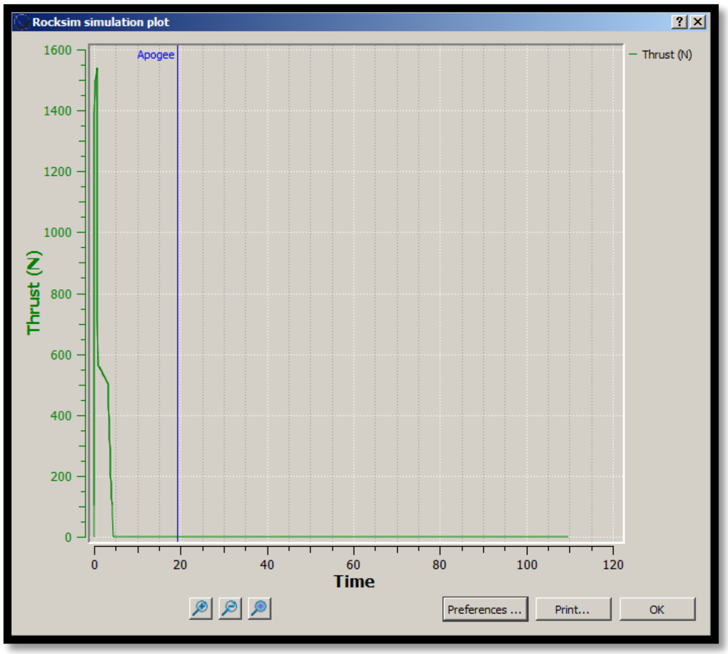
Altitude

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.

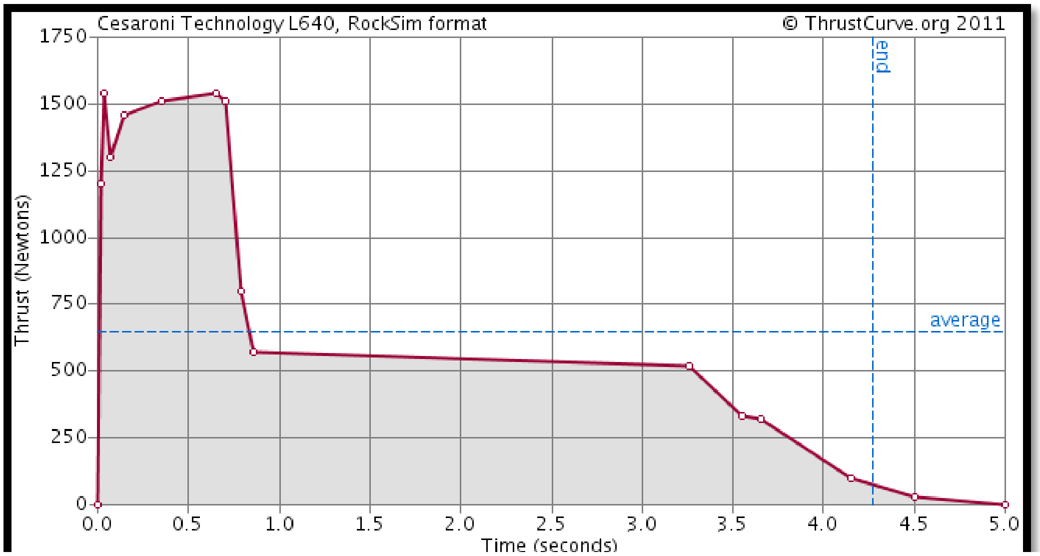


Velocity

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.



Simulated CTI L640-DT Motor Thrust Curve



CTI L640-DT Motor Thrust Curve

III.3.b.2 Test Flight Data

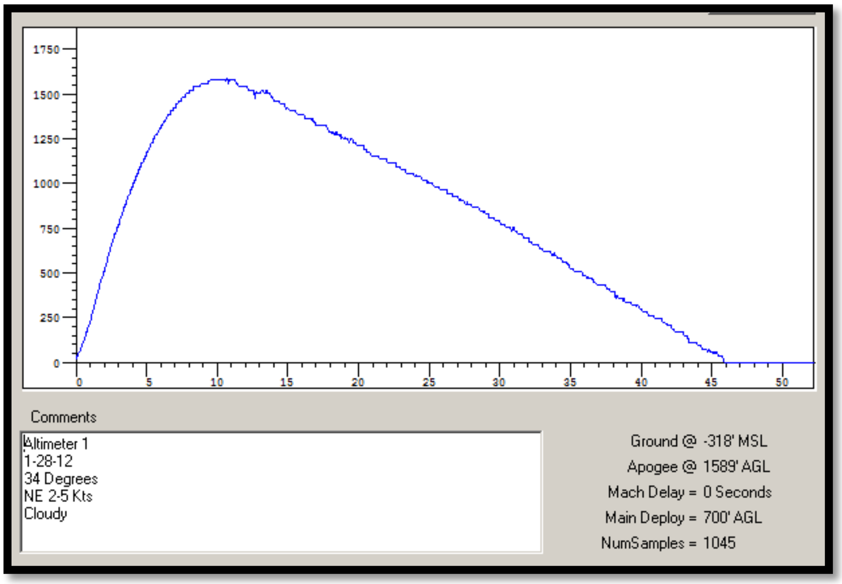
	Test #1		Test #2		Test #3	
Weather	28-Jan		4-Feb		18-Mar	
Ceiling	5500		Clear		4000	
Temperature	38		58		46	
Wind	NE 10-15		NE 10-15		SW 3-6 kts	
Motor Reload	CTI J330		AeroTech K1275		CTI J760	
Altimeter Data	MAWD 1	MAWD 2	MAWD 1	MAWD 2	Stratologger 1	Stratologger 2
Altitude	1589	1576	6239	6249	2183	2184
Main Deploy	700	1500	700	1500	700	650
Flight Duration	45.9	45.95	125.05	125.3	60	60

	Predicted Altitudes	**Actual Altitudes:**
Test Flight #1	2100’	1583
Test Flight #2	4388’	6244
Test Flight #3	2188’	2183

Flight #2 had the CD adjusted; however, as mentioned previously, we made a weighing error and the rocket was 6 pounds lighter than the simulation calculated because we entered the weight into Rocksim that included the motor’s weight.

III.3.c Thoroughness and validity of analysis, drag assessment, and scale modeling results. Compare analyses and simulations to measured values from ground and/or flight tests. Discuss how the predictive analyses and simulation have been made more accurate by test and flight data.

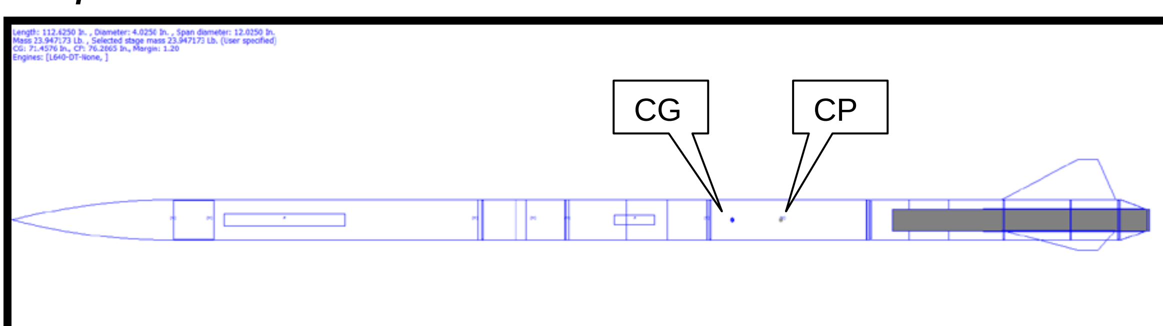
After Test Flight #1 on 1/28/12, we analyzed the altimeter data and adjusted the CD and re-ran the simulations until the predicted altitude matched the actual altitude.



MAWD #1 Altimeter Data

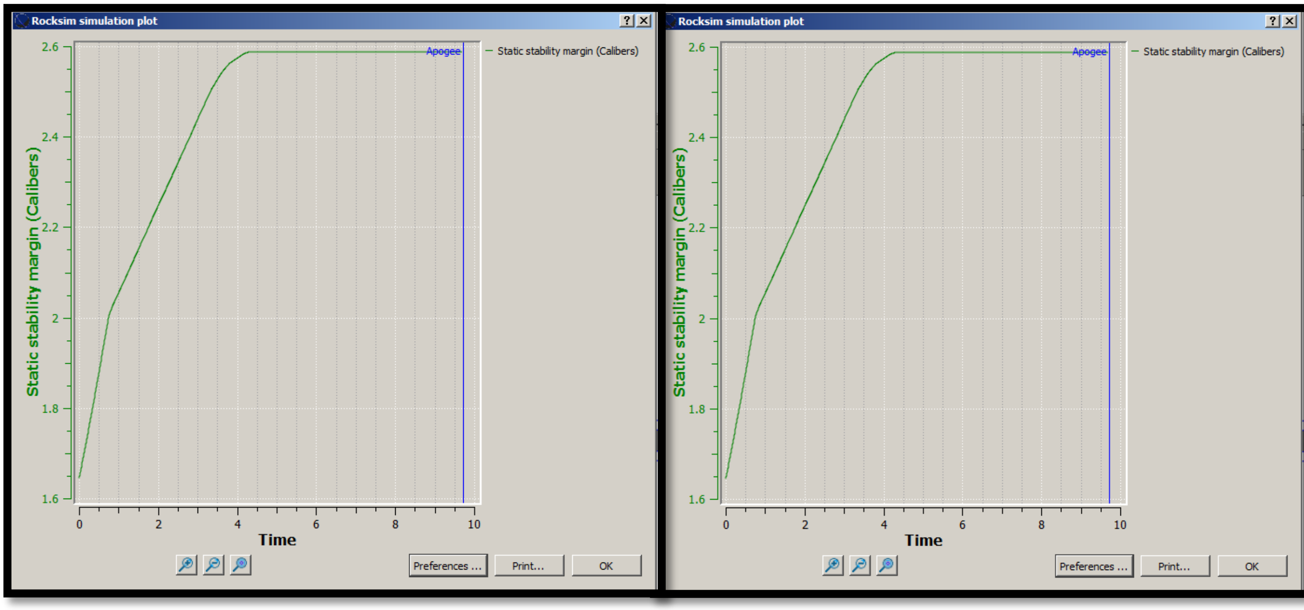
We adjusted the CD upwards to 0.85. On subsequent flights, the predicted and actual altitudes were much closer.

III.3.d Provide stability margin, with actual CP and CG relationship and locations. Include dimensional moment diagram or derivation of values with points indicated on vehicle. Include sensitivities.



Rocksim CP=76.29 CG=71.46, and Stability Margin at 1.2 with motor loaded

Center of Gravity	71.46	Center of Pressure	76.29
Static Stability	1.2 w/CTI L640 motor		

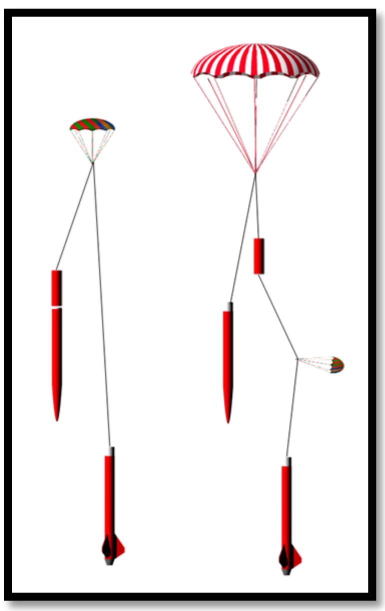


III.3.d Kinetic Energy

Rocksim Stability Graphs with air brakes retracted (L) and extended (R)

No discernible differences in stability between having the air brakes retracted or extended.

III.3.e Discuss the management of kinetic energy through the various phases of the mission, with special attention to landing.



Skybolt Recovery Sections

Section	Component	KE
Section 1	Fin Can	1074
	Science Bay	
	Drogue Bay	
Section 2	Ebay	1324
	Main Bay	
	Nose Cone	
Section 3	Ebay	
Section 4	Main Bay	
	Nose Cone	

KE while descending with drogue parachute

Section	Component	KE
Section 1	Fin Can	56
	Science Bay	
	Drogue Bay	
Section 2	Ebay	
	Main Bay	
	Nose Cone	
Section 3	Ebay	19
Section 4	Main Bay	50
	Nose Cone	

KE at landing under main parachute

Skybolt weights 23.95 pounds with a CTI L640 DT reload. Rocksim calculates the descent mass at 20.74 pounds With this weight and the USLI requirement of a landing force of 75 lb/fps^{2,} the above charts were calculated for each of the section. We are well within the 75 lb/fps^{2} requirement.

III.3.f Discuss the altitude of the launch vehicle and the drift of each independent section of the launch vehicle or winds of 0-, 5-, 10-, 15-, and 20-mph.

Wind from the left

- (-) - Guide rail tilt or landing to the left of the launch pad
- (+) - Guide rail tilt or landing to the right of the launch pad
-

Drift Distance from Launch Pad				
Guide Rail Angle	Wind Speed (Kts)			
	0-2	3-7	8-14	15-25
0	224	450	729	2276
5	1134	1614	1656	2311
10	2058	2457	2673	4166
15	2640	2888	4108	4079
20	3433	3794	4543	4817
-5	-644	-185	71	1228
-10	-1583	-1300	-912	71
-15	-2585	-2310	-1397	-1113
-20	-3266	-3011	-2344	-1636

Altitude				
Guide Rail Angle	Wind Speed (Kts)			
	0-2	3-7	8-14	15-25
0	5537	5530	5506	5487
5	5491	5497	5525	5517
10	5340	5375	5423	5455
15	5128	5179	4978	5363
20	4788	4882	4892	5112
-5	5485	5470	5425	5330
-10	5324	5270	5222	5052
-15	5073	5000	4992	4781
-20	4761	4670	4548	4357

III.4 Verification (Vehicle)

Appendix C details each requirement from pages 5, 6, 7, and 8, and how that requirement has been satisfied and by what method the requirement was verified.

III.5 Safety and Environment (Vehicle)

III.5.a Safety and Mission Assurance Analysis

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.

The biggest danger, at this point, is damage from shipping and transporting the rocket. It will be out of our hands and control during the shipping process:

1. Rocket components are lost or damaged during transport to launch site.
2. Wire connections in the rocket loosen during transport or flight.
3. Avionics are broken during the transport, storage, or flight.
4. Drogue and main parachutes are packed too tightly to release.
5. Static discharge to electronics.

We’ve experienced the “too-tightly-packed” parachute and are aware of the possibility.

Electronics are an interesting area for us. We’ve been very careful in the construction and testing; however, the electronics are the least robust of the entire system.

III.5.b Personnel Hazards and Hazard Mitigation

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.
Motors and Black Powder	Harm to team members (possible hospitalization).	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..
Launch Operations	Harm to team members (possible hospitalization).	1. Safety briefing prior to flight operations. 2. RSO matins an alert demeanor and on the lookout for safety violations

<u>III.5.c Environmental Concerns that Remain.</u>

Launch Operations

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.

Painting

1. Proper waste disposal
2. Adequate ventilation while painting
3. Appropriate personal safety equipment

III.6 Payload Integration

III.6.a Integration with Launch Vehicle

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.

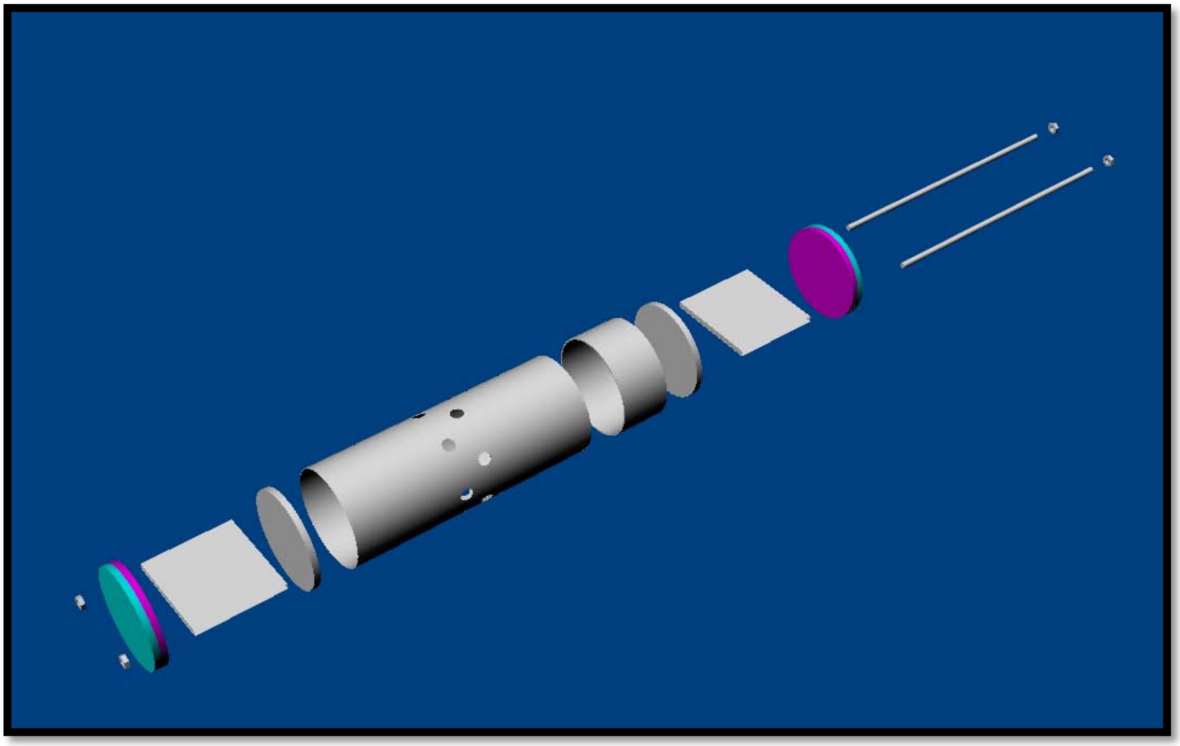
III.6.b Element Compatibility

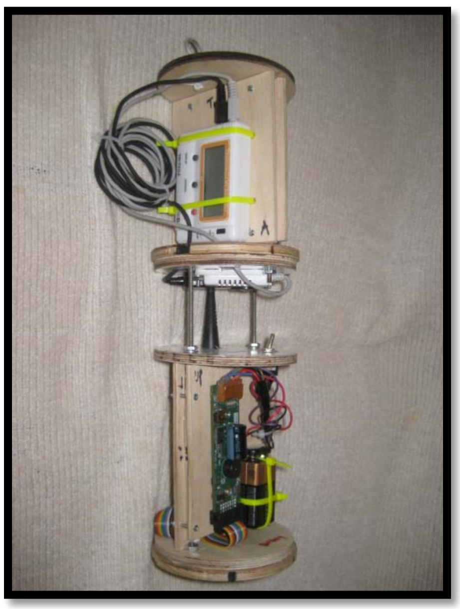
Each experiment is self-contained and independent of any other experiment. We designed them in this fashion to give more students an opportunity to be involved in our project and to make the installation more flexible and it is easier to inspect and install several smaller devices rather than a larger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

III.6.c Payload Housing Integrity

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 at either end. The couplers are bolted to the science payload bay, the drogue bay, and the fin can with 10-24 T-nuts and screws and a ¼" 5 ½" long threaded rod, washers and nuts.





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

IV) Payload Criteria

IV.1 Experiment Concept

IV.1.a Creativity and Originality

Essentially, we have two projects happening with this rocket; 1) the SMD atmospheric project, and, 2) the power management project. 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.1.b Uniqueness or Significance

These two projects are both unique and significant in that NWIC is essentially a two-year non-engineering school that is developing a cadre of students. These students, both returning and new, started out with not much interest in math or science and now they realize that both math and science are not only useful but can be applied to fun activities.

The atmospheric project will involve other students from the Environmental science program with the data obtained from our launches.

IV.2 Science Value

<u>Atmospheric Project</u>: 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.

The objective of the atmospheric project 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. We want to advance our developing skills in sensor data collection, micro-controller programming, and systems integration with this project.

<u>Power Management Project</u>: We wanted to branch out into an engineering type project to see what we could accomplish. As a result, we are attempting a power management system to give us more control of the rocket's flight to its altitude target.

The objective of the power management project is to see if we can put into practice ideas that involve engineering and construction skills beyond rocket construction and launching.

IV.2.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. We are using a combination of off-the-shelf products and home-built items and combining them into a functional system.

The second objective will develop our analytical, programming, engineering, and construction skills. Our team is composed of primarily 2-year students seeking direct transfer degrees with plans to attend a four-year university in such fields as education, humanities, science. The non-emphasis of science and math skills has been both a detriment and boon. A detriment in that nearly everything we do has to be learned from beginning levels; a boon in that we are not hamstrung by "conventional" solutions or attitudes toward the issues that we face.

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.)*

Imagination and the resultant ideas often meet challenges in the execution. This is where the USLI project and rocket program has greatly benefited NWIC students.

IV.2.b Payload Success Criteria

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

Power Management Success Criteria

- Velocity Reduction System deploys at the appropriate time and speed
- Microcontroller performs as programmed
- Mechanical system works as designed

- Target altitude reached

IV.2.c Experimental Logic, Approach, and Investigation Method

SkyWalkers' 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.2.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.

We have some concerns, brought to our attention by the USLI officials about electronic interference among the various components. Therefore we established a thorough testing process that looked at each of the components acting individually and in the multiple combinations with the other components to test for potential interference, particularly with the altimeters. Altimeter interference is a safety issue (early ejection charge detonation or non ejection charge detonation) whereas interference among the other components could result in data loss or corruption which would not be a safety issue.

IV.2.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.2.f 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.

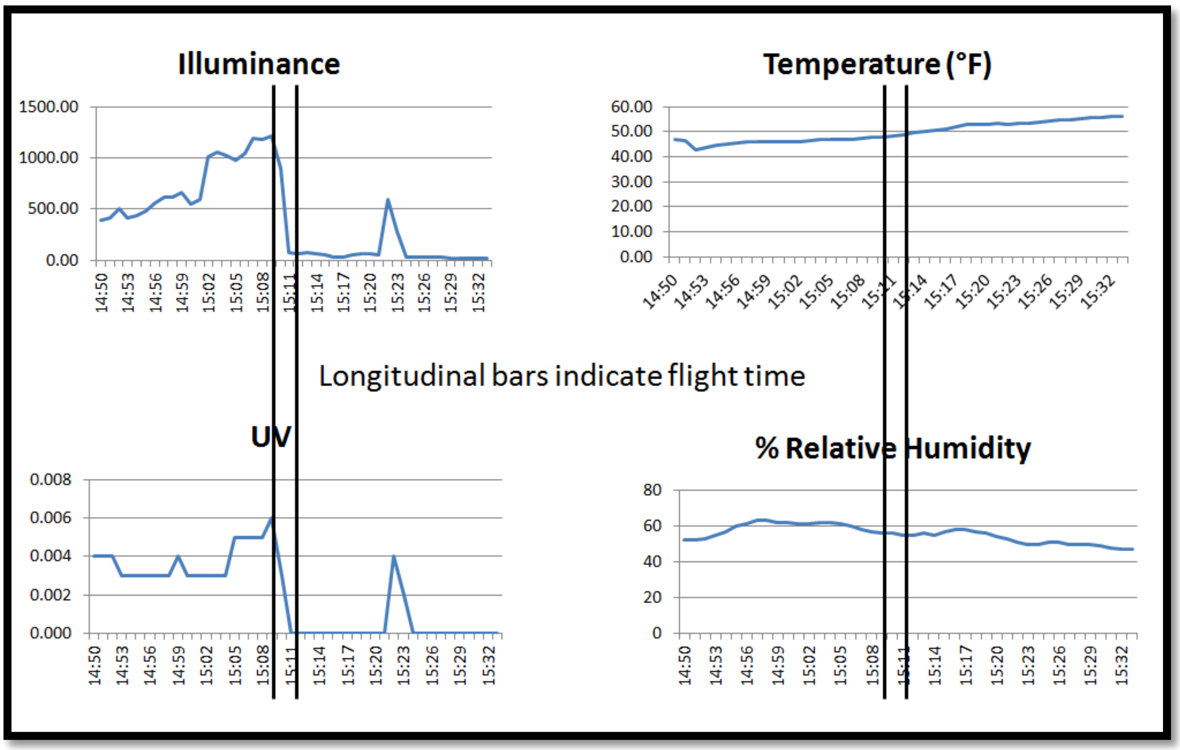
A typical test session follows this order:

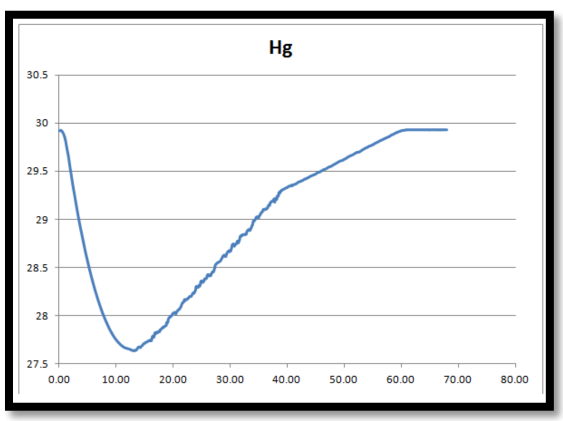
- Test battery voltages
- Power up the system
- Gather data for a set amount of time
- Power down the system
- Analyze the data

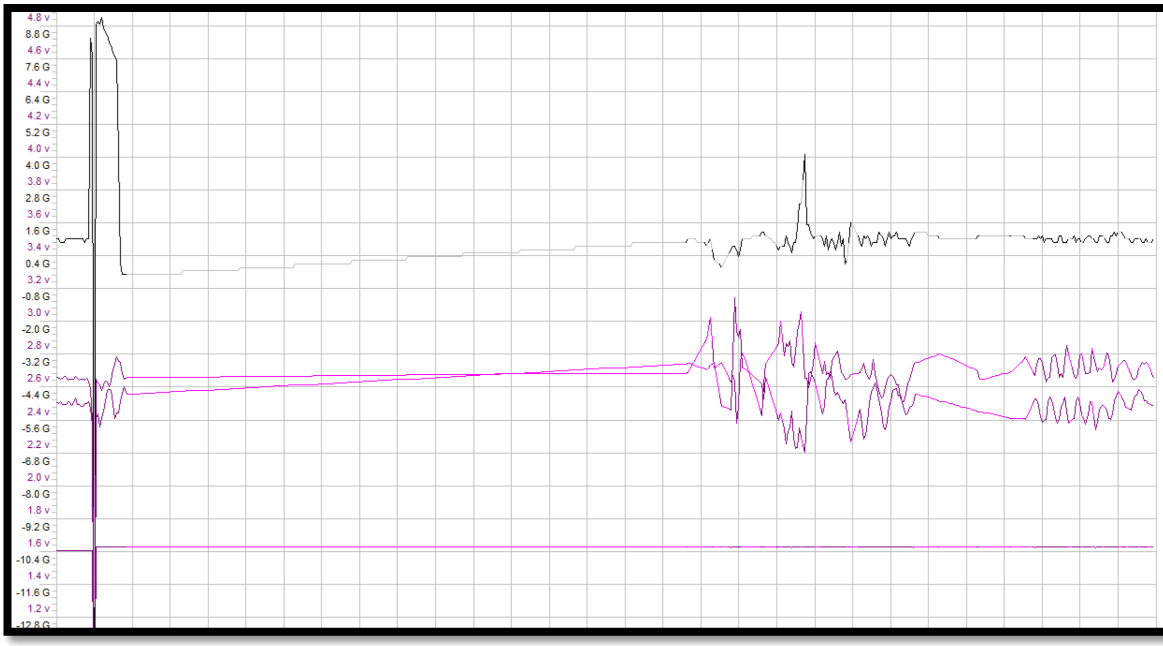
- Trouble shoot mechanical, electrical and/or programming issues.

We have had one test flight (#3) with the full set of instruments. The following is that data from that flight:

IV.2.f.1 Data from Test Flight #3







Raw data received at ground station from transmitter

IV.3 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

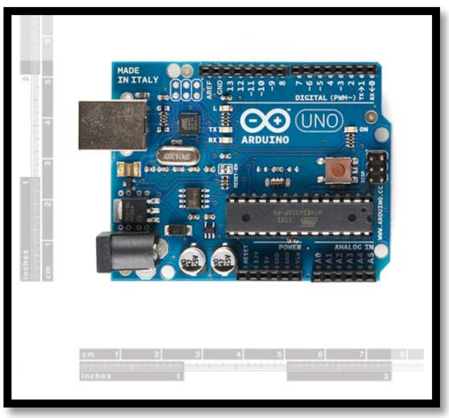
The measurements shall be made at least every 5 seconds during descent and every 60 seconds after landing. Furthermore, surface data collection operations will terminate 10 minutes after landing. Data from the payload shall be stored onboard and transmitted to the ground station after completion of surface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

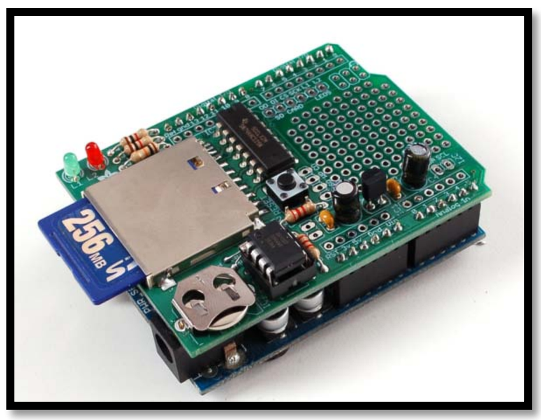
The secondary mission requires recording at least two pictures during descent and three after landing. The pictures need to portray the sky toward the top of the frame and the ground toward the bottom of the frame.

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.

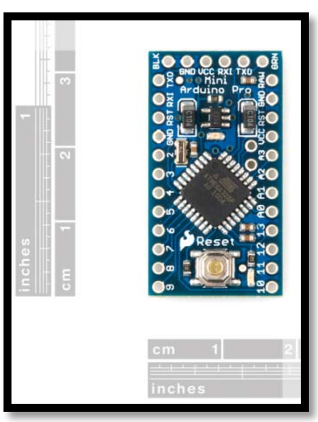
The software used for the payload will be developed using the Arduino Development Environment. The two primary purposes of the software aspect of the payload will be data acquisition and servo control for the power management system. The Arduino software will also tag all of the data and video with time 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.

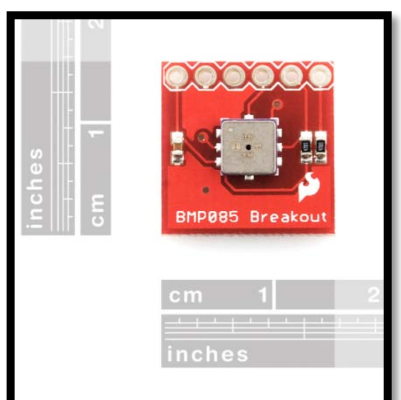




Arduino Uno

Adafruit Data Logger installed on Uno

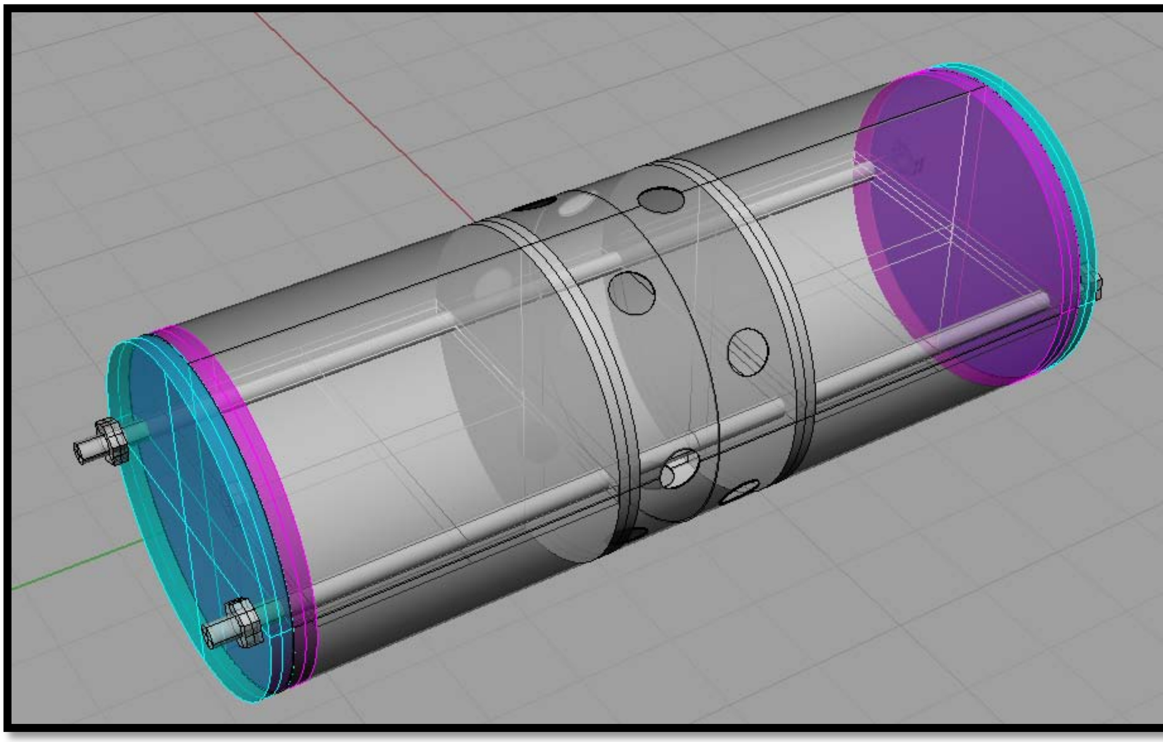




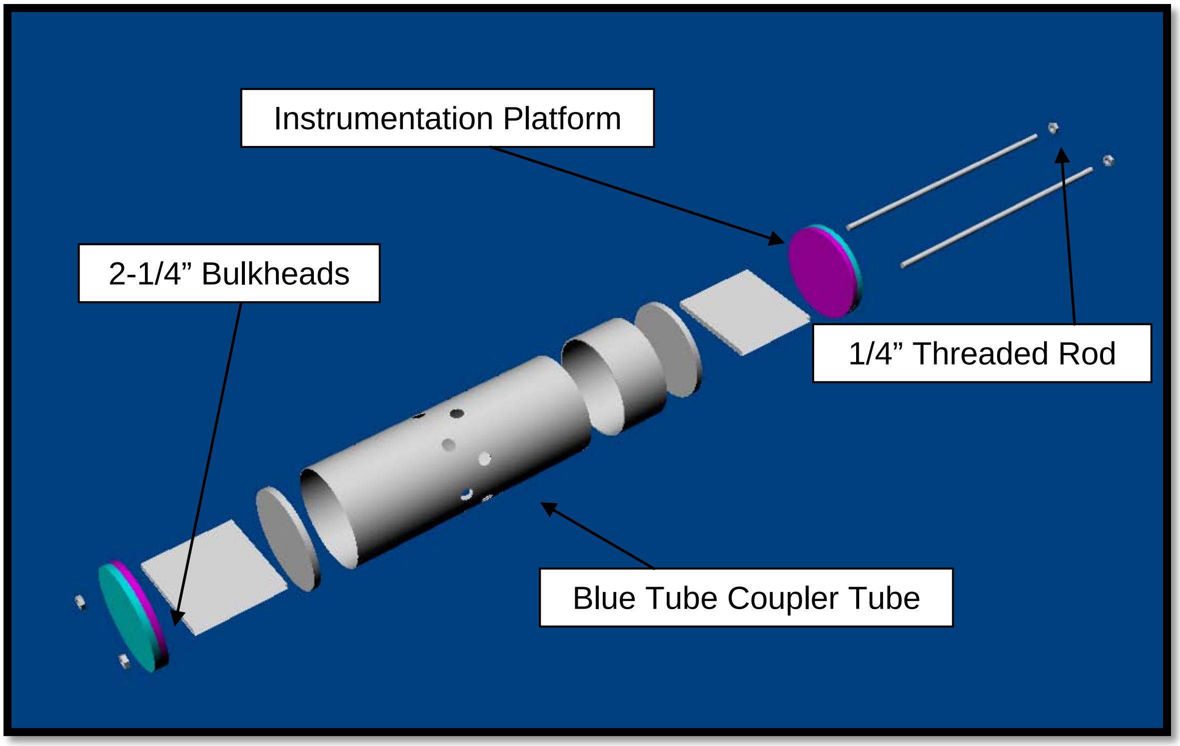
Arduino Pro Mini

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.



Science Payload Bay



Science Payload Bay – exploded

IV.3.a System’s Function

IV.3.a.1 Barometric Pressure

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

IV.3.a.2 Atmospheric Temperature

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

IV.3.a.3 Relative Humidity

The TR-74Ui 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.3.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.3.a.5 Ultraviolet Radiation

The TR-74Ui 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.

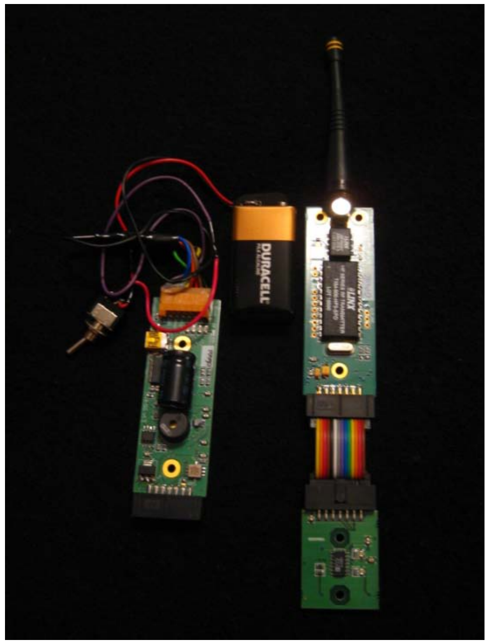
IV.3.a.6 Photography

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.

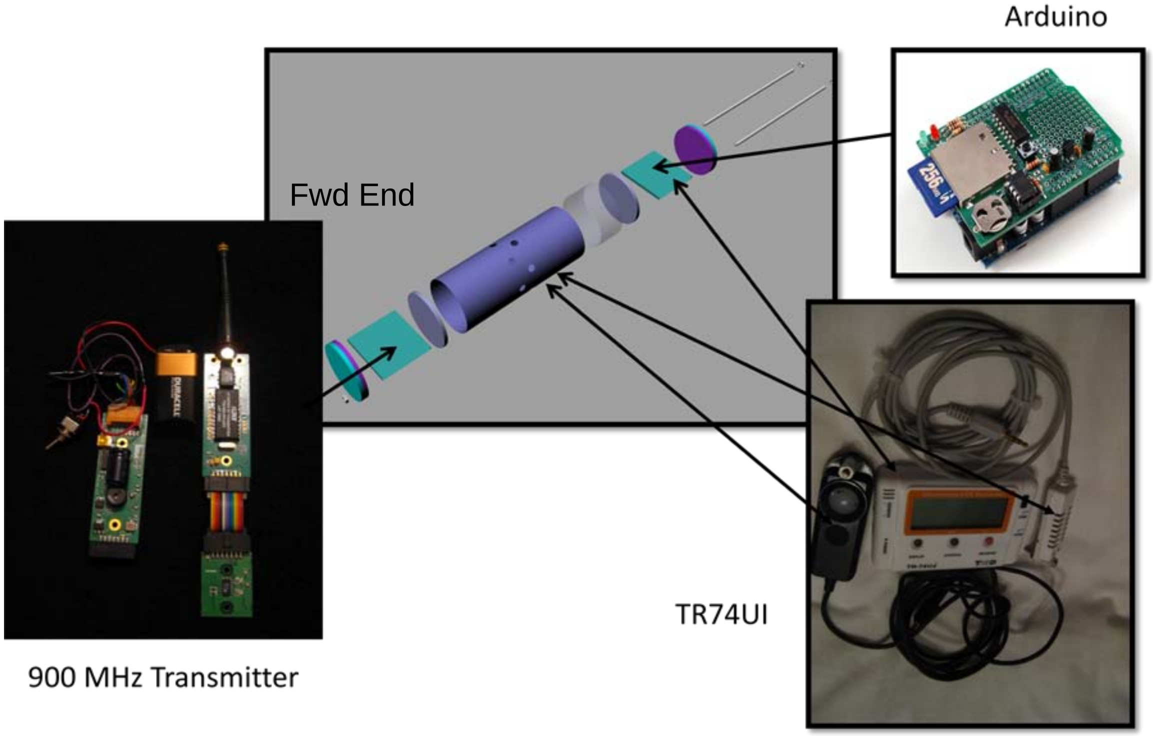
IV.3.b Data Recovery

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.

TAND TR74UI



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



Instrumentation Layout

IV.3.c 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.3.d Performance Characteristics

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

IV.4 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	Static and flight testing completed.
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	80% completed – some data not transmitted

IV.4.a Integration Plan

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

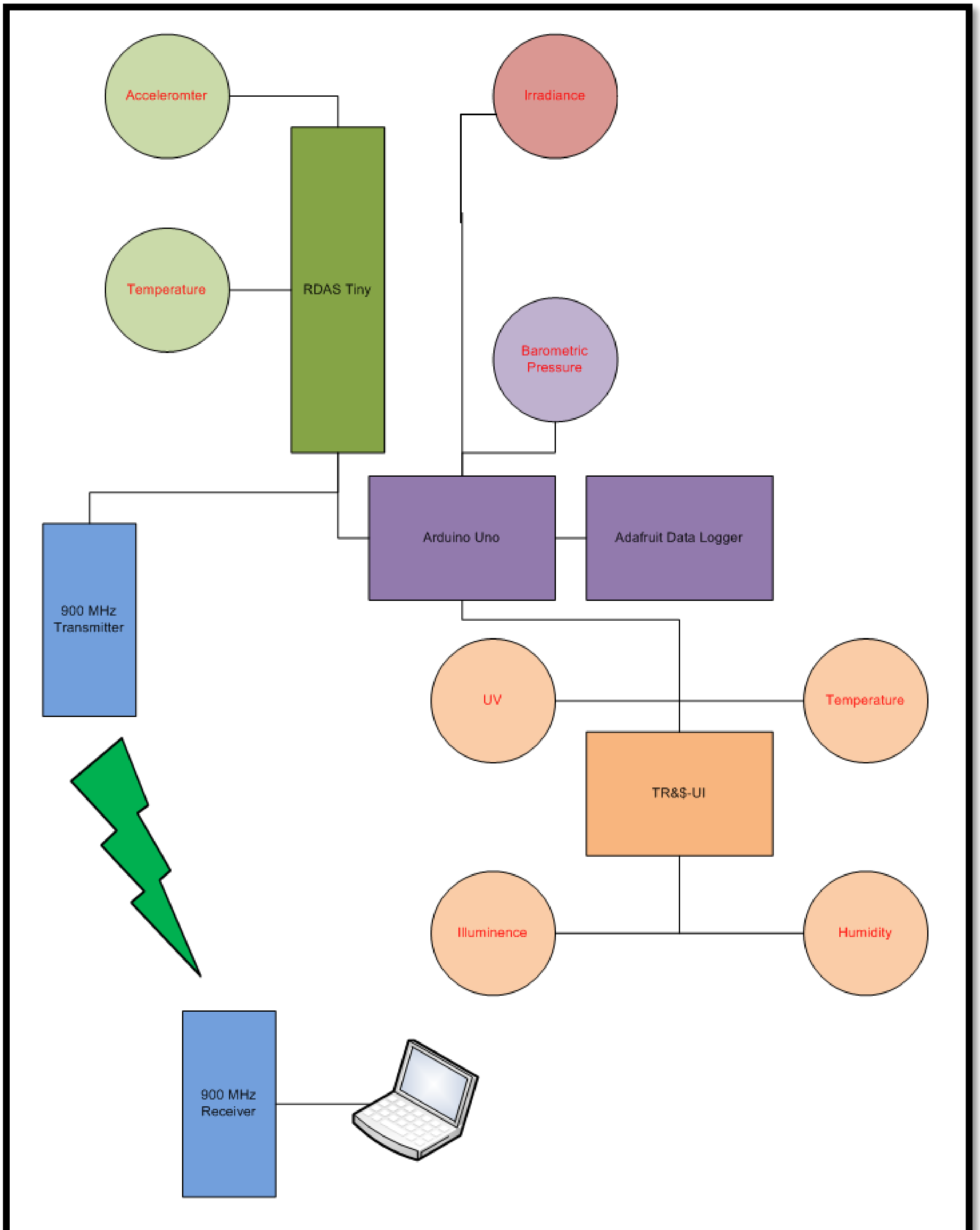
IV.4.b Instrumentation Precision, Repeatability and Data Recovery

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
Barometric Pressure Sensor - BMP085 Breakout	Barometric pressure	300-1100hPa (+9000m to -500m)

Table 8 - Instrument Precision

Precision has been 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.4.c Science Payload Schematics



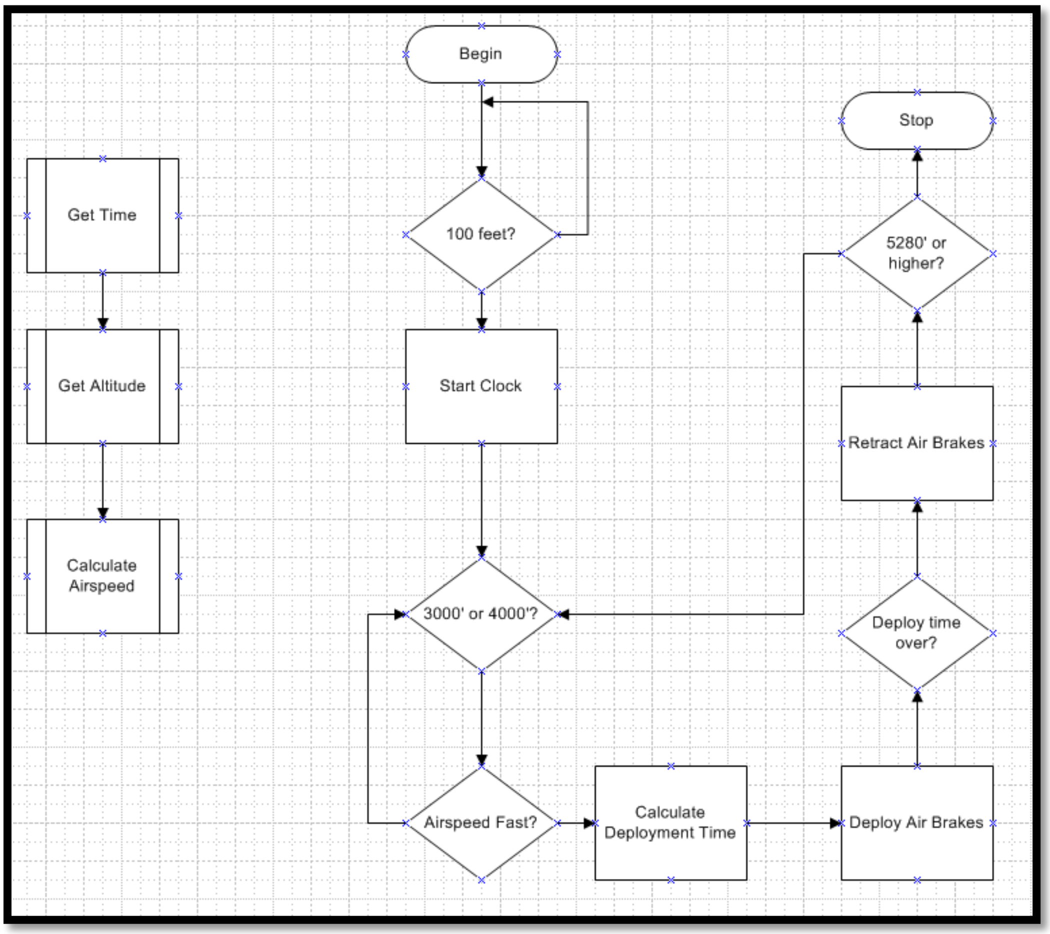
Instrumentation Block Diagram

IV.4.d Payload Key Components Interaction to Achieve Desired Results

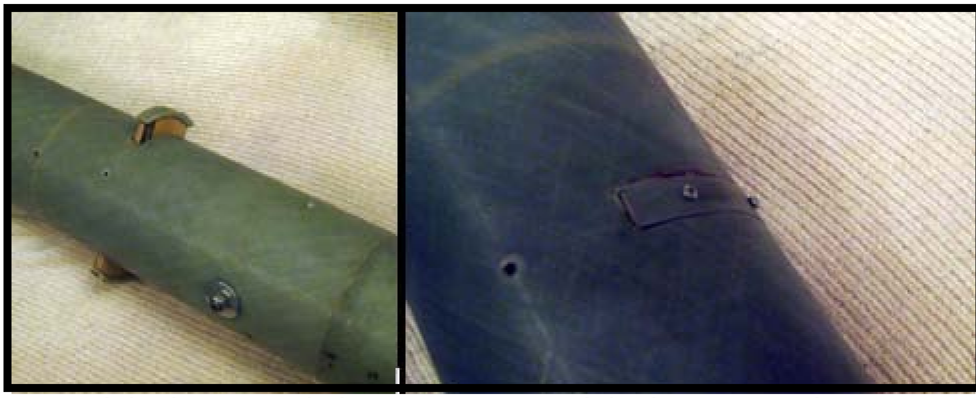
The sensors will collect information based upon the programming of the Arduino Uno. The data will be stored in the data logger as well as passed onto the 900 MHz transmitter. The transmitter will transmit the data to the receiver that is connected to a laptop.

IV.5 Power Management System

An Arduino microcontroller interfaces with a BMP085 barometric pressure sensor and a real time clock to measure altitude and airspeed. There are two check points that the microcontrollers program will check; one at 3,000 feet and the second at 4,000 feet. It will be looking for a target pair of altitude and airspeed. If the air speed is low or correct for the target altitude, nothing happens, if the airspeed is high, then the microcontroller will calculate an approximate length of time to deploy the air brakes. This procedure will repeat at 4,000 feet.



Flow Chart for Power Management System



Air brakes extended Air brakes retracted

IV.6 Payload Safety and Environment

IV.6.a Safety Officer

Justin is the safety officer.

IV.6.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.6.c Personnel Hazards

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

IV.6.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
2	CTI 54mm 3 grain reloads	$52.95	$104.90
			$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	52" Parachute	$79.95	$79.95
1	18" Parachute	$16.75	$16.75
1	RDAS-Tiny altimeter	$300.00	$300.00
2	STRATOLOGGER Altimeter	$99.95	$199.90
			$696.60
Payload and Tracking System			
1	GPS Unit	$295.00	$295.00
4	Payload camera	$9.95	$39.70
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
- Fairhaven Middle School
- Shucksen Middle School
- Bellingham High School
- Lummi HeadStart
- Lummi Nation School

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 SkyWalkers 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 SkyWalkers. 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 SkyWalkers 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

FRR

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	0.630” x 0.680” (large)
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)	2772.2/1862.8
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)	71.46 w/motor
Static Stability Margin	1.2
Thrust-to-Weight Ratio	13:1
Rail Size (in) / Length (in)	1.5 x 96 in

Ascent Analysis	
Rail Exit Velocity (ft/s)	81.12
Max Velocity (ft/s)	632
Max Mach Number	0.57
Max Acceleration (ft/s^2)	367.51
Peak Altitude (ft)	5,536/5,280

Recovery System Properties				
Drogue Parachute				
Manufacturer/Model	LOC Precision			
Size	18"			
Altitude at Deployment (ft)	5,280			
Velocity at Deployment (ft/s)	0.03			
Terminal Velocity (ft/s)	92.8			
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
	1075	1324		

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)	92.5			
Landing Velocity (ft/s)	21.24			
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
	56		19	50

Recovery System Properties	
Electronics/Ejection	
Altimeter(s) Make/Model	PerfectFlite STRATOLOGGER
Redundancy Plan	2nd PefectFlite STRATOLOGGER
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 900Mhz – 8 channels for transmitter
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

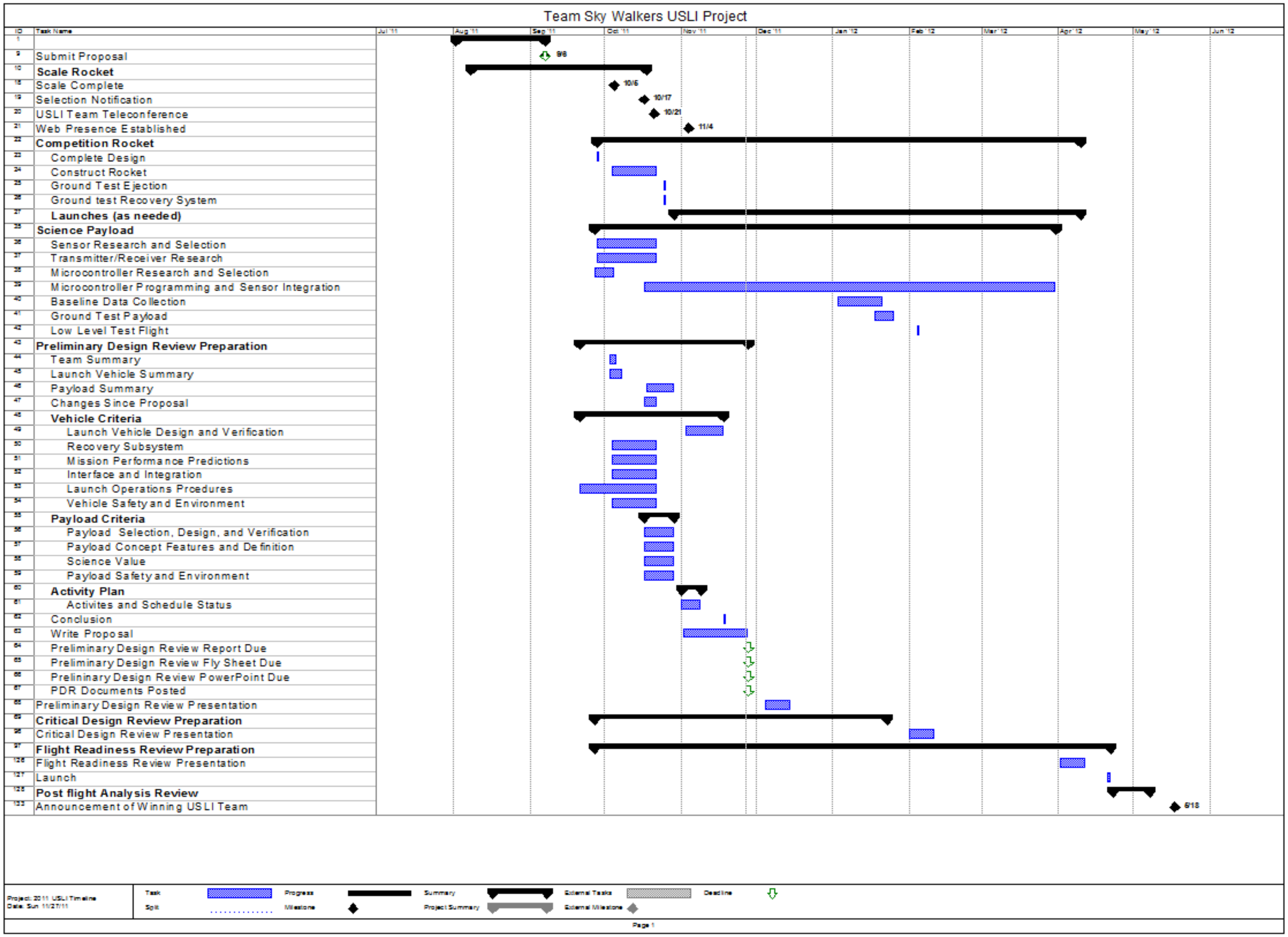
Milestone	FRR

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)	Test completed -
Sub-scale Test Flights	Complete 11/12/11
Full-scale Test Flights	Completed: 1/28, 2/4, 3/18 Scheduled: 4/7

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	Completed
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.			Completed
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	Completed
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 STRATOLOGGER 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 STRATOLOGGER altimeters	Inspection	Completed
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	Completed
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	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	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	Completed
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
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	Completed
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle	Test flight	Completed
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	Completed
▪ 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	Completed
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	Completed
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	Completed
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	Completed
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 - Science Payload Check List

GPS Unit

- ❑ Turn on DC-20
- ❑ Insert into Nose Cone
- ❑ Fasten to Nose Cone with 3 #8 screws
- ❑ Fasten nose cone to airframe with 3 #8 screws

Sensors

1. Radio Transmitter channel matched with receiver channel
    - ❑ Battery voltage at 8.5 volts or better
2. TR74-Ui
    - ❑ Battery voltage at 1.3 volts or better
    - ❑ Power on
    - ❑ Set REC(ord) on
    - ❑ Ensure sensors are plugged in
3. Arduino Barometric Pressure Sensor and Datalogger
    - ❑ Battery voltage at 8.5 volts or better
    - ❑ Power on

Installation into Payload Bay

- ❑ Align fastening marks on blue tube to marks on interior of fiberglass science payload bay
- ❑ Slide assembly to bottom of science payload bay
- ❑ Fasten two #6 x ½” screws at base
- ❑ Align drogue parachute bay over science payload bay
- ❑ Slide together
- ❑ Fasten with ¼” threaded rod

Power Management System

- ❑ Battery voltage at 8.5 volts or better
- ❑ Install programming cable
- ❑ Verify start altitude is as close to 0 as possible (+/- 5 feet maximum)
- ❑ Verify start clock time is set to 100 feet
- ❑ Remove programming cable
- ❑ Power on
- ❑ Check that air brakes cycle
- ❑ Power off

Appendix G – 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 H - 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 I - 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 on
- ❑ Altimeters – beeping
- ❑ Cameras on
- ❑ Radio transmitter on
- ❑ Power management system on
- ❑ Air brakes cycle

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 J - 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.
- ❑ Turn off altimeters
- ❑ Turn off power management system
- ❑ Turn off radio transmitter

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 K - 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 L - 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 M - 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 N - 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 O- November 2012 <u>Squol Quol</u> 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.

NOV

Appendix P – 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