NORTHWEST INDIAN COLLEGE
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2012-2013

Northwest Indian College Space Center USLI Flight Readiness Review

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Northwest Indian College Final Flight Review

I.0 FRR Report Summary

I.1 Team Summary

Northwest Indian College Team RPGs
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I.2 Launch Vehicle Summary

I.2a Size and Mass

Critical investigation has the rocket diameter at 6 inches with a length of 89.5 inches. The rocket airframe and nosecone will be carbon fiber, and the fins will be ¼" aircraft-grade plywood. The fins will be mounted through the wall. Water integrity and minimal weight are two of the requirements for our rocket; carbon fiber satisfies both of those requirements. Our recovery area for much of the winter and spring is flooded. Therefore our design will incorporate water tightness and waterproofing so that our test flights will not be as restricted as they have been in the past.

The mass of the empty rocket is 6.75 pounds empty and increases to 13.75 pounds fully loaded with recovery system, payload, avionics and K445 motor.

Airframe: Carbon Fiber

Length	89.50	Diameter	6.00
Weight	6.75/13.75	Fin Span	22.00
Center of Gravity	50.80/57.77	Center of Pressure	70.33
Static Stability	3.20/2.06		

Table 1, Rocket Specifications

I.2b Motor Choice

Diameter: 54 mm Cesaroni Technology Inc. K445

I.2c Recovery System

Parachute: Main: 52", Drogue: 28" Harness: 1/2" Tubular Kevlar Avionics: Dual PerfectFlite StratoLogger Altimeters

I.2d Rail Size: 1½ inch square x 96 inches

I.2e Milestone Review Flysheet (Appendix A)

I.3 Payload Summary: TOR (Tow Our Rocket)

The rocket will carry a multirotor vehicle (MV) that will become a tow tug after the rocket descends to 700 feet above ground. The MV, as an Unmanned Aerial Vehicle (UAV), will tow the rocket back to the launch area prior to landing. The MV will be deployed at 700 feet simultaneously with the main parachute and its autopilot will be autonomous with Radio Control (RC) backup. This will give it time to acquire its GPS position. The rotors will start after the main parachute is deployed at 700 feet. After the rotors start, the autopilot will maneuver the MV and its tethered vehicle toward the launch area.

The MV will tow the rocket to the launch area providing the winds are not too strong. We are still testing the towing power of the MV. Regardless of the wind strength, the MV will move the vehicle further towards the launch area than what would occur without the MV.

II.0 Changes Made Since Preliminary Design Review

II.1 Notable Changes and Reasons

II.1a Vehicle Criteria Changes

- The 1/8 inch Kevlar recovery harnesses have been replaced with ½” 2500 pound test tubular Kevlar
- Kevlar bridles have been replaced with U-bolts
- Two external camera pods have been mounted on the fin can.

II.1b Payload Criteria Changes (None)

II.1c Project Plan Changes

- Scheduling Educational Outreach is more difficult this year because of increased state-wide and school district educational expectations, and funding cutbacks.

III.0 Design and Construction of Vehicle

III.1 Design and Construction Features

The rocket is designed to be as light as possible while maintaining a strength-to-weight ratio sufficient for mission success and safety.

The overall vehicle stands slightly more than 89 inches tall with an airframe diameter of 6 inches. The airframe is constructed from carbon fiber while the fins are aircraft-grade birch plywood. All components are from Public Missiles Limited (PML), www.publicmissiles.com. Three fins are attached through-the-wall to the 54 mm motor tube 1/2 inch above the aft edge of the airframe. The fins are fastened in place with West Systems 2-part epoxy resin and reinforced with a fiberglass inlay across the inside. Table 1 and Figure 1 list the dimensions.

Length	89.50	Diameter	6.00
Weight	6.75/14.5	Fin Span	22.00
Center of Gravity	50.80/57.77	Center of Pressure	70.33
Static Stability	3.20/2.06		

Table 2, Dimensions

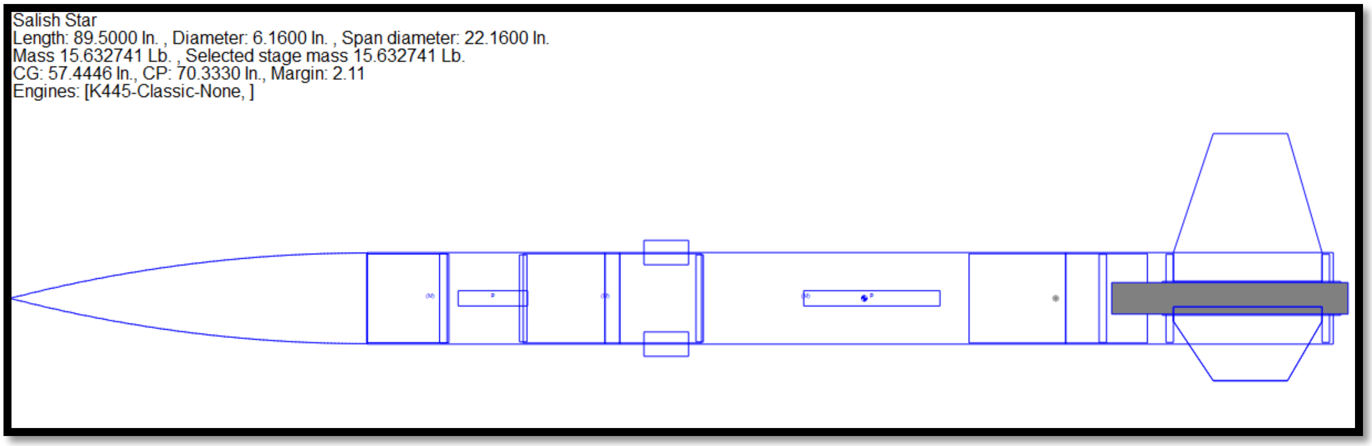
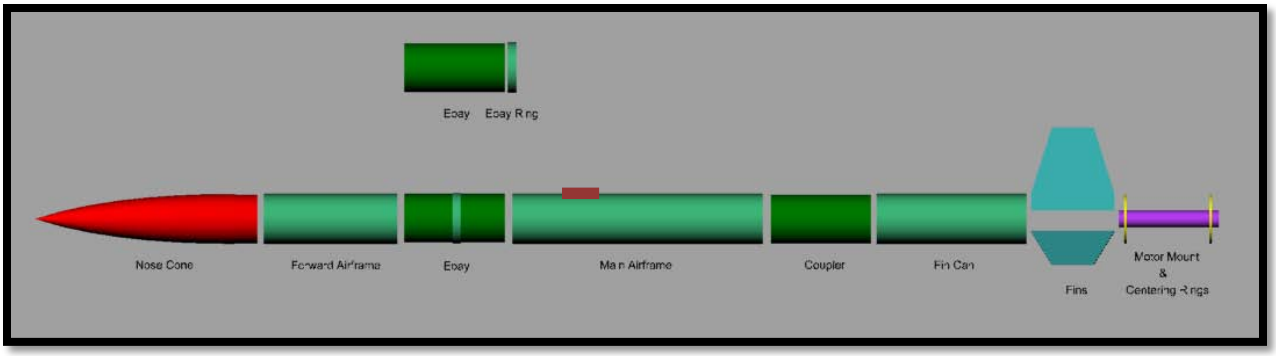

Salish Star
Length: 89.5000 In. , Diameter: 6.1600 In. , Span diameter: 22.1600 In.
Mass 15.632741 Lb. , Selected stage mass 15.632741 Lb.
CG: 57.4446 In., CP: 70.3330 In., Margin: 2.11
Engines: [K445-Classic-None,]

Figure 1, RockSim 9 Side View

We chose lightweight 6 inch carbon fiber airframe material for several reasons:

It is large enough to house our MV;
It is light enough so that the MV can tow it;
It is light enough that we can use a lower power, longer burn motor to reduce acceleration and velocity;
It has a high strength to weight ratio; and,
It provides water resistance to protect our vehicle from our often-flooded recovery area.

The airframe houses the parachutes, recovery electronics, MV, motor, motor mounts, bulkheads, nosecone, and fins in an aerodynamic structure. The airframe is constructed from carbon fiber manufactured by Performance Rocketry.



III.1a Structural elements (such as airframe, fins, bulkheads, attachment hardware, etc.).

III.1a.1 Nosecone

The nosecone is a fiberglass, commercial, 24-inch-long, 4:1 ogive-shaped nosecone with a 6 inch shoulder. The GPS transmitter will be housed here, (Figure 4), well away from all other electronics. A ½ inch aircraft-grade birch plywood bulkhead secures the GPS platform in the nosecone.

Figure 3, GPS Tracker on nose cone insert

III.1a.2 Electronics Bay (Ebay)

The ebay shown in Figure 3, is 6 x10 inches of lightweight carbon fiber. It will hold the dual altimeters. The drogue and main ejection charges will be ignited from the altimeters. It houses the two PerfectFlite StratoLogger altimeters for redundant dual deployment. The ends are capped with aircraft-grade ¼ inch plywood bulkheads. An eyebolt, two black powder cups, and connecting posts for the electric match wires finish the aft end. The main ejection charges are connected to a Tender Descender housed in the main airframe. The two altimeters and batteries are held in place on a plywood 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 radio frequency (RF) signals with a layer of aluminum foil glued to the ebay's interior.

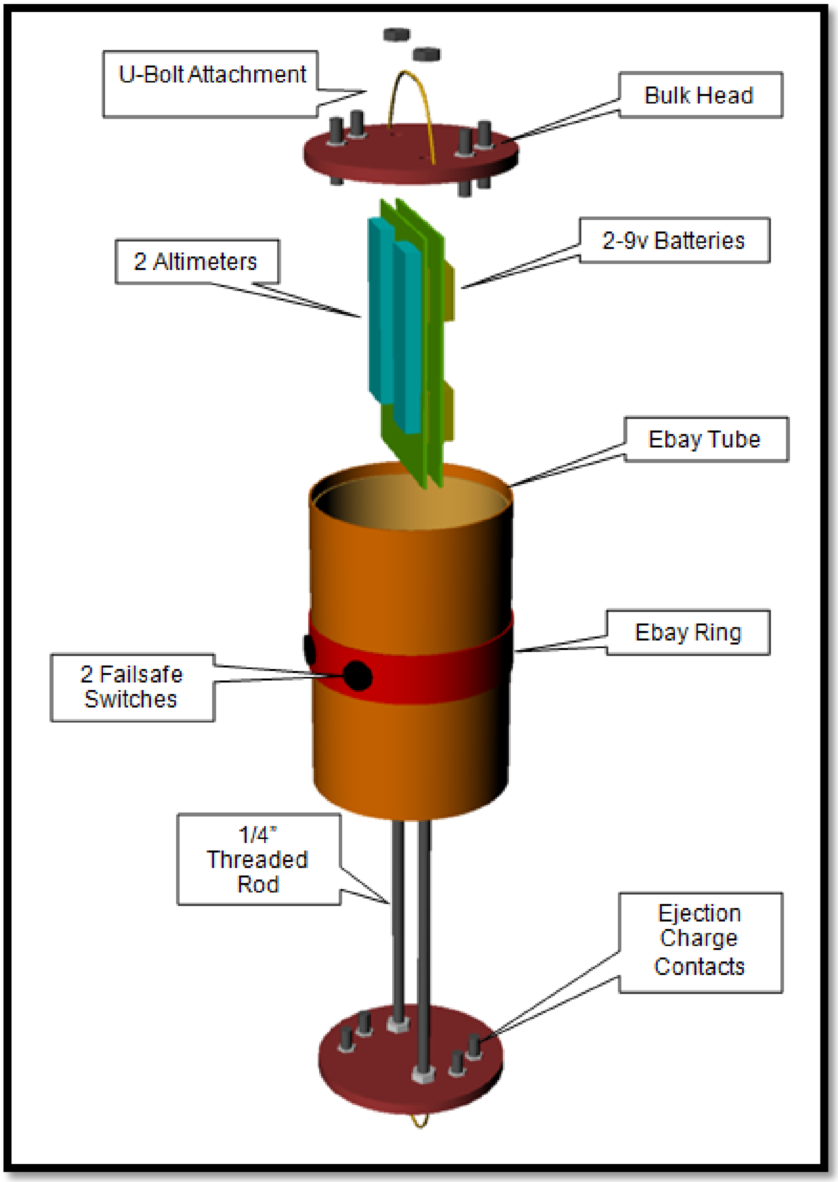


Figure 4, Ebay Concept

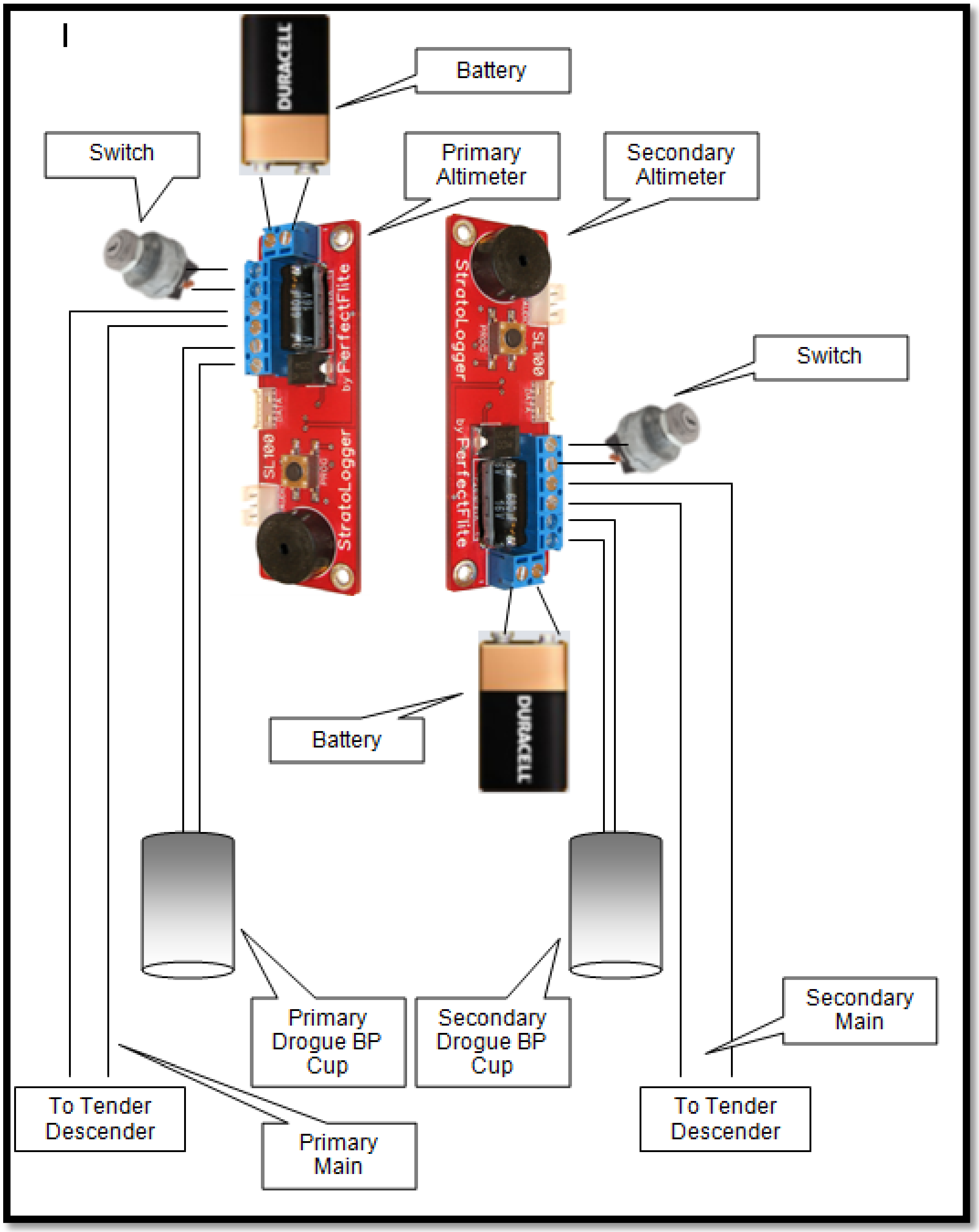


Figure 5, Redundant Dual Deploy Avionics Block Diagram

III.1b.3 Ebay Ring

The ebay ring is 6 x 1 inches of lightweight carbon fiber. It will have the fail-safe switches to the altimeters and the ejection charges.

III.1a.4 Tube Coupler

The tube coupler is 6 x 12 inches of lightweight carbon fiber. It will connect the ebay and the main airframe together. Four nylon shear pins will connect the ebay to the main airframe.

III.1a.5 Main Airframe

The main airframe is 6 x 48 inches of lightweight carbon fiber. The tube coupler, detailed in III.2c, above connects the upper portions of the rocket to the main airframe. This section houses the drogue and main parachutes, with the appropriate recovery harnesses, the MV, the fins, and the motor mount. Usable space is 25 inches. The parachutes and recover harness occupy about 9 inches; this leaves 17 inches for the MV and the eye bolt that connects the harness to the rocket. Two camera pods are mounted to the upper portion of the main airframe. The pods are constructed from 38mm blue tube and are fastened with fiberglass cloth and West Systems epoxy. The end caps are ¼ inch aircraft grade plywood.

Figure 6, Camera Pods

III.1a.5a Firewall

A 6 x ½ inch aircraft-grade plywood bulk head is fastened 32 inches from the top of the airframe with West Systems two part epoxy. This forms a firewall between the motor mount area and the remainder of the airframe.

III.1a.5b Motor Mount and Motor Retention

The motor mount is a 12 inch length of 54mm phenolic tubing. It is fastened to the airframe between two ¼ inch aircraft-grade plywood centering rings. West Systems two-part epoxy fastens the components together. The phenolic tubing is structurally stable and is used to provide a stable structure to contain and constrain the motor. Motor retention is via t-bolts, screws, and formed metal clips.

III.1a.5c Fins

Three fins constructed from ¼ inch aircraft-grade plywood are fastened through the airframe wall (TTW) onto the motor mount tube. The fins are fastened to the motor mount tube, filleted with a fiberglass and epoxy fillet. The fin/motor mount tube is then slid into the airframe and epoxied in place. Epoxy fillets complete the attachment.

Figure 7, Typical Through the Wall Fin Attachment

III.1a.6 Connecting the Components

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

III.1b Electrical Elements

The only electronics in *Salish Star* are the electronics necessary to deploy the drogue and main parachutes. The following diagrams and photos illustrate the ebay that contains the avionics and the block diagram of their connection and independence.

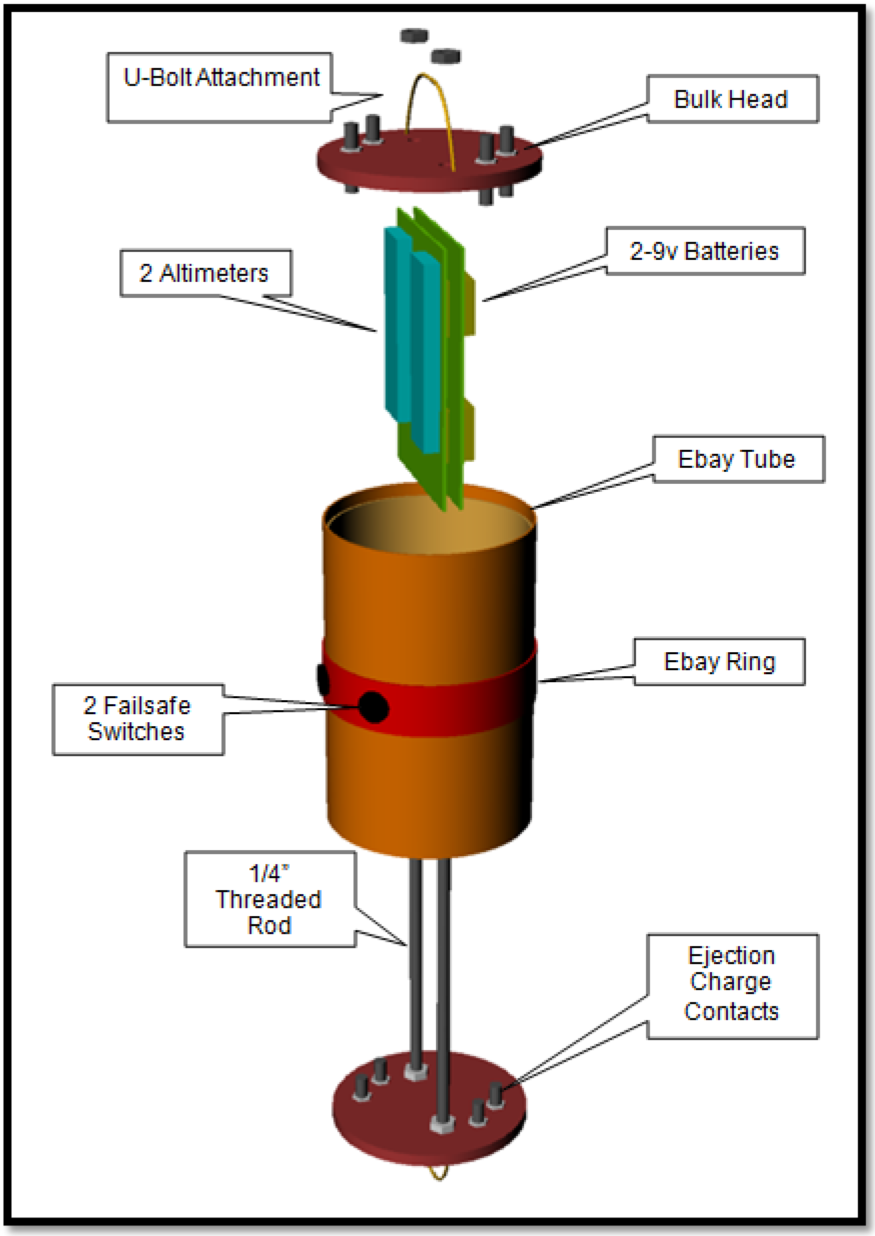


Figure 8, Ebay Concept

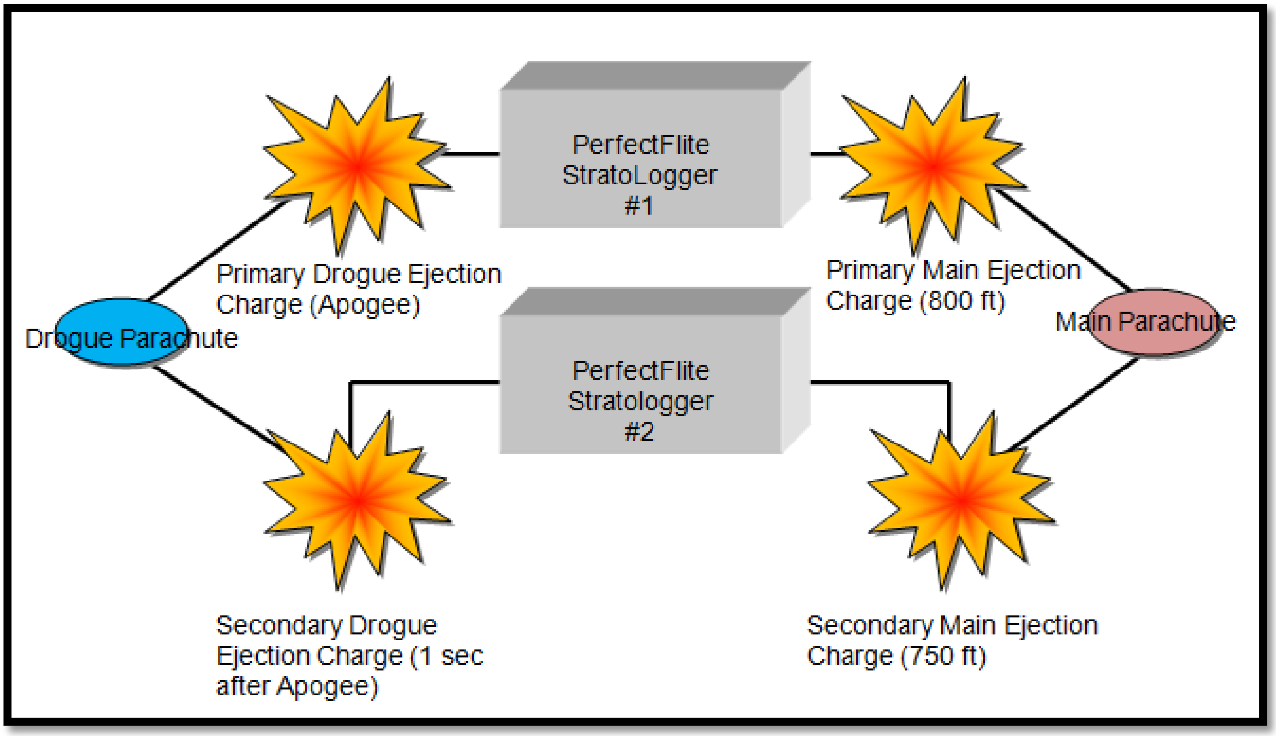


Figure 9, Avionics Block Diagram

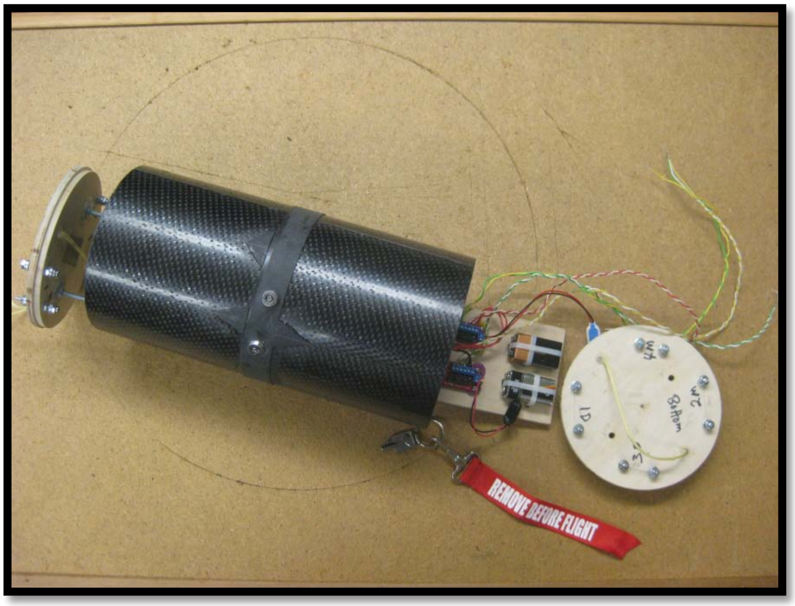


Figure 10, Ebay Layout

Figures 9 and 10 show the components of the ebay. The sled is ¼" plywood that slides on 2 – ¼ inch threaded rod. The threaded rod, in turn, is connected to both ½ inch plywood bulkheads. The bulkheads contain the electrical connectors for the main and drogue parachute ejection charges. Figure 10 shows the fail-safe switches that enable power to the altimeters.

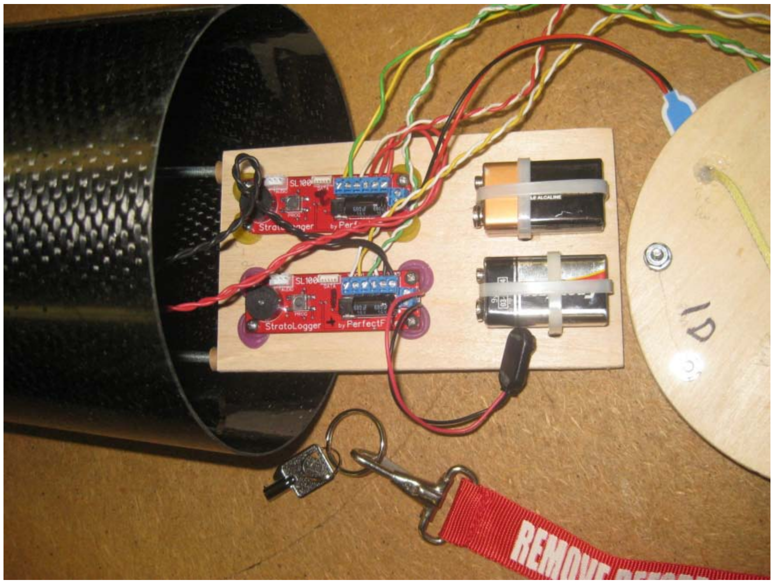


Figure 11, Avionics Sled

The altimeters are fastened to the sled with 4 x 40 nuts and bolts while the two batteries are fastened to the sled with crisscrossing zip ties. This arrangement has worked flawlessly for three launches as of March 9, 2013.

III.1c Vehicle Assembly Drawings and Schematics

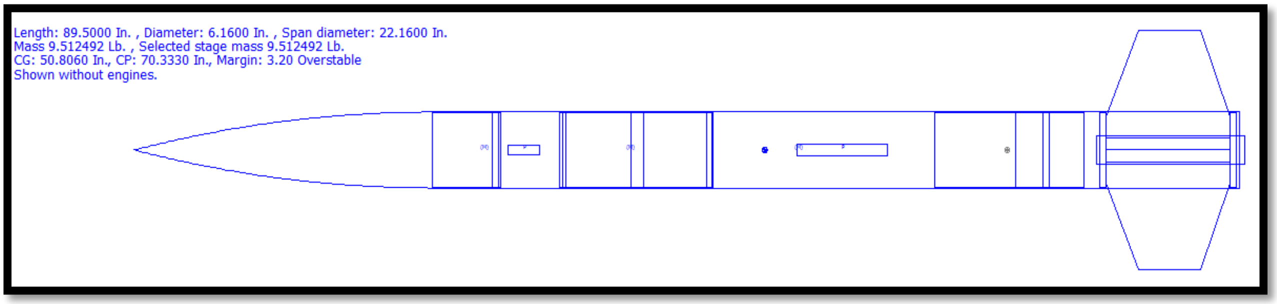


Figure 12, Salish Star Drawing

Salish Star is a very straight forward rocket; nose cone, airframe, and fins. Its primary purpose is to carry the TOR multirotor vehicle and to deploy it with the main parachute deployment. As such, there is nothing unique about *Salish Star*. It is composed of carbon fiber and plywood. The plywood forms the fins and various bulkheads to connect or separate components.

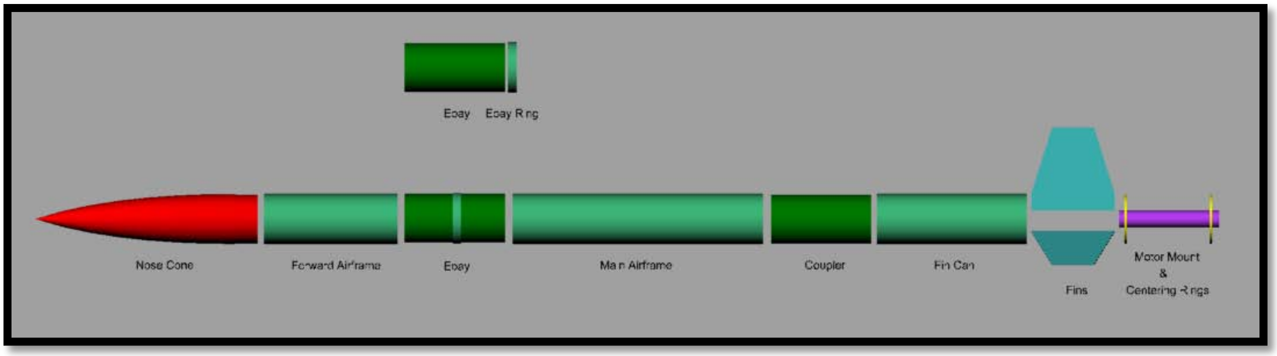


Figure 13, Salish Star exploded view

III.1d Flight Reliability Confidence and Demonstration Thereof

We have 100% confidence in *Salish Star*. As of March 9, 2013, Salish Star has been successfully launched and recovered four times. The launches, and other data follow:

Date	Motor	Purpose	Success	Result
1/3	CTI I287	Recovery Test	80%	Ejection Charge Gas Leak
2/17	CTI J240	Recovery Test	70%	Recovery Harness Separation
3/3	CTI J240	Recovery Test	100%	Successful Deployment
3/9	CTI J760	MV Deployment Test	100%	MV Deployed Successfully

Table 3, Salish Star Launch Results

III.1e Discuss Analysis, and Component, Functional, or Static Testing

Our black powder deployment tests ensured that the rocket would separate during its recovery. RocSim simulations ensured us of the proper relationship between the CP and the CG as well as aided in the motor selection. Visual examination throughout the building phases and continuous inspections further ensured that the *Salish Star* was appropriately constructed and should withstand the rigors of launch and recovery. We scheduled test launches as follows:

Launch 1	test *Salish Star* stability and recovery system
Launch 2	test MV deployment
Launch 3	test MV deployment and MV TOR system

III.1f Test Data Analysis, and Component, Functional, or Static Testing of Components and Subsystems.

Ground tests of the black powder amounts for ejection separation have been conducted with satisfactory results.

RockSim 9 simulations using predicted weather conditions at Toney, AL show a successful flight:

Engine Selection: CTI K445

Launch Conditions

- Altitude: 834.00000 Ft.
- Relative humidity: 80.000 %
- Temperature: 59.000 Deg. F
- Pressure: 29.9139 In.
- Wind speed model: Light (3-7 MPH)
- Latitude: 34.900 Degrees

Launch Guide Data

- Launch guide length: 96.0000 In.
- Velocity at launch guide departure: 72.1808 ft/s
- The launch guide was cleared at : 0.246 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 37.2170 In.

Max Data Values

- Maximum acceleration: Vertical (y): 368.090 Ft./s/s (11.441 gee)
- Maximum velocity: Vertical (y): 727.1357 ft/s
- Maximum range from launch site: 609.75121 Ft.
- Maximum altitude: 5307.85613 Ft.

Recovery System Data

- P: Drogue Parachute Deployed at : 16.953 Seconds
- Velocity at deployment: 32.9090 ft/s
- Altitude at deployment: 5307.85610 Ft.
- Range at deployment: -609.75121 Ft.
- P: Main Parachute Deployed at : 71.354 Seconds
- Velocity at deployment: 85.3670 ft/s
- Altitude at deployment: 699.90252 Ft.
- Range at deployment: -90.25102 Ft.

Time Data

- Time to burnout: 4.050 Sec.
- Time to apogee: 16.953 Sec.
- Optimal ejection delay: 12.903 Sec.

Landing Data

- Successful landing
- Time to landing: 99.974 Sec.
- Range at landing: 142.48859
- Velocity at landing: Vertical: -23.8252 ft/s , Horizontal: 7.6191 ft/s

Rocksim simulation plots, Figures 14 and 15, indicate a successful flight and they are within acceptable parameters.

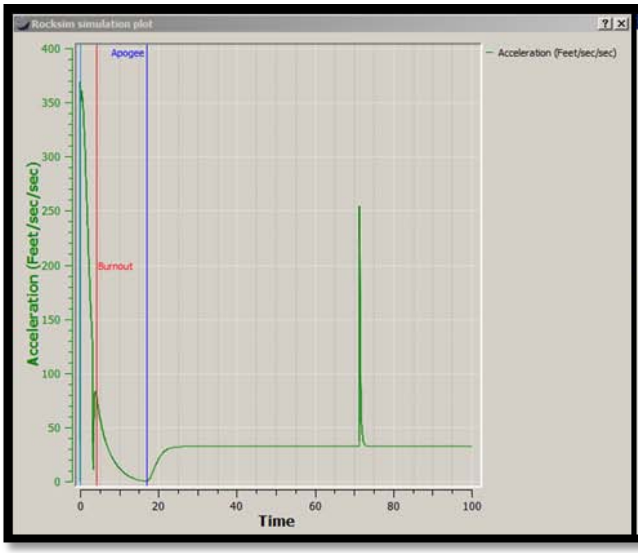


Figure 14, Acceleration

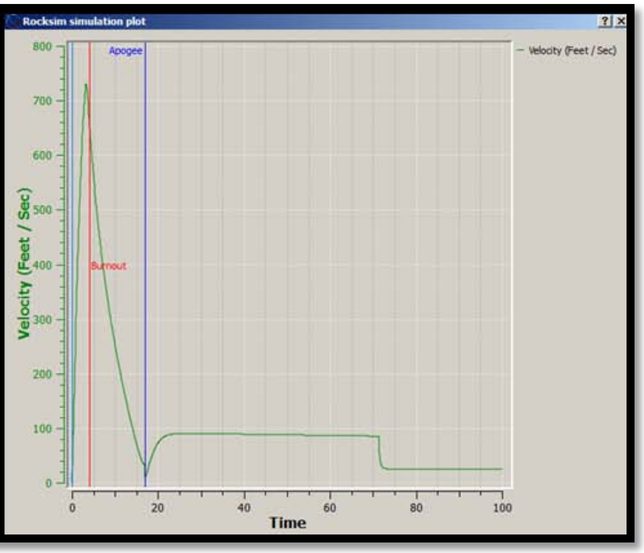


Figure 15, Velocity

III.1g Approaches to Workmanship that will Enable Mission Success

Established procedures built upon three years of high power rocket construction and flying ensures an excellent degree of workmanship. Construction techniques and procedures have, and will continue to, result in well flying rockets that are robust enough to withstand multiple launches and landings. We have our own launch area and a 5000’ FAA waiver that we can activate for any Friday, Saturday, or Sunday. This permits us to thoroughly test our vehicles and payloads.

III.1h Safety, Failure Analysis and Risk Mitigations

Patrisha is RPGs’ Safety Officer

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

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

Structural Failures	Potential Effects of Failure	Failure Mitigation
Fins fail during flight due to shear forces or inadequate use of	Rocket will experience an unstable and unpredictable flight trajectory.	Use suitable building materials, through-the-wall fin mounting, and

adhesive.		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.
Recovery 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.
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.
Avionics 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.
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.
Payload Failures	**Potential Effects of Failure**	**Failure Mitigation**
MV fails to unfold	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during deployment.	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during descent.	Payload experiment fails.	Testing and careful packing.
GPS system fails to record the position of the rocket on the ground.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
GPS system fails to record the position of the rocket while in the air.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more motors fail to start.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more propellers become entangled in the recovery harnesses.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
Wind too strong for towing.	Rocket/payload land safely under parachute.	Design more powerful MV
Battery looses power.	Rocket/payload land safely under parachute.	Fully charged batteries of sufficient size to complete mission.
MV lands on rocket/parachutes after fin can contacts the ground and crashes.	Damage to MV, rocket, and or parachutes.	Proper harness lengths
MV lands further than the 100 feet mission criteria.	Failure of that mission criterion.	Test

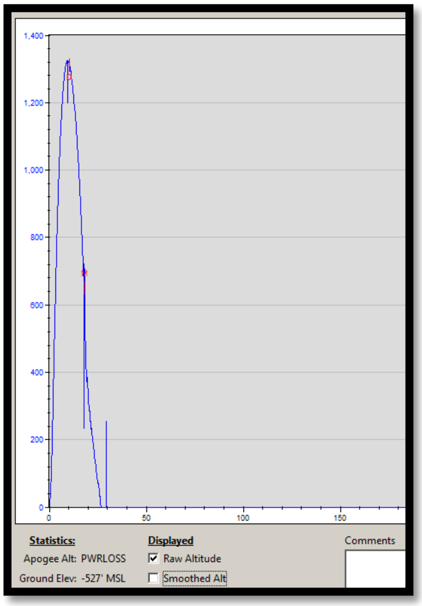
Table 4, Failure, Failure Effects, Failure Mitigation

III.1i Full-Scale Launch Test Results.

To date, we have launched Salish Star four times (Table 3), launches of 2/17/13 and 3/3/13 were to correct some recovery discrepancies. The 1/3/13 launch showed an ejection gas leak into the ebay. We wanted to make certain that it was fixed and not leaking before risking our MV. Launch two on 2/17/13 showed that we had corrected the ejection charge leak; however, an preparation error caused the nose cone/GPS section to break free from the recovery harness. The nose cone/GPS tumbled over 1500 feet and sustained no damage, a testimony to the strength of carbon fiber (and luck). This of course necessitated another launch to make certain everything was working properly. March 3, 2013 saw another launch and this time everything worked as designed and planned.

This brought *Salish Star* to the launch on March 9, 2013. Here the MV was carried and successfully deployed it. It deployed as planned, the MV kept its proper orientation and all lines were in no danger of becoming entangled.

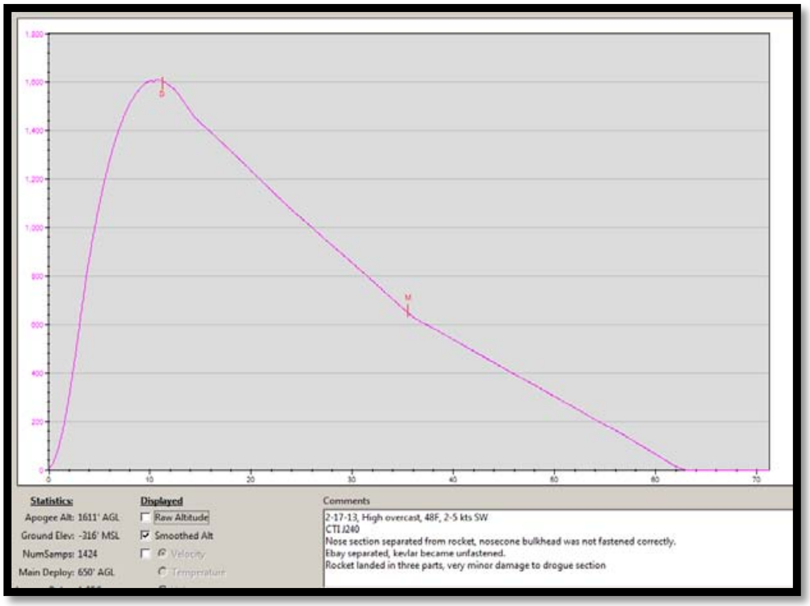
III.1i.1 Flight Data Analysis and Discussion



Apogee Alt: PWRLOSS
Ground Elev: -527' MSL
☑ Raw Altitude
☐ Smoothed Alt

Figure 15, 1/13/13 Launch

Altimeters lost power shortly after main deployment. Zip ties failed due to shock loading from main ejection charge detonation. We expoxied a plywood shelf to support the batteries and well as the zip ties that hold them in place. A CTI I287 reload was used.



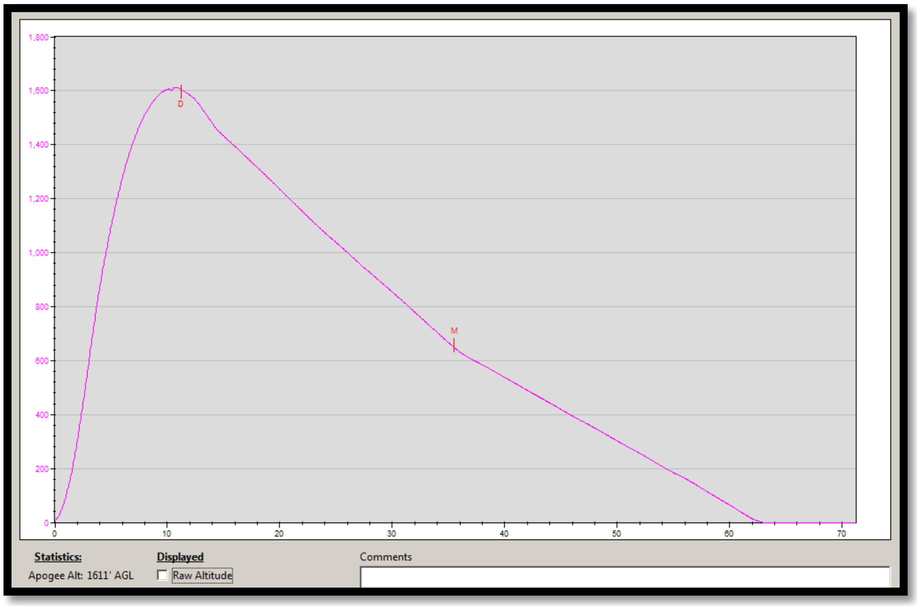
Statistics:
Apogee Alt: 1611' AGL
Ground Elev: -316' MSL
NumSamps: 1424
Main Deploy: 650' AGL

Displayed
☐ Raw Altitude
☑ Smoothed Alt
☐ ● Velocity
○ Temperature

Comments
2-17-13, High overcast, 48F, 2-5 kts SW
CTI J240
Nose section separated from rocket, nosecone bulkhead was not fastened correctly.
Ebay separated, kevlar became unfastened.
Rocket landed in three parts, very minor damage to drogue section

Figure 16, 2/17/13 Launch

Nose cone separated from recovery harness due to inadequate fastening during prelaunch preparation. An additional check list step was added to ensure that this human induced error was mitigated. A CTI J240 reload was used.



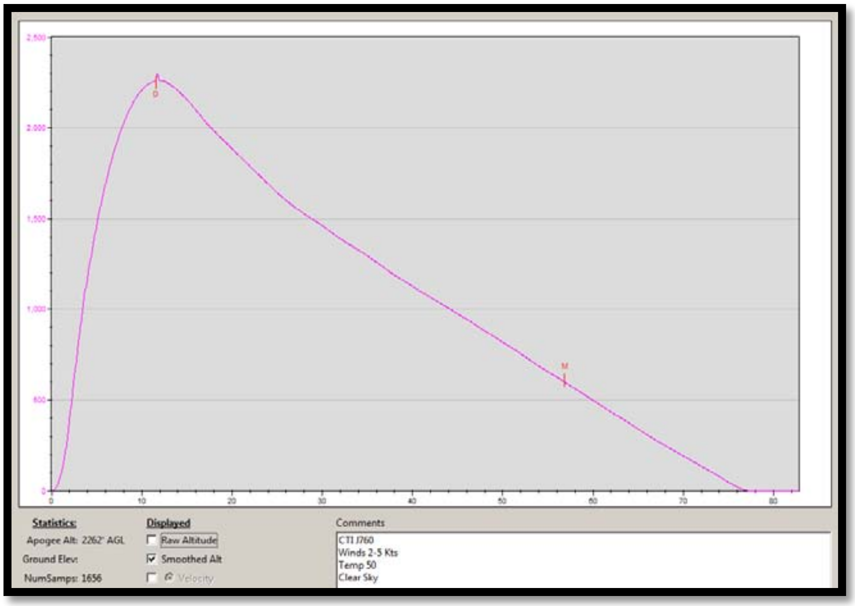
Statistics:
Apogee Alt: 1611' AGL

Displayed
☐ Raw Altitude

Comments

Figure 17, 3/3/13 Launch

This launch was 100% successful. Parachutes deployed as programmed and the rocket descended well within our target area. Winds were in the 15-18 kt range and *Salish Star* displayed minimum weather cocking. A CTI J240 reload was used.



Statistics:
Apogee Alt: 2262' AGL
Ground Elev:
NumSamps: 1656

Displayed
☐ Raw Altitude
☑ Smoothed Alt
☐ Velocity

Comments
CTI J760
Winds 2-5 Kts
Temp 50
Clear Sky

Figure 18, 3/9/13 Launch

The MV was carried during this launch. We used a larger drogue parachute with the idea that the rocket might not swing so much. The MV deployed without incident and stayed in a horizontal alignment throughout the descent. Landing was successful with no damage.

The MV stayed clear of the recovery harness. Our next test launch will have the MV motors running and a test of our auto pilot and manual flight. A CTI J760 reload was used.

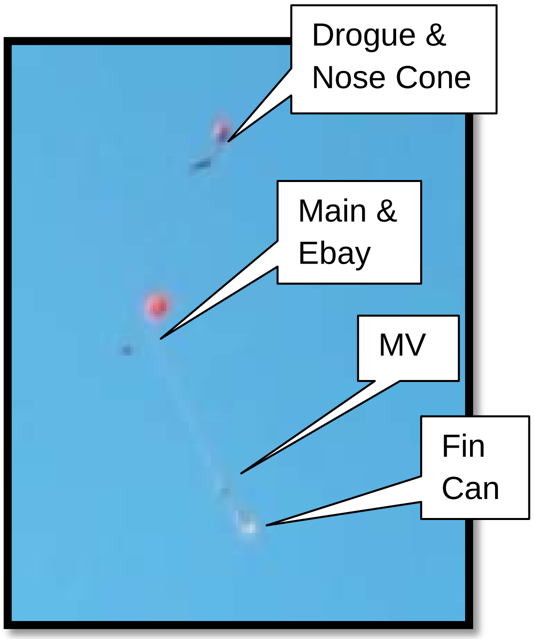


Figure 19, Salish Star Lifting Off ***Figure 20, MV Deployment***

Figure 21, Initial MV Deployment-1(ignore date stamp)

Figure 21 shows the MV shortly after leaving the fin can. The drogue and nose cone can be seen at the bottom center of the photograph. The white tube is the ½ inch PVC standoff that keeps the propellers from coming in contact with the aft bulkhead in the fin can. The bulkhead separates the payload bay from the motor area. The tubular Kevlar is the line extending from the standoff through the center of the MV and then continues to the aft end of the ebay.

Figure 22, MV Deployment-2

Figure 22 illustrates the MV a few moments later. The pedestal has slide down the Kevlar recovery harness into the fin can. One can also see the ebay, nose cone, drogue and main parachutes. The nose cone is light enough that the drogue parachute is still flying and holding the nose cone out of reach of any possible entanglement.

III.1j Mass Report and Basis for Reported Masses

The mass statement and budget are based upon actual weighing of the various pieces and components of Northwest Indian College's USLI project.

Mass Statement

Material	Component	Mass (lb)	Subsystem	KE Component	Mass (Kg)
Carbon Fiber	Aft Airframe	1.75	Airframe	Aft	0.80
Plywood	Fin Set	0.28	Airframe	FC	0.13
Carbon Fiber	Fin Can Tube Coupler	0.25	Airframe	FC	0.11
Plywood	Firewall Bulk Head	0.02	Airframe	FC	0.01
Carbon Fiber	Fwd Airframe	0.03	Airframe	Fwd	0.01
Fiberglass	Nose Cone	1.50	Airframe	Fwd	0.68
Plywood	Nose Cone Bulk Head	0.13	Airframe	Fwd	0.06
	Epoxy	0.13	Misc	Aft	0.06
	Paint	0.13	Misc	Fwd	0.06
	Multirotor Vehicle	2.50	Payload	MV	1.14
Plywood	Aft Motor Mount Center Ring	0.01	Propulsion	FC	0.00
	CTI K445	3.08	Propulsion	FC	1.40
Plywood	Fwd Motor Mount Center Ring	0.01	Propulsion	FC	0.00
Phenolic	Motor Mount	0.01	Propulsion	FC	0.00
Nylon	Main Parachute	0.56	Recovery	Aft	0.25
Tubular Nylon	Main Recovery Harness	0.44	Recovery	Aft	0.20

Steel	Fin Can Eybolt	0.06	Recovery	Aft	0.03
Plywood	Aft Ebay Bulk Head	0.02	Recovery	Ebay	0.01
Steel	Aft Ebay Eyebolt	0.06	Recovery	Ebay	0.03
	Avionics (altimeters, batteries)	0.75	Recovery	Ebay	0.34
Carbon Fiber	Ebay Coupler	0.25	Recovery	Ebay	0.11
Carbon Fiber	Ebay Ring	0.05	Recovery	Ebay	0.02
Plywood	Fwd Ebay Bulk Head	0.02	Recovery	Ebay	0.01
Steel	Threaded Rod	0.03	Recovery	Ebay	0.01
Nylon	Drogue Parachute	0.25	Recovery	Fwd	0.11
Tubular Nylon	Drogue Recovery Harness	0.44	Recovery	Fwd	0.20
	GPS Unit	1.00	Recovery	Fwd	0.45
Total Mass w/loaded CTI K445 motor=		**13.75**			**6.25**

Table 5, Mass Statement

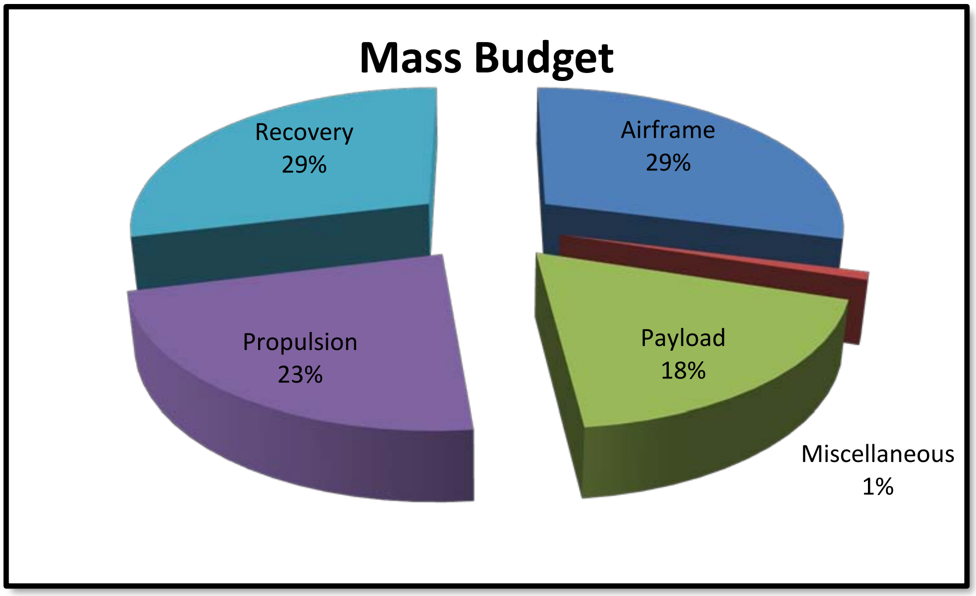


Figure 23, Mass Budget

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

Mass growth has increased by 3.15 pounds because of the extra weight in increasing the rocket's length and the MV weighing more than expected.

The selected motor has reserve power for up to 13 extra pounds and still deliver a safe liftoff and flight. The 13 pounds will not adversely affect the stability margin; however, the target altitude will be greatly reduced.

III.2 Recovery Subsystem

III.2a Tested Recovery System Robustness

Rocksim calculated the fully loaded weight for the rocket at 13.75 pounds while descending. We've looked at Top Flight, Wildman Rocketry, LOC Precision, and SkyAngle parachutes and compared their specifications to what Rocksim predicted would be a suitable size and descent rate. Rocksim indicated that a 50 inch parachute would have a descent rate of 24 fps. We settled on the LOC Precision 50 inch parachute for the main and a SkyAngle Drogue (24 inch) parachute for the drogue. Both are made with Rip-Stop coated nylon fabric with shroud lines of heavy duty braided nylon on the LOC Precision and nylon webbing on the SkyAngle.

Salish Star has been launched four times as of this writing. The recovery systems have proven themselves to be robust and they have performed their designed function flawlessly.

III.2b Structural Elements

Each bulkhead, nose cone, ebay forward end, ebay aft end, firewall is constructed from ¼ inch aircraft grade plywood. They are fastened to the airframe with West System two-part epoxy. The ebay bulkheads are two layers of the ¼ inch plywood fastened at each end of the ebay by two ¼ inch threaded rods. A 5/16 inch U-Bolts are fastened to the ebay bulkheads to form attachment points for the recovery harnesses. A Kevlar loop and ¼ inch eyebolt are fastened through the firewall at the base of the airframe and a third 5/16 inch U-Bolt is fastened to the nose cone bulkhead for recovery harness attachment points.

The parachute bay is connected to the ebay using frictional fitting and secured with nylon #2-56 machine screws that act as shear pins. These screws prevent dynamic separation which will cause 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 of force to shear the screws.

III.2c Electrical elements (such as altimeters/computers, switches, connectors).

We are using a Garmin Astro 220 dog tracker, a GPS transmitter, to track and locate Salish Star in the event it doesn't land where we want it to. We have an externally mounted antenna because of the EMF blocking features of carbon fiber.

Other electronics that will be addressed in the payload section are the MV's:

- autopilot,
- RC receiver,
- motor ESC,
- GPS,
- FPV camera, and
- RD3 telemetry system.

III.2d Redundancy Features

This subsystem consists of the ebay which contains the avionics that control parachute deployment. We are using two PerfectFlite Stratologger altimeters to record the altitude and to deploy the parachutes. Each altimeter has its own power supply and having two altimeters provides redundant parachute deployment. The primary altimeter is programmed to deploy the drogue parachute at apogee and the main parachute at 800 feet, whereas the secondary altimeter will activate the drogue charge 1 second after apogee and activate the secondary main ejection charge at 750 feet.

III.2e Parachute Sizes and Descent Rates

Salish Star has a LOC Precision 50 inch parachute for the main and a SkyAngle Drogue (24 inch) parachute for the drogue. Both are made with Rip-Stop coated nylon fabric with shroud lines of heavy duty braided nylon on the LOC Precision and nylon webbing on the SkyAngle.

RockSim 9 indicates that the descent rate under drogue is 66.01 ft/s and 22.02 ft/s while descending under the main parachute. Using the data from our last launch, the measured descent rates were 61.03 ft/s under drogue and 22.97 ft/s under main with the fin can impacting the ground at 20.53 ft/s

III.2f Electrical and Structural Assemblies Drawings and Schematics

The primary electronics in *Salish Star* are the electronics necessary to deploy the drogue and main parachutes. The following diagrams and photos illustrate the ebay that contains the avionics and the block diagram of their connection and independence.

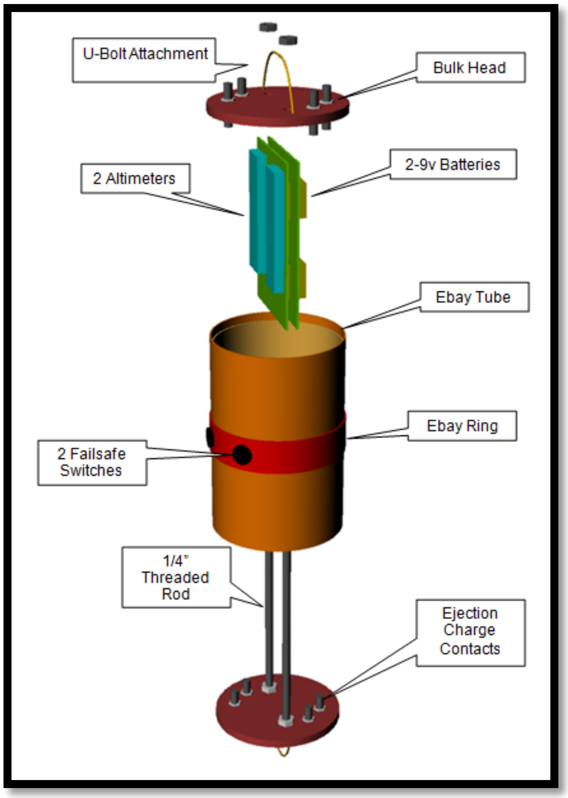


Figure 24, Ebay Concept

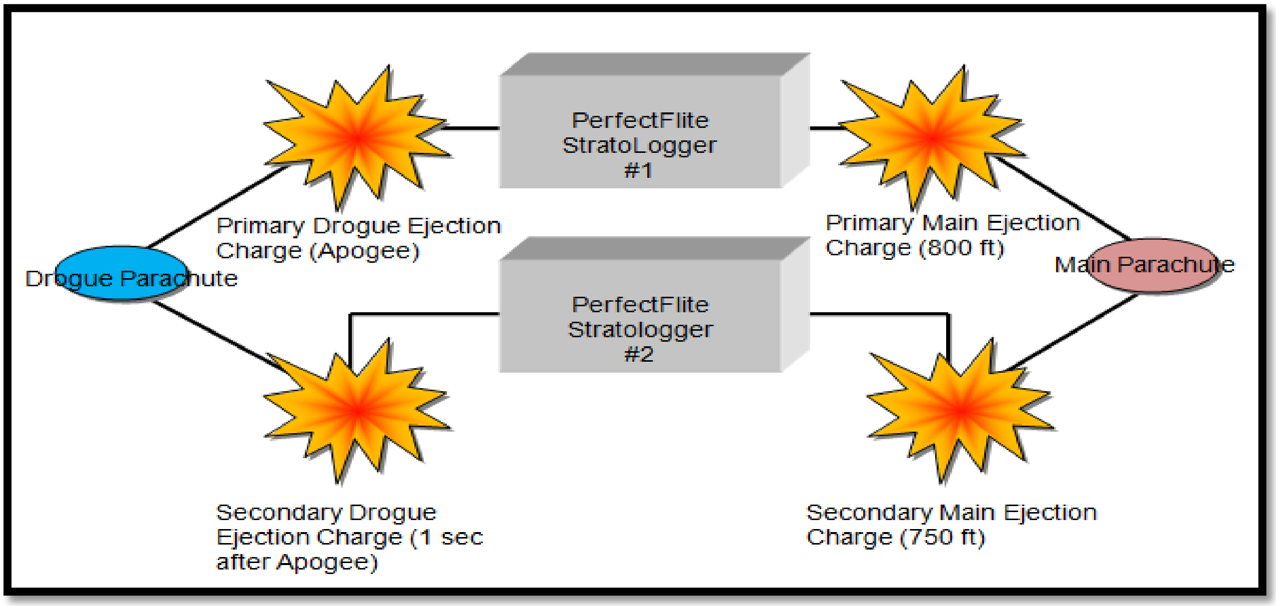


Figure 25, Avionics Block Diagram

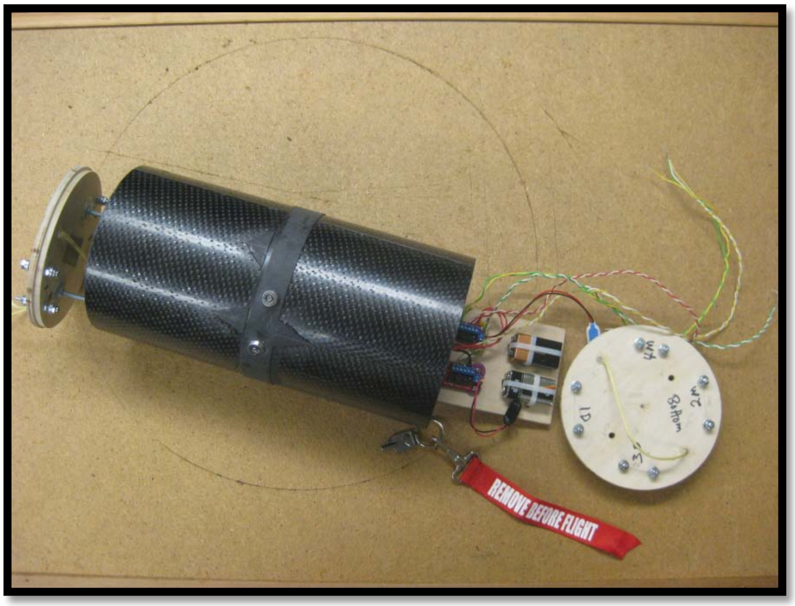


Figure 26, Ebay Layout

Figures 26 and 27 show the components of the ebay. The sled is ¼” plywood that slides on 2 – ¼ inch threaded rods. The threaded rod, in turn, is connected to both ½ inch plywood bulkheads. The bulkheads contain the electrical connectors for the main and drogue parachute ejection charges. Figures 26 and 28 shows the fail-safe switches that enable power to the altimeters.

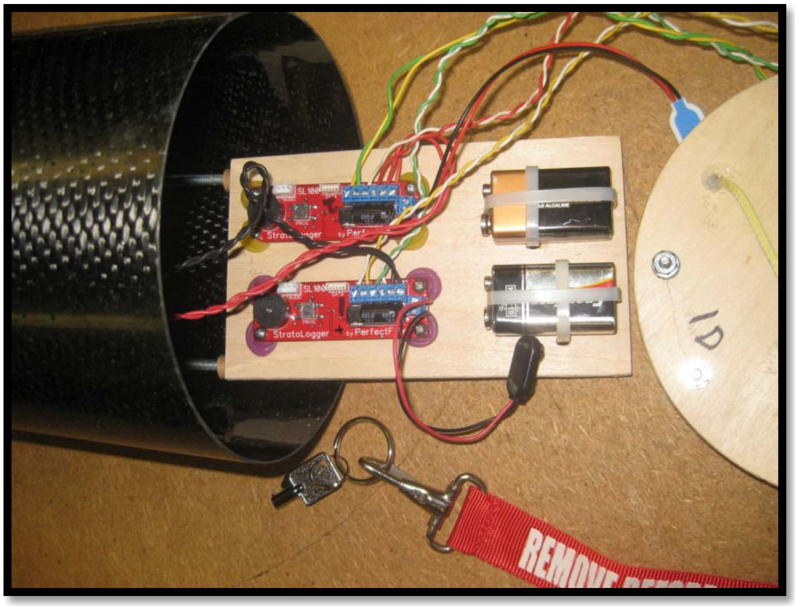


Figure 27, Avionics Sled

The altimeters are fastened to the sled with 4 x 40 nuts and bolts while the two batteries are fastened to the sled with crisscrossing zip ties. This arrangement has worked flawlessly for three launches as of March 9, 2013.

Figure 28, Key Switches

III.2g Transmitter Data

Item	Video Camera	Garmin GPS	Spektrum Radio Contol	3DR Radio
Frequency	**5.8 gHz**	**151 MHz**	**2.4 gHz**	**915 mHz**
Wattage	**200 mW**	**2 W**	**200 mW**	**100 mW**
Range	**500 m**	**8 km**	**1.2 km**	**2 Km**
Channels	5.705	151.82	2.400-2.4835	895 - 935
	5.685	151.88		
	5.665	151.94		
	5.885	154.57		
	5.645	154.60		
	5.905			
	5.925			
	5.945			

Table 6, Transmitter Data

Salish Star will be carrying the Garmin Astro 220 GPS dog tracker for locating it. The MV will be carrying the other transmitters: the 5.9 gHz video camera/transmitter; the RC receiver; and a 915 mHz 3DR radio for telemetry and backup MV control

III.2h EMF Testing

RF Interference Test Results

	Garmin GPS	5.8 gHz Video Transmitter	2.4 gHz RC Unit	915 mHz 3DR Telemetry	Altimeter 1	Altimeter 2
Garmin GPS	▨	OK	OK	OK	OK	OK
5.8 gHz Video Transmitter	OK	▨	OK	OK	OK	OK
2.4 gHz RC Unit	OK	OK	▨	OK	OK	OK
915 mHz 3DR Telemetry	OK	OK	OK	▨	OK	OK
Altimeter 1	OK	OK	OK	OK	▨	OK
Altimeter 2	OK	OK	OK	OK	OK	▨

Table 7, EMF Testing for Interference

We tested each electrical transmitting/receiving component singly and in various combinations until all components were tested simultaneously. We experienced no interference as was expected because each of the components had its own frequency. None appeared to interfere with either of the altimeters.

III.2i Suitable Parachute Size and Ground Test Results

Rocksim calculated the fully loaded weight for the rocket at 13.75 pounds while descending. We've looked at Top Flight, Wildman Rocketry, LOC Precision, and SkyAngle parachutes and compared their specifications to what Rocksim predicted would be a suitable size and descent rate. Rocksim indicated that a 50 inch parachute would have a descent rate of 24 fps. We settled on the LOC Precision 50 inch parachute for the main and a SkyAngle Drogue (24 inch) parachute for the drogue. Both are made with Rip-Stop coated nylon fabric with shroud lines of heavy duty braided nylon on the LOC Precision and nylon webbing on the SkyAngle.

Salish Star has been launched four times as of this writing. The recovery systems have proven themselves to be robust and they have performed their designed function flawlessly.

Drogue		
Volume =	282.7	in^3
Dia =	6	inch
Len =	10	inch
Desired Pressure =	20	psi
mass BP =	2.92	grams
Ejection F =	565.5	lbf
Main		
Volume =	424.1	in^3
Dia =	6	inch
Len =	15	inch
Desired Pressure =	20	psi
mass BP =	4.38	grams
Ejection F =	565.5	lbf

Table 8, Black Powder (BP) Calculations

We used 3 2-56 nylon shear pins on the drogue/ebay connection and 4 2-56 shear pins on the main/ebay connection. Ground testing and actual flight verified the BP quantities.

III.2j Safety and Failure Analysis

Patrisha is RPGs' Safety Officer

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

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

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.
Recovery 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.
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.
Avionics 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.
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.
Payload Failures	**Potential Effects of Failure**	**Failure Mitigation**
MV fails to unfold	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during deployment.	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during descent.	Payload experiment fails.	Testing and careful packing.
GPS system fails to record the position of the rocket on the ground.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
GPS system fails to record the position of the rocket while in the air.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more motors fail to start.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more propellers become entangled in the recovery harnesses.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
Wind too strong for towing.	Rocket/payload land safely under parachute.	Design more powerful MV
Battery looses power.	Rocket/payload land safely under parachute.	Fully charged batteries of sufficient size to complete mission.
MV lands on rocket/parachutes after fin can contacts the ground and crashes.	Damage to MV, rocket, and or parachutes.	Proper harness lengths

MV lands further than the 100 feet mission criteria.	Failure of that mission criterion.	Test

Table 9, Safety, Failure Analysis, and Mitigation

III.3 Mission Performance Predictions

III.3a State the mission performance criteria.

The goals of Team RPG’s rocket is to safely deliver the payload to an altitude above 3,000 feet, deploy the MV and then safely descend to the earth using the redundant dual deploy recovery system while the vehicle is being towed back to the launch area.

III.3a.1 Detailed Mission Performance Criteria

Successful motor ignition
Successful liftoff
Successful drogue parachute deployment
Successful MV deployment
Successful main parachute deployment
Successful autopilot-controlled MV tow vehicle back to launch area
Successful landing
Successful reaching the target altitude within ±30 feet

III.3b Flight Profile Simulations

III.3b.1 CTI J760 Reload Simulation/Actual Test Flight

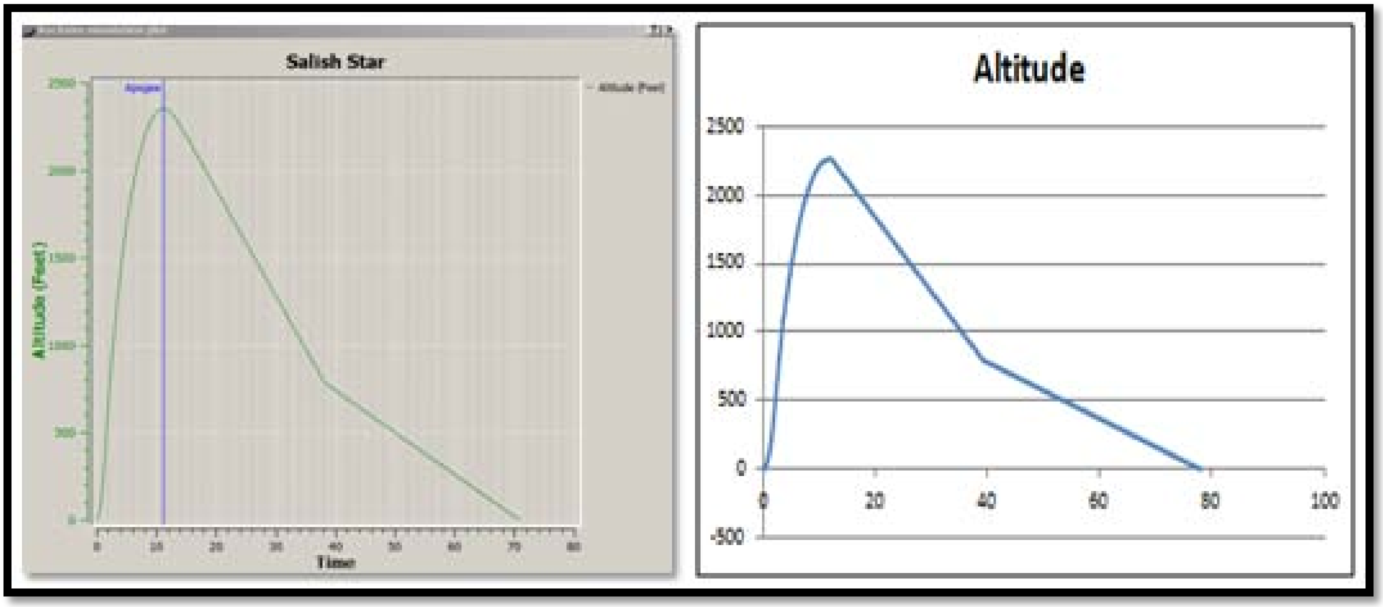


Figure 29, Altitude – Simulated (2,352 ft) versus Actual (2,263 ft)

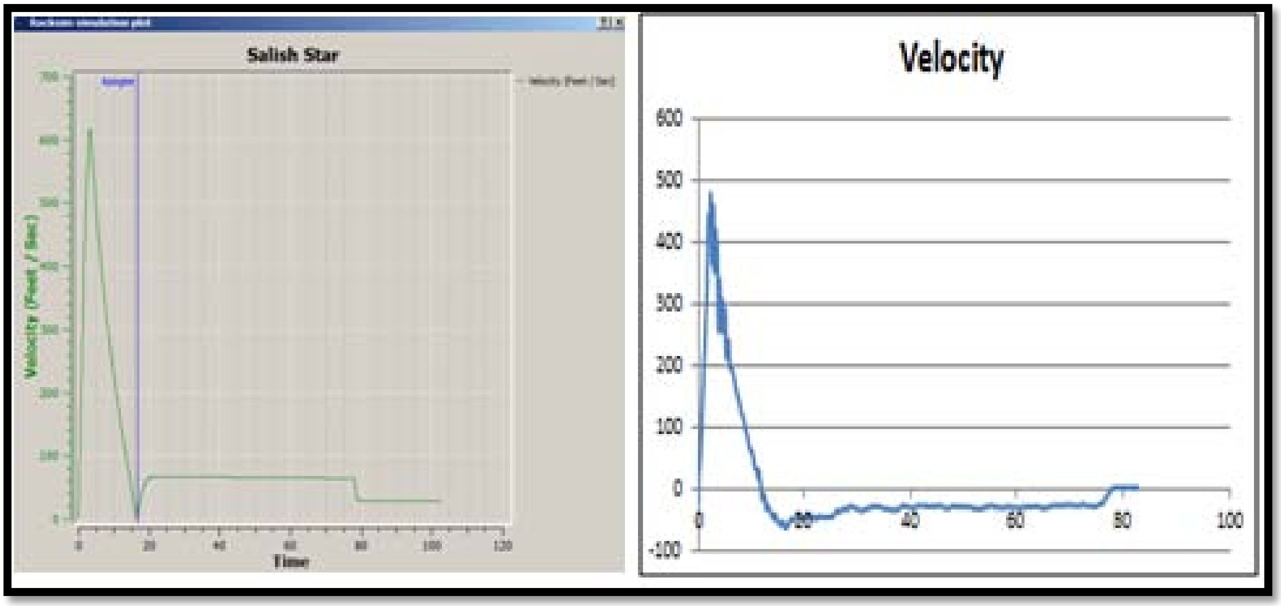


Figure 30, Velocity – Simulated (522mph) versus Actual (480 mph)

III.3b.2 CTI K445 Reload Simulation

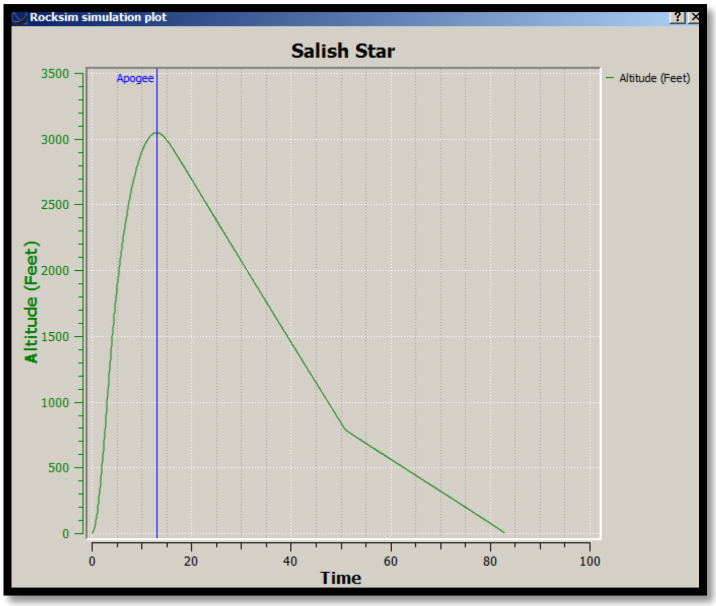


Figure 31, Simulated Altitude with CTI K445 (3,049 ft)

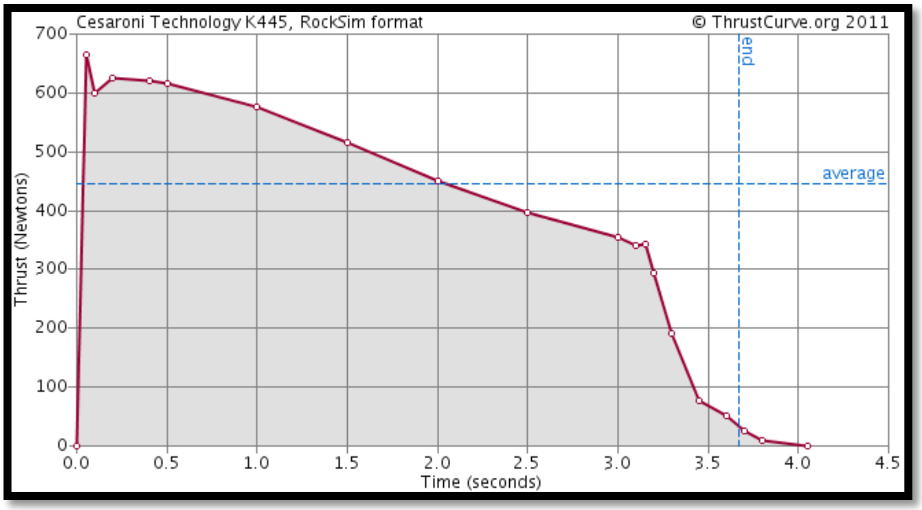


Figure 32, CTI K445 Thrust Curve

III.3c Thoroughness and Validity of Analysis

After the first test flight, we adjusted the Coefficient of Drag number provided by RockSim simulations to more accurately reflect the actual flight data. Subsequent test flight predicted altitudes were between 2% - 4% higher than the actual flights. Figures 29 and 30 reflect the most recent simulation prediction and the actual test f flight.

III.3d Static Stability Margin

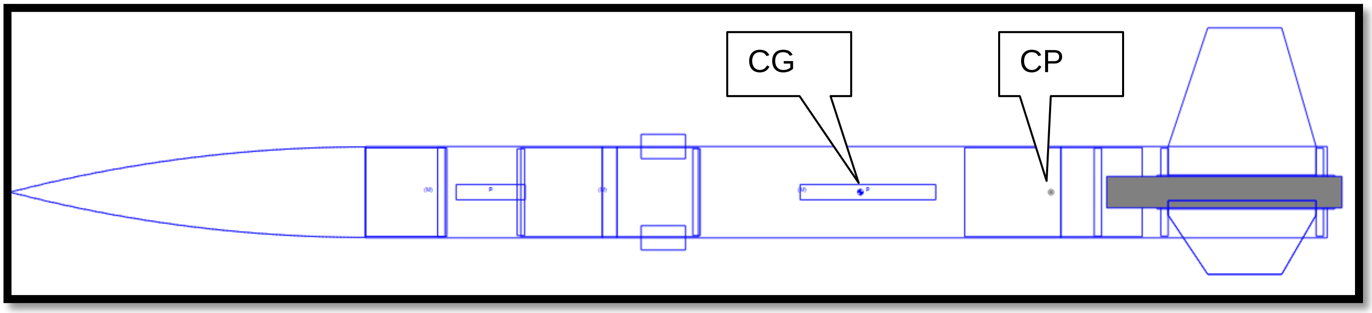


Figure 33, Center of Gravity (CG) and Center of Pressure (CP) Positions

CG: 57.44 inches CP: 70.33 inches Margin: 2.11

III.3e Kinetic Energy

USLI requires a 75 lb/ft^3 Kinetic Energy (KE) impact maximum for each section of the rocket. We used this formula to calculate the KE for a 50” main parachute and a 28” drogue parachute using the simulated data from RockSim.

KE=Kinetic Energy
m=mass in pounds
V=velocity in feet per second

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

Kinetic Energy by Section		Weight Lb	KE Drogue (fps)	KE Main (fps)
Section 1	Fin Can Aft Airframe MV	7.70	417	67
Section 2	Ebay	1.19	64	10
Section 3	Fwd Airframe Nose Cone	5.98	324	52

Table 10, Kinetic Energy Calculations

The USLI requirements stipulate that the KE of each section is to be 75 foot pounds/second or less. The three rocket sections have a calculated Kinetic Energy force well below the maximum KE allowed. The calculations indicate that ground impact of each section is significantly higher (64-417 fps) if the rocket descend entirely under the drogue parachute compared to the ground impact (10-67 fps) while under the main parachute. The design of the MV is to tow the rocket and in doing so will contribute a yet-to-be-determined amount of lift that will lessen the impact fps even more.

III.3f Launch Vehicle Altitude and Drift for Various Wind Speeds

Latitude: 34° 38' 50" N
Longitude: 86° 33' 11" W
Elevation: 827 feet
Wind Speed is Constant

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

Distances are in Feet	Wind Speed (Kts)				
	0-2	3-7	8-14	15-25	20-30
Rail Angle at 0^{o}	159	174	614	735	1,329
Altitude	3,044	3,044	2,935	2,924	2,831

Table 11, Altitude and Drift Predictions

Table 11 is based upon RockSim 9 predictions using the CTI K445 reload. Until we can test the MV and its towing capabilities, we cannot factor in what its effect will have on the drift. We are planning on it returning the *Salish Star* to within 100 feet of the launch area.

III.4 Vehicle Verification

III.4a Requirement Satisfaction and Verification

We will verify all components and subsystems for soundness, suitability, and flight worthiness according to our verification plan (Appendix B). 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 have provided a starting point for safety and flight success probability.

System	Subsystem	Functional Requirement	Design Feature	Evaluation	Verification	Status
Airframe: Tie together flight components, recovery system, and payload	Nose Cone	Reduces rocket's drag, houses GPS unit	Designed to High Power Rocketry standards, fins are through-the-wall mounted	Team & Advisor Visual Inspection, Rocksim 9, Simulations, NAR Mentor Inspection	Successful Test Flights	Completed and successfully tested
	Ebay Ring	Avionics power switch location				
	Fwd Airframe	Houses drogue parachute				
	Aft Airframe	Houses main parachute and MV				
	Fin Can	Houses motor mount and provide mounting area for fins				
	Fins	Provide flight stability				
Recovery: consists of hardware, parachutes, and electronics to ensure a safe landing	Main Parachute	Control rocket's descent to a maximum of KE=75 flbs	Designed to keep descent Kinetic Energy to 75 lb ft^3 or less.	Team & Advisor Visual Inspection, Rocksim 9, Simulations, NAR Mentor Inspection	Successful Test Flights	Completed and successfully tested
	Ebay	House recovery avionics	Designed to High Power Rocketry standards.			

	Drogue Parachute	Control rocket's descent from apogee to main parachute deployment to minimize drift from launch area	Designed to keep descent rate in the 80-90 fps range to minimize drift.			
	Avionics	Altimeters to control recovery deployment and to record flight data	2 - Dual deploy PerfectFlite StratoLogger altimeters to ensure parachute deployment	Multiple Ground Tests that demonstrate successful parachute ejection	Successful Ground Tests and Successful Flight	
Payload: functional requirement of USLI project	Multirotor Vehicle	Tow vehicle to return rocket to launch area	Designed as a light weight, foldable quadcopter with GPS autopilot and a 2.54 GHz Radio Control as backup.	Multiple Ground Tests and flight tests both with RC control and under autopilot	Successful Flight	Completed and awaiting testing
	Cameras	Flight data collection	Light weight mini-cameras designed to record the entire flight as well as being strategically placed to video significant flight events.	Team & Advisor Visual Inspection, ground tests	Successful Flight	

Propulsion: provides thrust to launch rocket so that the rocket can achieve its mission and objectives	Motor mount	House reloadable 54 mm rocket motor	Designed to securely contain and restrain a K-powered 54mm reloadable rocket motor. Through-the-wall fin mounting adds additional support both to the fins and to the motor mount.	Team & Advisor Visual Inspection, Rocksim 9, Simulations, NAR Mentor Inspection	Successful Flight	Completed and successfully tested

III.4b Verification Schedule and Results Analysis

Task	Scheduled	Actual	Result
Black Powder ejection test with altimeters	1/4/13	1/4/13	Successful
Salish Star launch and recovery	Scheduled each weekend from 1/6/13 – 3/31/13	1/13/13	Successful
		2/17/13	Successful
		3/03/13	Successful
		3/09/13	Successful
Flight test of dual deployment recovery system		1/13/13	50%
		2/17/13	75%
		3/03/13	Successful
		3/09/13	Successful
Drogue deployment during flight test		1/13/13	Successful
		2/17/13	Successful
		3/03/13	Successful
		3/09/13	Successful
Main deployment during flight test		1/13/13	Successful
		2/17/13	Successful
		3/03/13	Successful
		3/09/13	Successful
Safe main parachute-to-ground descent rate		1/13/13	Successful
		2/17/13	Successful
		3/03/13	Successful
		3/09/13	Successful
Predicted altitude		1/13/13	80%
		2/17/13	93%
		3/03/13	90%
		3/09/13	96%
Launch rail and GSE equipment function		1/13/13	Successful
		2/17/13	
		3/03/13	
		3/09/13	
Recovery team performance		1/13/13	Successful
		2/17/13	
		3/03/13	
		3/09/13	
Range setup		1/13/13	Successful
		2/17/13	
		3/03/13	
		3/09/13	

Safety implementation		1/13/13 2/17/13 3/03/13 3/09/13	Successful

III.5 Safety and Environment (Vehicle)

III.5a Safety and Mission Assurance Analysis

Patrisha is RPGs Safety Officer

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

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

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.
Recovery 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.
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	Team risks not launching the rocket unless repairs can be made.	Pack components safely and securely for transport and have

launch site.		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.
Avionics 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.

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.
Payload Failures	**Potential Effects of Failure**	**Failure Mitigation**
MV fails to unfold	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during deployment.	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during descent.	Payload experiment fails.	Testing and careful packing.
GPS system fails to record the position of the rocket on the ground.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
GPS system fails to record the position of the rocket while in the air.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more motors fail to start.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
One or more propellers become entangled in the recovery harnesses.	Reduced towing power of MV.	Obtain manual RC control and pilot rocket & MV back to launch area.
Wind too strong for towing.	Rocket/payload land safely under parachute.	Design more powerful MV
Battery looses power.	Rocket/payload land safely under parachute.	Fully charged batteries of sufficient size to complete mission.
MV lands on rocket/parachutes after fin can contacts the ground and crashes.	Damage to MV, rocket, and or parachutes.	Proper harness lengths
MV lands further than the 100 feet mission criteria.	Failure of that mission criterion.	Test

III.5b Top Failures Likelihood and Potential Consequences

Our top concerns involve our MV payload. It is the least tested item of our USLI project, and, of course, the key element to our success. As of the writing of this report, *Salish Star* has flown once with the MV. This test did not involve powering up the MV. It successfully tested its deployment and orientation during descent.

Failure of any one of the items in the chart below will result in the experiment having an unsuccessful conclusion. None will involve any safety hazards or endanger anyone or anything (other than our pride).

We are attempting a rather aggressive project; however; as has been the case in all of our USLI projects, this is ground that none of us have any experience in. Having four successful launches under our belt, and two very competent MV pilots using the RC system, we are confident that our project will be successful.

Payload Failures	Potential Effects of Failure	Failure Mitigation
MV becomes entangled during deployment.	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during descent.	Payload experiment fails.	Testing and careful packing.
GPS system fails to record the position of the rocket on the ground.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
GPS system fails to record the position of the rocket while in the air.	MV tows rocket in wrong direction.	Obtain manual RC control and pilot rocket & MV back to launch area.
Wind too strong for towing.	Rocket/payload land safely under parachute.	Design more powerful MV

III.5c Update of Personnel Hazards and Data

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

The safety officer is responsible for having all MSDS for hazardous materials. Complete lists of the MSDS sheets are posted in the workshop area. Also, the safety officer shall inform the team of any material or substance hazards before use. As new materials with no MSDS sheets are encountered, the safety officer locates them and posts them both on the website and in our work area. Furthermore, the safety officer makes certain that all team members are familiar with the new MSDS sheets. A sample MSDS sheet and hyperlinks to the MSDS sheets are located on our website:

http://blogs.nwic.edu/2012usli

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

Figure 34, PPE latex gloves while working with epoxy resin

Figure 35, MSDS and PPE

Safety glasses shall be worn when any member is using a tool that may create fragments of a material (Dremmel tool, hammer, band saw, etc.)
Power tool use requires at least two members be present. All team members shall wear the appropriate PPE.

Safety is the responsibility of all team members. The safety officer shall make all team members aware of any hazards, but individual team members shall be responsible for following all regulations and guidelines set forth by the safety officer.

A new hazard is the operation of the MV. It has four 11 inch thin propellers that spin as fast as 8,800 rpm. We have dubbed it the people blender. While under Radio Control, the MV behaves very well, responding to pilot input as designed. While under our autopilot, things are a bit different. It takes three seconds for the RC pilot to regain control from the autopilot, during that time the MV can cover quite a bit of distance both vertically and horizontally. We have instituted additional safety rules and procedures to ensure personnel and property safety.

Figure 3, Carrie Practicing MV Piloting

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.
Being attacked by the MV	Harm to team members (possible hospitalization).	Safety check lists, adequate separation between MV and personnel, an observer as well as a pilot during any flight

		testing.

III.5d Environmental Safety at the Northwest Indian College Launch Complex

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

III.6 Payload Integration

III.6a Integration of Payload into the Launch Vehicle.

The MV's arms fold in a downward position. This allows the MV to slide into the rocket's lower airframe. An 18 inch length of ½ inch PVC supports the MV while in the fin can. This prevents the propellers from being damaged during the launch. The MV is attached 10 feet above the aft attachment point with ½ inch tubular Kevlar. The upper harness which is 12 feet long, (tubular Kevlar) is attached to the top of the MV and continues to the aft end of the ebay. A protective cap is covers the electronics and this in turn, is followed by the bulkhead which further protects the electronics and provides a bearing surface for the upper recovery harness.

Both ground testing and actual flight testing has proven that the MV will deploy without entanglement. Furthermore, the bulkhead, with a minimum two inch layer of fire retardant material, has shown no indication of black powder discharge marks, thus ensuring the protection of the MV's electronics.

Heavy duty swivels (Spro 1580 pound) are located at each attachment point throughout the rocket's recovery harness system to help stabilize the MV during descent.

III.6b Element Compatibility and Interface Fit

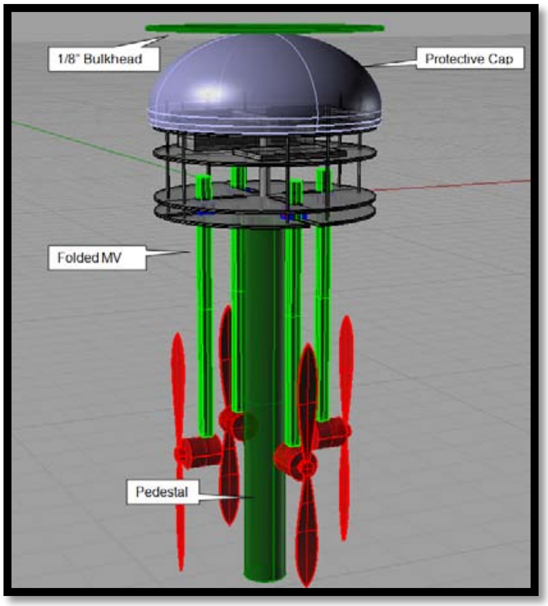


Figure 37, Folded MV Concept
(aft airframe removed for clarity)

Figure 38, Arms Folded

Figure 39, Arms Extended and in Flight Mode

Figure 40, Arms Folded with Support Pedestal and Kevlar Harness

Figure 41, Protective Cover

III.6c Describe and Justify Payload-Housing Integrity

The payload housing is the carbon fiber after airframe. The recovery harness is fastened to a 3/16 inch forged eyebolt installed in the fin can. The aft airframe is connected to the fin can with 3/16 inch bolts and T-nuts. Its primary function is to house the MV and 25% of the main recovery harness in the lower ¾ length and the remaining 75% of the recovery harness and the main parachute in the upper portion of the aft airframe. The tubular Kevlar recovery harness passes through the center of the MV for several reasons:

1. Deployment forces will be directed through the center of the MV
2. Swivels will assist in allowing the MV to operate with a minimum of interference from the gyrating descending sections.
3. The recovery harness is placed the farthest from potential entanglement with the propellers.
4. Towing forces will be directed at the center of the MV.

III.6d Demonstrate Integration

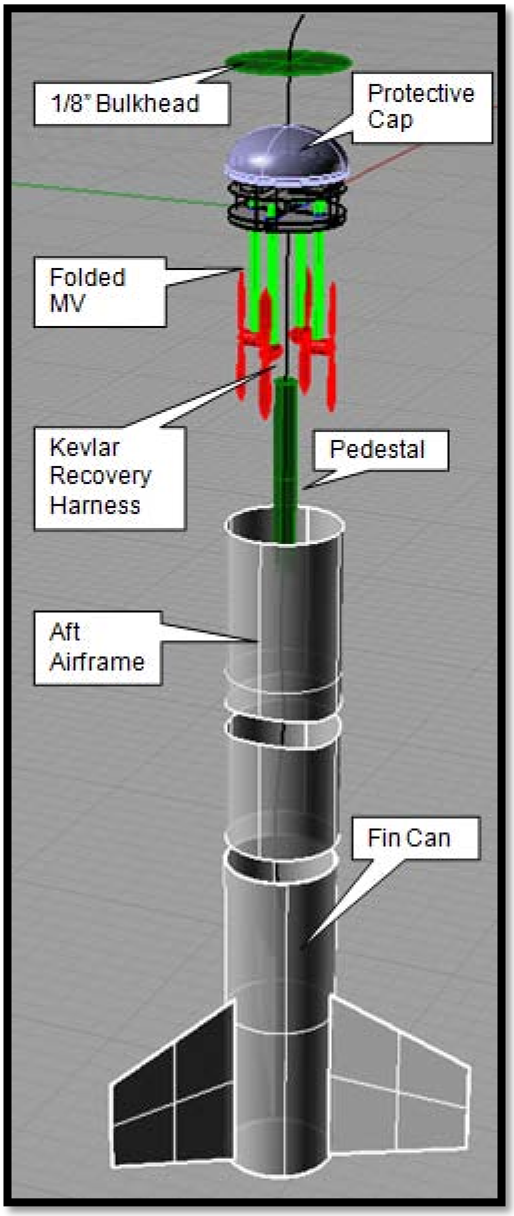


Figure 42, Integration into Aft Airframe

Figure 43, Right, Aluminum Recovery Harness Pass-Through Tube

IV.0 Payload Criteria

IV.0a Experiment Concept

The rocket will carry a multirotor vehicle (MV) that will become a tow tug after the rocket descends to 800 feet above ground. The MV, as an Unmanned Aerial Vehicle (UAV), will tow the rocket back to the launch area prior to landing. The MV will be deployed at 800 feet simultaneously with the main parachute and its autopilot will be autonomous with Radio Control (RC) backup. This will give the MV time to acquire its GPS lock. The rotors will start after the main parachute is deployed at 800 feet. After the rotors start, the autopilot will maneuver the MV and its tethered vehicle toward the launch area.

The MV will tow the rocket to the launch area providing the winds are not too strong. We are still testing the towing power of the MV. Regardless of the wind strength, the MV will move the vehicle further towards the launch area than what would occur without the MV.

IV.0b Uniqueness and Significance

We believe that this is one of the first attempts at towing a rocket back to the launch pad with a multirotor vehicle. To add to this, we are planning on doing so with an GPS controlled autopilot. The is significant for us, because if this proves feasible, we will be able to launch our larger rockets with little concern for the water covered recovery area during much of the winter months.

IV.1 Science Value

IV.1a Science Payload Objectives

The objective of the payload is to learn engineering and aerodynamic skills. By building a MV and having it successfully bring the rocket back to the launch area without human interaction will prove to be a useful way for us to launch and retrieve our rockets in our often water-covered recovery area.

Our major reason for doing this is 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 successes.

IV.1b Mission Success Criteria.

- MV deploys as designed
- MV tows rocket vehicle to launch area
- MV lands with rocket within 100 feet of launch tower without human interaction

IV.1c Experimental Logic, Scientific Approach, and Method of Investigation.

RPG's 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.

Since most of everything is new to us, we use the Internet to assist our learning. Learning is through investigation and actual "doing" things. We, of course, try to anticipate any hazards and to mitigate them.

After having built and manually tested the MV we will be testing it in full flight. The first flights will be held to an altitude of 1000 feet. After successful launches and recoveries, we will launch to higher altitudes as time permits. Data collection and analysis will allow us to make any programming changes or other modifications necessary to obtain consistent and accurate results.

IV.1d Detailed Experiment Procedures

Test, evaluate, modify, and repeat as necessary.

A typical non-rocket deployed MV test session follows this order:

- Test battery voltages
- Power up the system
- Fly the MV manually
- Fly the MV under autopilot
- Power down the system
- Analyze the data
- Trouble shoot mechanical, electrical and/or programming issues.

A typical rocket deployed MV test session follows this order:

- Test battery voltages
- Power up the system
- Launch rocket
- Check autopilot functioning
- Test manual over ride
- Return MV to autopilot mode
- Power down the system
- Analyze the data
- Trouble shoot mechanical, electrical and/or programming issues.

IV.2 Designing and Building the MV

The Quadcopter multirotor vehicle (MV) that is the payload must be able to fit into the rocket and slide out easily. In order to meet this requirement, The MV has arms that have a pivot point and fold down so they are vertical instead of horizontal to the body, which allows the MV to slide into the rocket with ease. It is our intention that we will be able to control the actions of the MV through a 3DR radio that connects through the Ardupilot-Mega (APM) Mission planner wirelessly using the 915 mHz band.. Other uses for the APM Mission planner are to test and ensure that all motors are powered and spinning in the correct directions, and to calibrate the Spektrum Dx6i transmitter that we are using to manually fly the MV when not in autopilot mode.

More recently we have been having an issue with the transmitter and one of our RC receivers, a Spektrum clone, on the MV, it is difficult to bind the two and use them as desired and when the power on the transmitter is off, the propeller motors will all of a sudden go into full power creating a hazardous situation. We have learned that in order to avoid this, we must leave the transmitter on and then disconnect the batteries and then turn off the RC transmitter. By turning the transmitter off first, we have inadvertently activated the RC receiver’s “Failsafe” mode which is to return to launch (RTL). Also, this particular receiver would not always allow us to disarm the MV. We are replacing it with a new Spektrum receiver.

Over the course of a month, we have been working diligently every day, in order to become comfortable flying a MV should we have to manually take over with the RC transmitter and return the rocket to our location to the best of our ability.

We purchased a DIYdrones Arducopter in July 2012 to test the feasibility of our TOR project. Throughout the course of interaction with the Arducopter, we have learned about the electronic systems that power the Arducopter and our MV. The two systems, the Arducopter and our MV, are similar in operation. So, the following remarks refer to both systems. The key electronic unit is the APM 2.5 board that powers and controls the thrust of each individual motor, which in turn, control the direction and speed of MVs. The APM 2.5 has gyroscopes, accelerometers, magnetometer, as well as a GPS unit and connection points for the 3DR telemetry system. It is a fully programmable autopilot system that connects via USB to a computer and the APM Mission Planner software. The receiver allows us to fly the MV manually if the autopilot were to malfunction. The 3DR telemetry system also allows us to send flight commands to the APM with a laptop computer base station that has the 3DR receiver attached.

The 11 volt 2200 mah 3 cell Lithium Polymer battery is connected to a power distribution board which distributes the power to each of the four motors via the Electronic Speed Controllers (ESC) and also provides 5 volts to the RC receiver and the APM 2.5.

We also have a 5.8 gHz video camera that will transmit live video to our base station. We have successfully used the camera while flying the Arducopter locally and have received excellent video from 150 meters horizontally and vertically, the practical limit of our flight testing area on the NWIC campus.

As usual, this is a new process for the entire Northwest Indian College Space Center team members. We have learned a great deal about MV electronics and technology. We have learned a great deal about GPS technology, 3DR radio telemetry, and of course, how to use RC equipment and to fly and RC controlled MV.

We are very confident in our RC piloting skills and have flown the MV in wind speeds up to 20 kts with little difficulty.

We have 3 small RC quadrotor vehicles that we have studied extensively to determine optimal airframe size, motor power, and battery size. We also have a large commercially built quadcopter, the Arducopter. We have built two experimental multirotor vechicles, a tri-copter and a small quadcopter and our MV, the Mini-Mincer.

We have built a motor stand to measure the motor thrust in order that the combined thrust of the motors provide enough power to tow the rocket. We’ve also constructed a propeller balancer so that we can minimize the vehicles’ vibration which may affect the GPS and the stabilization systems.

Figure 44, Motor Test Stand

Each of the MV motors produces about 1.5 pounds of thrust. Conventional wisdom indicates that factoring in the weight, drag, and electrical efficiency, one can rely on an 80% working lift capability. Thus, our MV should produce 4.8 pounds of useful thrust. This is not near enough to carry the rocket, but it is enough to drag it while it descends back to the launch area.

Figure 45, Jessica Prop Balancing

The MV's fuselage of will be constructed of aircraft-grade plywood and the arms will be constructed 5/8 inch fir. The strength-to-weight ratio, the price, and the availability helped make the decision to choose these building materials.

Figure 46, Mini-Mincer Front View

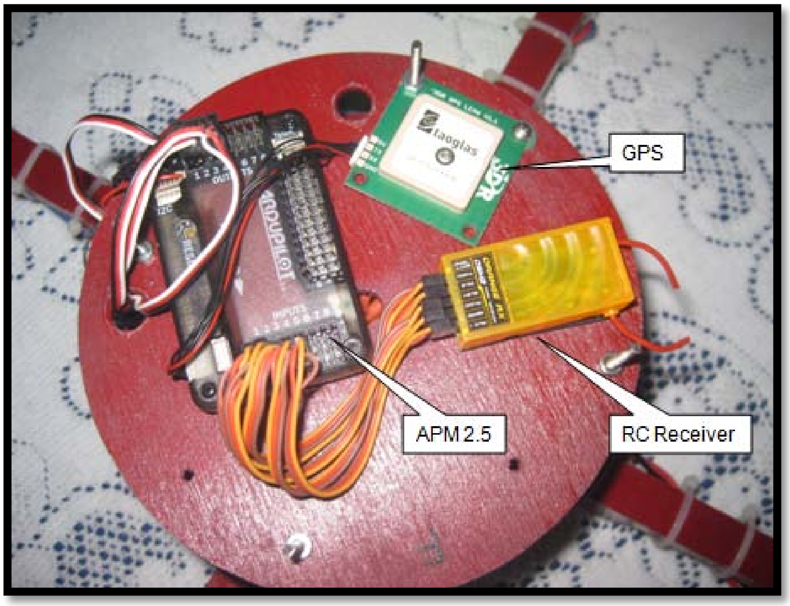


Figure 47, Top View

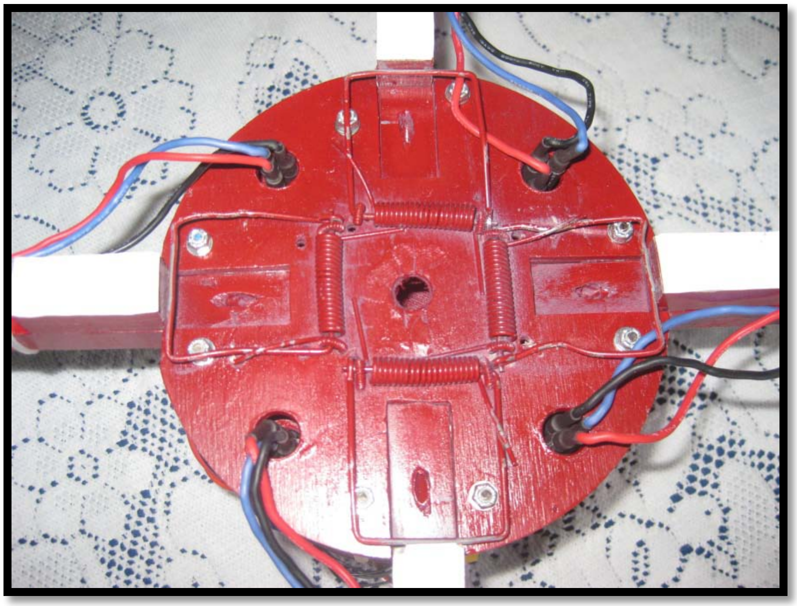


Figure 48, Bottom View Showing Mouse Trap Arm Extenders

We cannibalized the springs from four mouse traps. These will extend the arms and then fall in place behind wood blocks to lock the arms in their flight position. The wood block have a plastic covering to ease the sliding of the mouse trap arm over the wooden block.

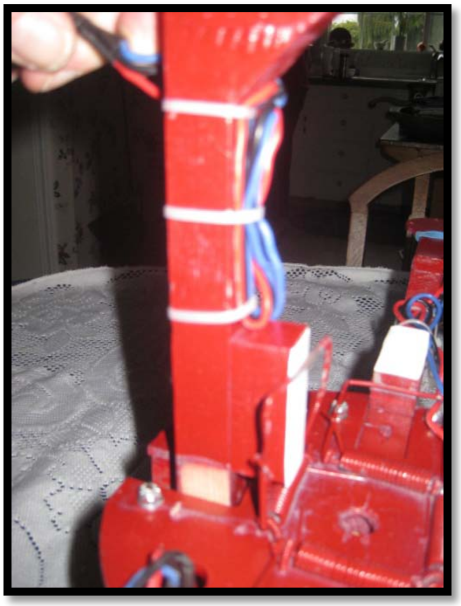


Figure 49, Arm Folded Showing Mouse Trap Spring and Locking Block

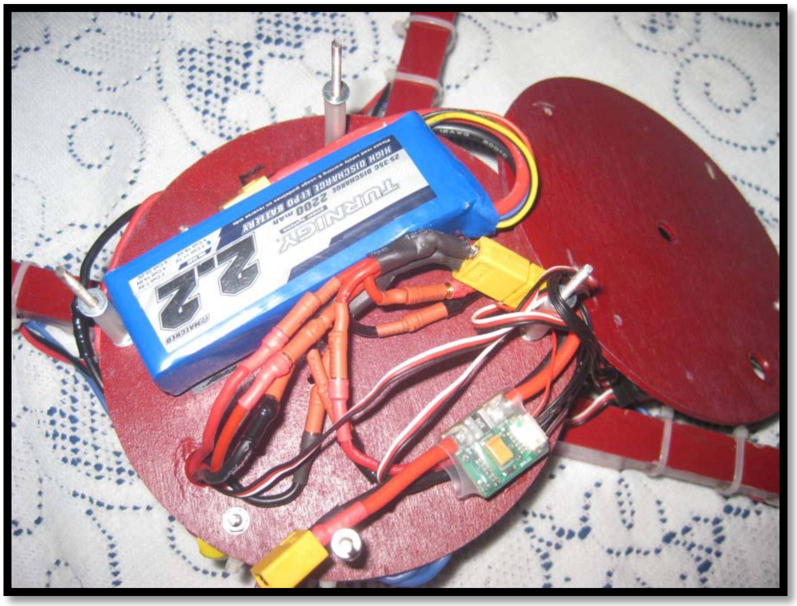


Figure 50, Mid-Deck with Battery and Power Distribution

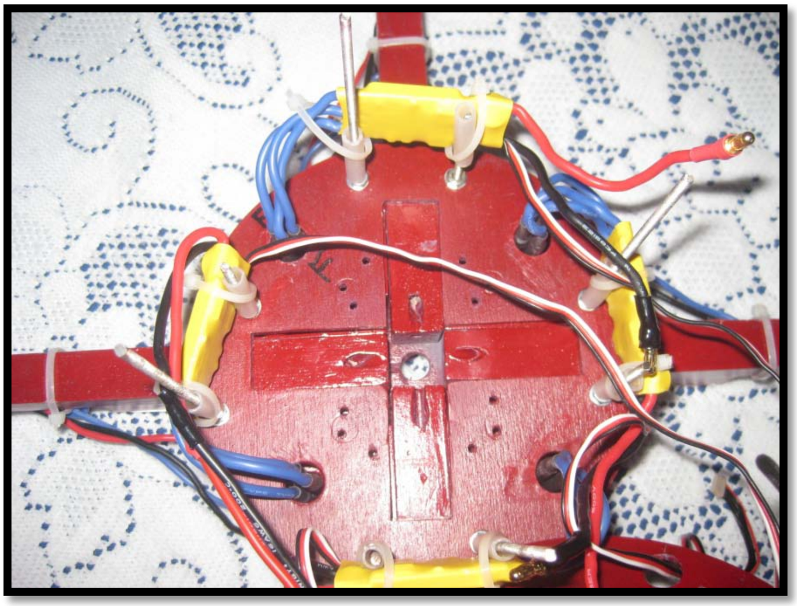


Figure 51, Top Motor Deck with ESC and Folded Arm Slots

IV.2a Designing the Autopilot Electronics

We are starting with an ArduoPilot 2.5 which is an open source system based upon the Arduino micro controller. The ArduoPilot ‘s Arduino integrates the GPS and magnetometer for navigation. The navigation module interfaces with the flight control board to manipulate the motors for directional and stability control.

IV.2b Programming the Autopilot

Programming considerations included:

1. waking the autopilot at 800 feet;
2. navigating to the set waypoints;

3. controlling the altitude descent rate so that the MV can bring the rocket back to the launch area prior to grounding; and,
4. having the MV land the rocket and itself without entanglement with the parachutes/recovery harnesses or the rocket.

IV.2c Designing the MV Deployment and Towing Scheme

We have designed and tested our dual deploy recovery system that will allow us to “string” the rocket components, the protective container, and the MV in a single line. See Figure 42 for a conceptual drawing of this plan. We have tested the MV deployment system and it has worked as designed. The Mini-Mincer stayed in a horizontal attitude throughout the descent and showed no signs of becoming entangled in any of the recovery harnesses.

IV.2d Learning to fly the MV

None of the team members or advisors are/were RC pilots. We have several multirotor vehicles ranging in size from 4 inches between motors to 20 inches between motors. The 4 inch quad is the Ladybird and we have 2 MQX quadcopters, a scratch build tricopter and a scratch built quadcopter and our MV, the Mini-Mincer. The commercial MVs are ready-to-fly multirotor aircraft from hobby shops. The RPGs have two accomplished pilots, Carrie and Christian.

Figure 52, Arducopter in Hover

Figure 53, Christian Flying MQX Quad

Figure 54, Arducopter Autopilot Test

We have flown Mini-Mincer once on March 9, 2013. This was a test to:

- see if the deployment system functioned as designed;
- check the arm extending mechanism;
- examine Mini-Mincer's orientation during descent; and,
- see if there were any real or potential entanglement issues with the recovery harness and the propellers.

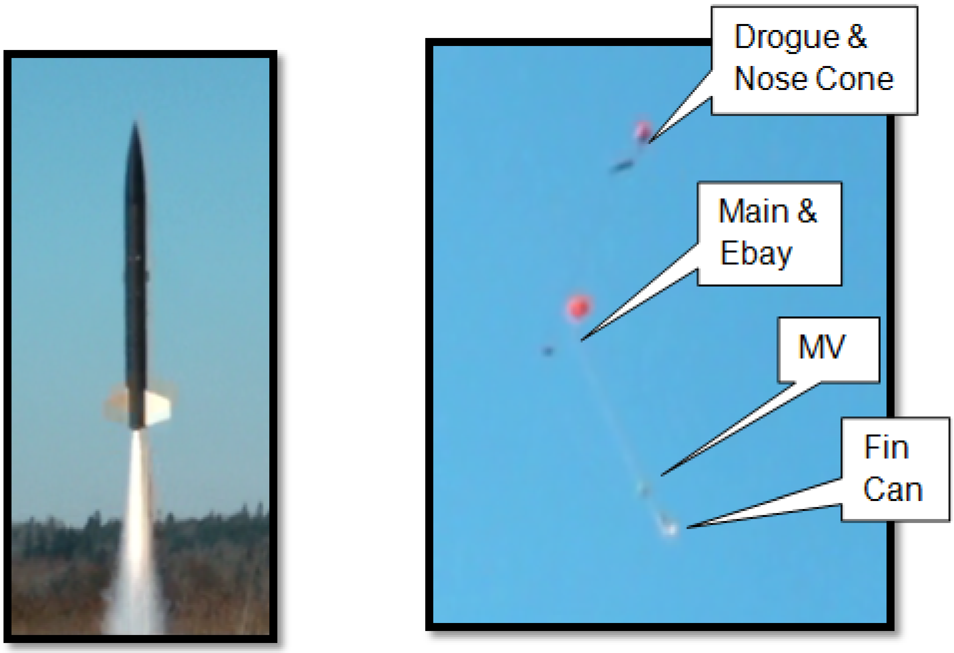


Figure 56, Mini-Mincer Deployment

As can be seen from figure 56, the deployment system functioned as designed.

Figure 57, Views from the Up-Pointing Camera

The camera that was pointing up recorded the successful deployment of our MV (Figure 57), Mini-mincer. Furthermore, the recordings showed that the MV stayed in a near horizontal position throughout the descent irrespective of the swaying vehicle sections. It appeared that there is little risk of the propellers becoming entangled in light wind conditions.

Figure 58, Touchdown

Figure 58 shows the positions of the recovery system 0.1 seconds after the fin can landed. The main parachute drifted down wind and stayed clear of Mini-Mincer. The operational procedure is to have Mini-Mincer shutdown upon reaching an altitude of 5 feet agl and/failing that, upon contact with the ground. The pilot will also be able to shut the system down either with the RC transmitter or the 3DR radio.

IV.3 Payload Safety and Environment Plan

IV.3a Safety Officer

Patrisha is the safety officer.

IV.3b 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 pages 15, 43 and 47 for more details.

IV.3c Personnel Hazards

Personnel hazards have discussed elsewhere. Please see page 49 for more details.

IV.4d Payload Environmental Concerns

Nothing in the payload constitutes an environmental hazard.

V.0 Launch Operations Procedures

V.1 Checklists

Please see Appendices E-J for the following checklists:

Check List	Responsible Person
Recovery preparation	Nicole
Motor preparation	Carrie
Igniter installation	Kiya
Setup on launcher	Brandon
Launch procedure	Christian
Troubleshooting	Kien
Postflight inspection	Brandon

VI.0 Project Plan

VI.1 Budget Plan

Qty	Description		Total Price
	Scale Model Rocket		
1	LOC Precision Vulcanite Kit	$74.95	$74.95
2	Tube Couplers - 4"	$7.54	$15.08
1	1/4" Plywood	$6.99	$6.99
4	CTI G79	$26.99	$107.96
			$204.98

	Full Scale Rocket		
1	6" x 90" Carbon Fiber Airframe	$499.00	$499.00
1	6" x 12" Carbon Fiber Coupler	$94.60	$94.60
1	6" x 24" Fiberglass Nose Cone	$83.50	$83.50
2	G10 Sheet, 3/32 x 12 x12	$13.30	$26.60
1	1/4" Plywood	$6.99	$6.99
2	G10 Sheet, 1/8 x 12 x12	$17.10	$34.20
			$744.89

	Motors for Full Scale Rocket		
4	CTI 54mm 2 grain reload	$72.95	$291.80
1	CTI 54 mm 2 grain motor casing	$51.65	$51.65
			$343.45

	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	55" Parachute	$45.95	$45.95
1	28" Parachute	$16.75	$16.75
1	~~RDAS-Tiny altimeter~~	~~$300.00~~	$0.00
2	StratoLogger Altimeter	$99.95	$199.90
			$362.60

Payload and Tracking System			
1	GPS Unit	$295.00	$295.00
1	FPV Camera	$195.00	$195.00
1	Science Payload	$2,300.00	$2,300.00
			$2,790.00

Total **$4,645.83**

Travel			
8	Huntsville Travel	$983.00	$7,864.00
4	Huntsville Lodging	$453.00	$1,812.00
			$9,676.00

Project Income			
	Outreach		$4,000.00
	Washington State Space Grant		$5,000.00
	Tribal Support		$10,000.00

$19,000.00

Budget Summary	
Scale Rocket	$204.98
Competition Rocket	$744.89
Propulsion	$343.45
Construction Supplies	$200.00
Recovery	$362.60
Electronics & Payload	$2,790.00
	$4,645.83

Travel & Lodging	$9,676.00

Project Income	
	$19,000.00

VI.2 Funding Plan

We are currently seeking funds from neighboring tribe's Community Action Grants. We have done two "bake sale" fund raising activities and collected $223.00

VI.3 Timeline

Please see Appendix C.

VI.4 Educational Engagement

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

- Washington Space Grant Annual Poster Session
- SACNAS Conference Presentation
- Eagle Ridge School
- Lummi Nation Tribal School
- Bellingham Middle School
-

We continue to be in communication with the school districts in Whatcom County. 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.

VII.0 Conclusion

The RPGs are confident in the design that we have created to meet the overall mission requirements in the USLI competition. We have conducted multiple launches, each has been satisfactory in most of the test elements. The complete design will 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 is safe as well as successful.

The payload presents many challenges to us. It has been an exciting endeavor to have created a MV and to have learned to fly it.

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 RPGs is dependent upon dedication, hard work, and the excitement of doing something that few of us have previously done.

Appendix A – Milestone Review Fly Sheet

Milestone Review Flysheet

PDR, CDR, FRR

Institution Name	Northwest Indian College

Milestone	FRR

Vehicle Properties	
Diameter (in)	6
Length (in)	83
Gross Liftoff Weight (lb)	15.3
Launch Lug/button Size	0.630” x 0.680” (large)
Motor Retention	10-24 Tie Down Bolts

Motor Properties	
Motor Manufacturer	CTI
Motor Designation	K445
Max/Average Thrust (N/lb)	664/403.86 N 177.1/102.85 lbs
Total Impulse (N-sec/lb-sec)	1636.3/333.68
Mass pre/post Burn (lb)	3.08/1.38

Stability Analysis	
Center of Pressure (in from nose)	70.3
Center of Gravity (in from nose)	57.6
Static Stability Margin	2.09
Thrust-to-Weight Ratio	10:1
Rail Size (in) / Length (in)	1.5" X 1.5"/96"

Ascent Analysis	
Rail Exit Velocity (ft/s)	65.3
Max Velocity (ft/s)	617
Max Mach Number	0.55
Max Acceleration (ft/s^2)	286.7
Peak Altitude (ft)	5,343

Recovery System Properties				
Drogue Parachute				
Manufacturer/Model	SkyAngle			
Size	28			
Altitude at Deployment (ft)	3,300			
Velocity at Deployment (ft/s)	0.0024			
Terminal Velocity (ft/s)	59.41			
Recovery Harness Material	Tubular Kevlar			
Harness Size/Thickness (in)	1/2”			
Recovery Harness Length (ft)	24			
Harness/Airframe Interfaces	3/16” U-Bolt			
Kinetic Energy During Descent (ft-lb)	Section 1	Section 2	Section 3	Section 4
	417	64	324	

Recovery System Properties				
Main Parachute				
Manufacturer/Model	Top Flite			
Size	50			
Altitude at Deployment (ft)	800			
Velocity at Deployment (ft/s)	59.41			
Landing Velocity (ft/s)	21.27			
Recovery Harness Material	Tubular Kevlar			
Harness Size/Thickness (in)	1/2”			
Recovery Harness Length (ft)	24			
Harness/Airframe Interfaces	3/16” U-Bolt			
Kinetic Energy Upon Landing (ft-lb)	Section 1	Section 2	Section 3	Section 4
	67	10	52	

Recovery System Properties

Recovery System Properties

Electronics/Ejection	
Altimeter(s) Make/Model	PerfectFlite StratoLogger
Redundancy Plan	Redundant Dual Recovery with 2 PerfectFlite StratoLogger altimeters with independent power supplies
Pad Stay Time (Launch Configuration)	2 hrs

Electronics/Ejection	
Rocket Locators (Make, Model)	Garmin Astro

	Video Transmitter	Garmin GPS	Spektrum Radio Contol	3DR Radio
	5.8 gHz	MHz	2.4 gHz	915 mHz
Transmitting Frequencies	5.705	151.82	2.400-2.4835	895 - 935
	5.685	151.88		
	5.665	151.94		
	5.885	154.57		
	5.645	154.60		
	5.905			
	5.925			
	5.945			

Black Power Mass Drogue Parachute (gram)	4
Black Power Mass Main Parachute (gram)	6

Milestone Review Flysheet

PDR, CDR, FRR

Institution Name	Northwest Indian College		**Milestone**	CDR

Payload/Science	
Succinct Overview of Payload/Science Experiment	An autonomous multirotor vehicle that will tow the rocket back to the launch area
Identify Major Components	Nosecone, ebay, airframe, fins, motor mount, GPS, 2 altimeters, drogue and main parachutes, multirotor vehicle
Mass of Payload/Science	3 pounds

Test Plan Schedule/Status	
Ejection Charge Test(s)	11/10, 11/20, 12/4 complete
Sub-scale Test Flights	3-Nov - complete

Full-scale Test Flights	1/13/13, 2/17/13, 3/03/13, 3/09/13 All completed successfully

Additional Comments

Appendix B – Verification Plan

Requirement	Design Feature	Verification	Status
2. The launch vehicle shall deliver the science or engineering payload to, but not exceeding, an altitude of 5,280 feet. above ground level (AGL). One point will be deducted for each foot achieved below the target altitude. Two points will be deducted for each foot achieved above the target altitude. Any team whose vehicle travels over 5,600 ft. according to their competition altimeter will be disqualified from being able to receive the overall competition award and will receive a score of zero for the altitude portion of their total score.	Design through Rocksim 9, Power Management System	Test	Work in Progress
3. The vehicle shall carry one Perfect Flight MAWD or ALT15 altimeter for recording of the official altitude used in the competition scoring. Teams may have additional altimeters to control vehicle electronics and payload experiments. At the flight hardware and safety check, a NASA official will mark the altimeter which will be used for the official scoring. At the launch field, a NASA official will also obtain the altitude by listening to the audible beeps reported by the altimeter. The following circumstances will warrant a score of zero for the altitude portion of the competition:	Two PerfectFlite Stratologger altimeters	Inspection	Complete
a. The official, marked altimeter is damaged and/or does not report an altitude after the team's competition flight.	Safe Recovery will preclude this	Inspection	Work in Progress
b. The team does not report to the NASA official designated to record the altitude with their official marked altimeter by 5:00 pm on the day of the launch.	Check list will preclude this		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	Complete
b. The recovery system electronics shall be completely independent of the payload electronics.	Payload electronics in separate science by		Complete
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		Complete
d. Each altimeter shall be armed by a dedicated arming switch.	Locking Key Switches		Complete
e. Each altimeter shall have a dedicated battery.	Designed with two independent systems including batteries		Complete
f. Each arming switch shall be accessible from the exterior of the rocket airframe.	Locking switches located on ebay ring		Complete
g. Each arming switch shall be capable of being locked in the ON position for launch.	Switches that lock with a key are installed		Complete
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		Complete
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	Complete
6. The launch vehicle and science or engineering payload shall remain subsonic from launch until landing.	Designed with Rocksim 9 to stay subsonic	Simulation	Complete

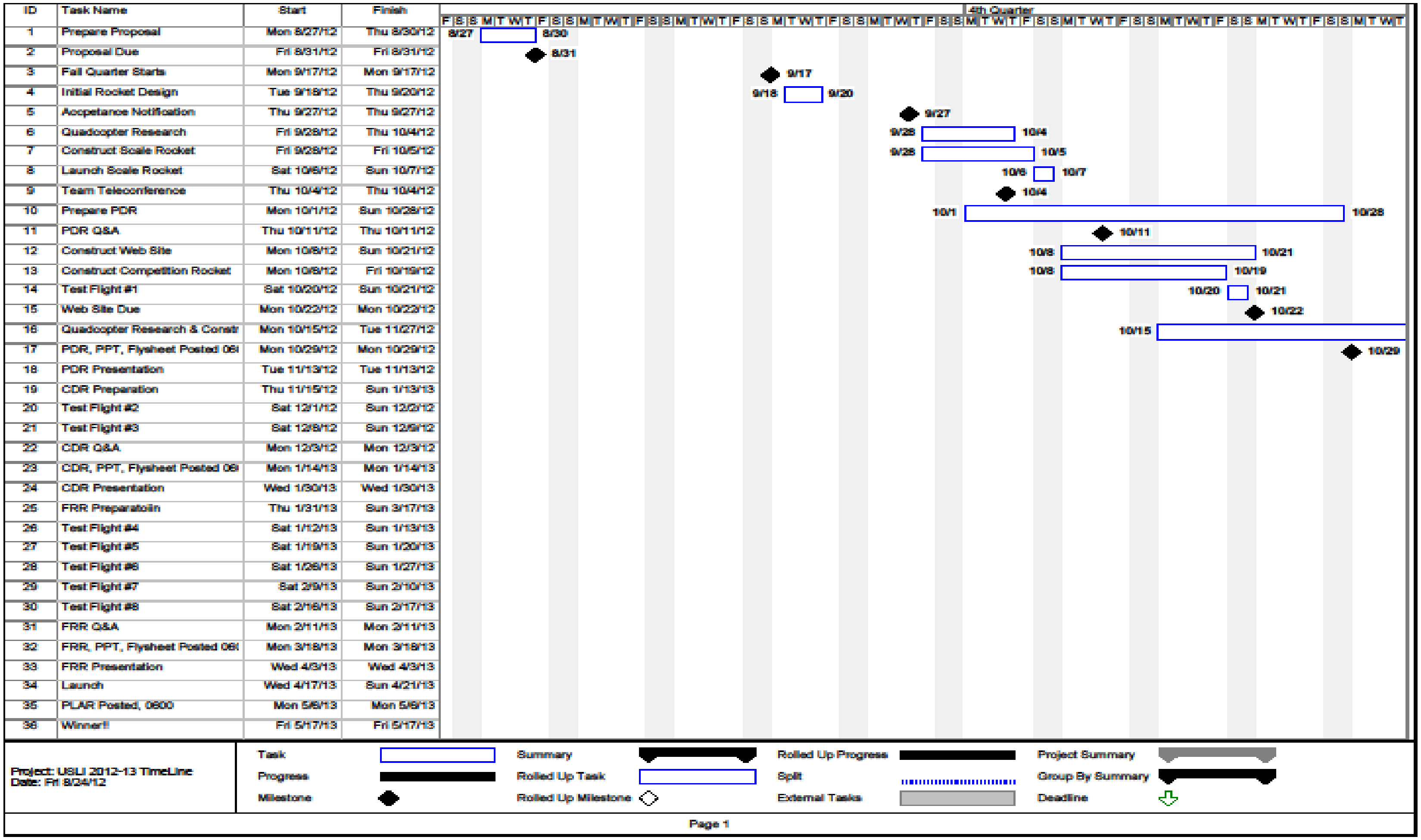
7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Simulation	Complete
8. The launch vehicle shall stage the deployment 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	Complete
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	Complete
10. The launch vehicle shall have a maximum of four (4) independent or tethered sections.	Designed with three	Inspection	Complete
a. At landing, each independent or tethered sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Designed via calculations	Simulation	Complete
b. All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.	Designed with Rocksim 9	Simulation analysis	Complete
11. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the waiver opens.	Designed as required	Check lists	Work in Progress
12. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any onboard component.	Battery power calculated to last at least 2 hrs for each device using a battery	Simulation analysis	Work in Progress

13. The launch vehicle shall be launched from a standard firing system (provided by the Range) using a standard 10 - second countdown	Designed as required	Test	Complete
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	Complete
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	Complete
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 reloadable motor	Inspection	Complete
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	Complete
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	Complete
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle		Complete
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	Complete
▪ 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		Complete
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		Complete
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 2 other NAR L2 individuals are available		Complete
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.		Complete
20. The following items are prohibited from use in the launch vehicle:			

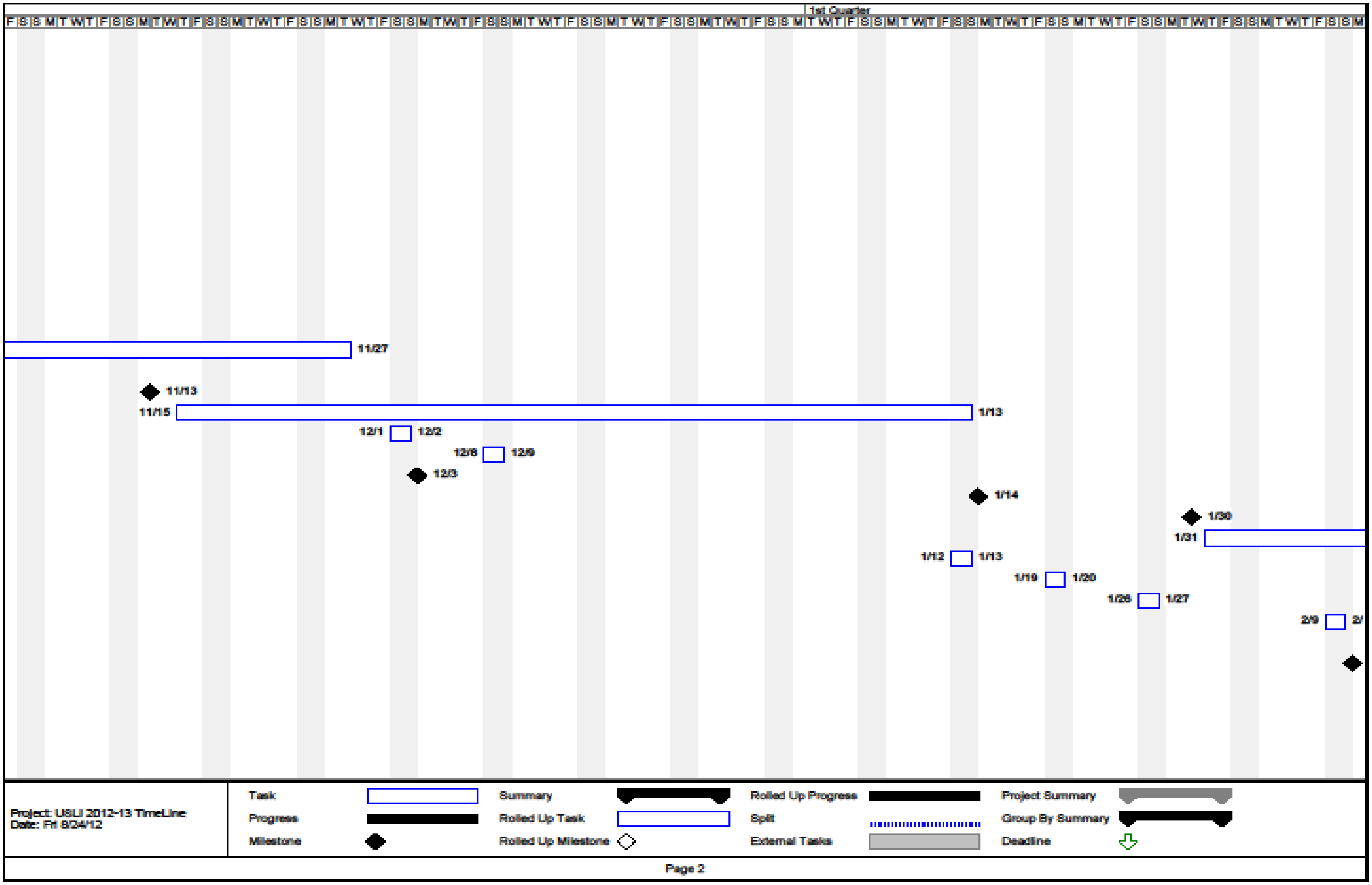
a. Flashbulbs. The recovery system must use commercially available low-current electric matches.	None of these have been included in the rocket design	Inspection	Complete
b. Forward canards.	Not Applicable		
c. Forward firing motors.			
d. Rear ejection parachute designs.			
e. Motors which expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).			
f. Hybrid motors.			
21. Each team shall use a launch and safety checklist. The final checklist shall be included in the FRR report and used during the flight hardware and safety inspection and launch day.	Check lists are designed	Inspection and actual testing	Complete
22. Students on the team shall do 100% of the work on the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder charges.	Implemented as required	Inspection	Work in Progress
23. The rocketry mentor supporting the team shall have been certified by NAR or TRA for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 15 flights in this or a higher impulse class, prior to PDR.	Implemented as required	Inspection	Complete
24. The maximum amount teams may spend on the rocket and payload is $5000 total. The cost is for the competition rocket as it sits on the pad, including all purchased components and materials and the fair market value of all donated components and materials. The following items may be omitted from the total cost of the vehicle:			Complete
a. Shipping costs.	Implemented as required	Inspection	Complete
b. Ground Support Equipment.			
c. Team labor.			

Appendix C – Time Line



ID	Task Name	Start	Finish
1	Prepare Proposal	Mon 8/27/12	Thu 8/30/12
2	Proposal Due	Fri 8/31/12	Fri 8/31/12
3	Fall Quarter Starts	Mon 9/17/12	Mon 9/17/12
4	Initial Rocket Design	Tue 9/18/12	Thu 9/20/12
5	Accpetance Notification	Thu 9/27/12	Thu 9/27/12
6	Quadocopter Research	Fri 9/28/12	Thu 10/4/12
7	Construct Scale Rocket	Fri 9/28/12	Fri 10/5/12
8	Launch Scale Rocket	Sat 10/6/12	Sun 10/7/12
9	Team Teleconference	Thu 10/4/12	Thu 10/4/12
10	Prepare PDR	Mon 10/1/12	Sun 10/28/12
11	PDR Q&A	Thu 10/11/12	Thu 10/11/12
12	Construct Web Site	Mon 10/8/12	Sun 10/21/12
13	Construct Competition Rocket	Mon 10/8/12	Fri 10/19/12
14	Test Flight #1	Sat 10/20/12	Sun 10/21/12
15	Web Site Due	Mon 10/22/12	Mon 10/22/12
16	Quadocopter Research & Constr	Mon 10/15/12	Tue 11/27/12
17	PDR, PPT, Flysheet Posted 08(	Mon 10/29/12	Mon 10/29/12
18	PDR Presentation	Tue 11/13/12	Tue 11/13/12
19	CDR Preparation	Thu 11/15/12	Sun 1/13/13
20	Test Flight #2	Sat 12/1/12	Sun 12/2/12
21	Test Flight #3	Sat 12/8/12	Sun 12/9/12
22	CDR Q&A	Mon 12/3/12	Mon 12/3/12
23	CDR, PPT, Flysheet Posted 08(	Mon 1/14/13	Mon 1/14/13
24	CDR Presentation	Wed 1/30/13	Wed 1/30/13
25	FRR Preparatoiin	Thu 1/31/13	Sun 3/17/13
26	Test Flight #4	Sat 1/12/13	Sun 1/13/13
27	Test Flight #5	Sat 1/19/13	Sun 1/20/13
28	Test Flight #6	Sat 1/26/13	Sun 1/27/13
29	Test Flight #7	Sat 2/9/13	Sun 2/10/13
30	Test Flight #8	Sat 2/16/13	Sun 2/17/13
31	FRR Q&A	Mon 2/11/13	Mon 2/11/13
32	FRR, PPT, Flysheet Posted 08(	Mon 3/18/13	Mon 3/18/13
33	FRR Presentation	Wed 4/3/13	Wed 4/3/13
34	Launch	Wed 4/17/13	Sun 4/21/13
35	PLAR Posted, 0800	Mon 5/6/13	Mon 5/6/13
36	Winner!!	Fri 5/17/13	Fri 5/17/13

Project: USLI 2012-13 TimeLine
Date: Fri 8/24/12


1st Quarter
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Project: USLI 2012-13 TimeLine
Date: Fri 8/24/12
Task
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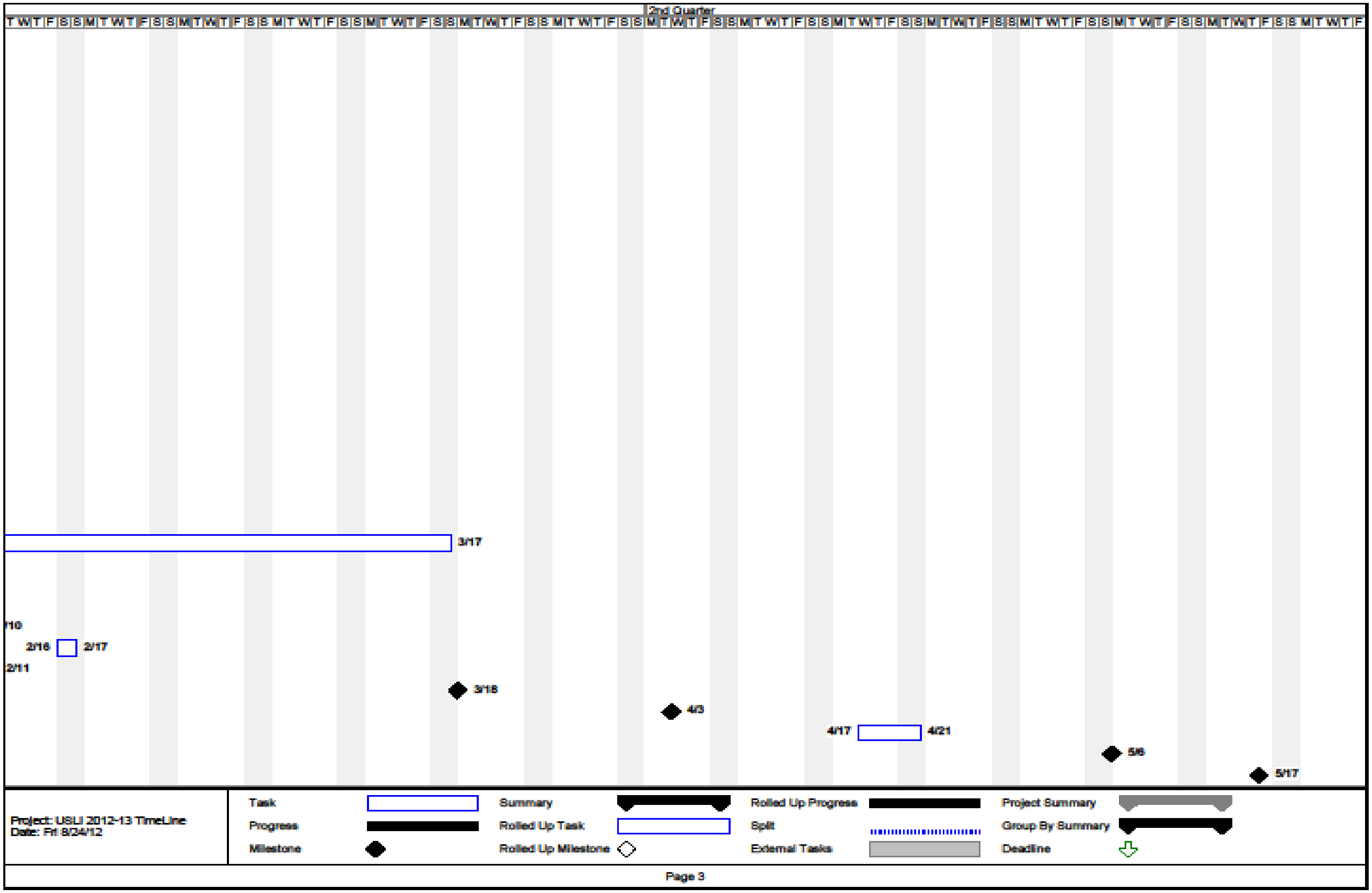
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline
Page 2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Date: Fri 8/24/12
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline
Page 3

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. Furthermore, I will never fly rocket motors more powerful than my certification will allow except when engaged in a formally supervised NAR or TRA certification flight attempt. I also agree that I will fly only commercially manufactured rocket motors that are certified for use by NAR and/or TRA.

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

Name (Please print)____
Signature & Date ____
Parent/Guardian (17 and younger) __________________________________
Address ____
City State Zip ____
Email address ____
Phone (   )____

NAR Membership __________________ Cert Level __________ Expires _____
TRA Membership ___________________ Cert Level __________ Expires ______

Appendix E - GSE Check List

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

Appendix F – Ebay and Recovery System Check List

Recovery System Preparation

Recovery System, Drogue Chute:

- *Check all connections. Insure all devices are in good condition and properly secured:*

- ☐ Forward ebay recovery harness to drogue
- ☐ Nose cone to harness
- ☐ Fold drogue chute per manufacturer's instructions.
- ☐ Drogue into burrito
- ☐ 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:*

- ☐ Connect aft recovery harness to ebay
- ☐ Fasten, in order, main parachute, bulkhead, protective container, MV, after tow line, fin can
- ☐ Fold main chute per manufacturer's instructions.
- ☐ Main into burrito
- ☐ 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 on top of MV assembly

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
- ☐ Tape over the BP container with tape to make certain that no BP escapes 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
- ☐ Tape over the BP container with tape to make certain that no BP escapes 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.

Insure all black powder electronic devices are in disarmed mode during EBay final installation.

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

Appendix G – GPS and MV 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

MV Check List – Pre Launch

☐ Fold MV arms
☐ Power onRC transmitter
☐ Power on MV battery
☐ Check for RC connection between transmitter and receiver
☐ Cycle through arming and disarming
☐ Disarm
☐ Check 3DR telemetry connection
☐ Check FPV reception
☐ Fasten lower harness to bottom of MV
☐ Slide assembly to bottom of science payload bay
☐ Fasten upper harness to bottom of MV
☐ Slide Protective Container over MV
☐ Arm MV
☐ Slide bulkhead into airframe
☐ Pack main recovery harness on top of MV
☐ Connect main recovery harness to main parachute burrito
☐ Place main parachute burrito in airframe
☐ Connect upper recovery harness to ebay
☐ Pack drogue parachute into airframe
☐ Fasten drogue quicklink to ebay
☐ Slide nosecone and ebay together
☐ Fasten with ¼" screws
☐ Slide nosecone/ebay assembly into airframe
☐ Fasten with 10-54 nylon screws

Post Launch

☐ Keep transmitter ON
☐ Disconnect battery from MV

☐ Power off transmitter
☐ Disconnect MV from recovery harness
☐ Transport back to preparation area

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 device
- ☐ Tape igniter to rocket airframe
- ☐ Discard trash properly

Launch Pad Preparation

- ☐ Assemble legs onto main pad body
- ☐ Attach guide rail to pad
- ☐ Drive rebar hoops into ground for pad stabilization
- ☐ Run launch control wires to launch control area
- ☐ Attach batteries to launch controller
- ☐ Check power light when safety key is in and turned on
- ☐ Remove safety key
- ☐ Check continuity light by shorting igniter clips

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 – beeping
- ☐ Cameras on

Igniter installation

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

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

Final Launch Sequence

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

Misfire Procedures

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

Appendix 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. Deactivate is necessary
- ☐ Safe all ejection circuits.
- ☐ Remove any non-discharged pyrotechnics.
- ☐ Pack all recovery materials into airframe for carrying ease.
- ☐ Return vehicle to RSO for inspection.

MV Recovery

- ☐ Take at least five photographs of the MV BEFORE touching it.
- ☐ Ensure propellers are stopped and the MV is disarmed.
- ☐ Disconnect battery.
- ☐ Turn off transmitter.
- ☐ Disconnect the MV from the recovery harness.
- ☐ Transport back to preparation area.

Flight Failure Checklist

- ☐ Take at least five photographs of the rocket and its components BEFORE touching it
- ☐ Check for non-discharged pyrotechnics. Deactivate is necessary
- ☐ Safe all ejection circuits.
- ☐ Carry the pieces back to the staging area with great solemnity and respect.
- ☐ Return vehicle to RSO for inspection.

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.

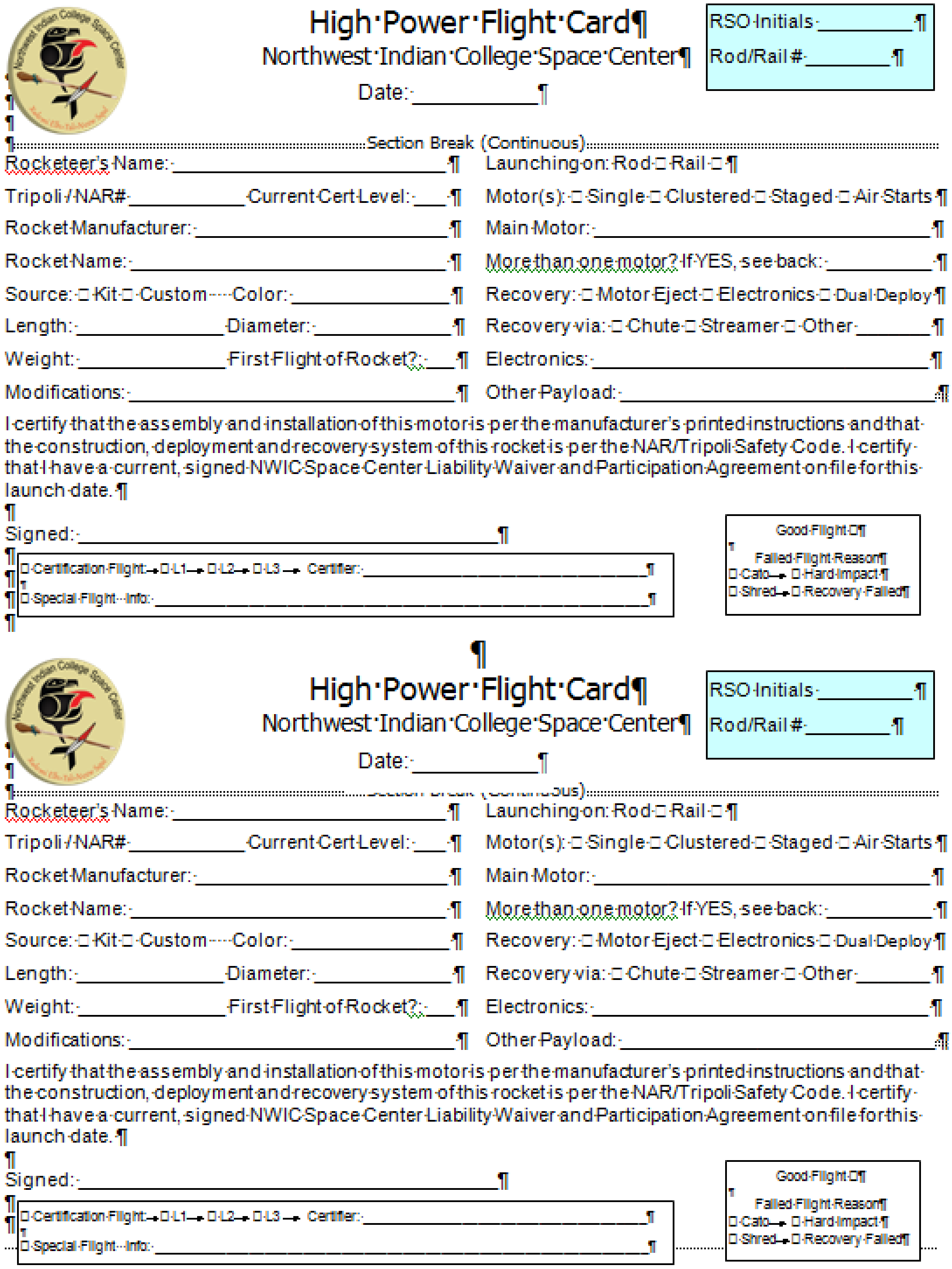
Signed:
____

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: ______________________

Tripoli / NAR# __________ Current Cert Level: ___

Rocket Manufacturer: ______________________

Rocket Name: ______________________

Source: ☐ Kit ☐ Custom Color: ______________

Length: __________ Diameter: __________

Weight: __________ First Flight of Rocket?: ___

Modifications: ______________________

Launching on: Rod ☐ Rail ☐

Motor(s): ☐ Single ☐ Clustered ☐ Staged ☐ Air Starts

Main Motor: ______________________

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

Recovery: ☐ Motor Eject ☐ Electronics ☐ Dual Deploy

Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Electronics: ______________________

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: ______________________

Tripoli / NAR# __________ Current Cert Level: ___

Rocket Manufacturer: ______________________

Rocket Name: ______________________

Source: ☐ Kit ☐ Custom Color: ______________

Length: __________ Diameter: __________

Weight: __________ First Flight of Rocket?: ___

Modifications: ______________________

Launching on: Rod ☐ Rail ☐

Motor(s): ☐ Single ☐ Clustered ☐ Staged ☐ Air Starts

Main Motor: ______________________

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

Recovery: ☐ Motor Eject ☐ Electronics ☐ Dual Deploy

Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Electronics: ______________________

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