NORTHWEST INDIAN COLLEGE
Xwlemi Elh>Tal>Nexw Squl

2012-2013

Northwest Indian College Space Center USLI Critical Design Review

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Figures and Tables

Northwest Indian College Critical Design Review

I.0 CDR Report Summary

I.1 Team Summary

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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: 9/16" Tubular Nylon Avionics: Dual PerfectFlite StratoLogger Altimeters

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

I.2e Milestone Review Flysheet (Appendix A)

I.2e 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 between apogee and 700 feet and 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

- Rocket length: increased from 83.0 to 89.5 inches to allow more room for the main parachute.
- Empty Rocket weight: increased from 5.0 pounds to 6.75 pounds because of additional airframe length, additional tube coupler and recovery hardware.

II.1b Payload Criteria Changes (None)

II.1c Project Plan Changes

- Inclement weather has delayed initial tests of our full scale rocket. What we had scheduled to accomplish before 12/15/2012 is now scheduled for January 2013.
- Scheduling Educational Outreach is more difficult this year because of increased state-wide and school district educational expectations.

III.0 Vehicle Criteria

III.1 Launch Vehicle Design and Verification: Flight Reliability & Confidence

III.1a The Mission

Through the USLI program, the Northwest Indian College Space Center's RPGs Team enhances its involvement in science, technology, engineering, and math (STEM), and encourages others in Tribal communities to do the same. Another aspect of our mission is to take a disparate collection of non-engineering students and involve them in exciting and comprehensive aspects of science with the goal of enticing them into considering STEM subjects as career choices.

Furthermore, we plan to:

- design and build a recoverable, reusable rocket;
- design an engineering payload that will act as a tow vehicle;
- incorporate a GPS-based autopilot system for autonomous flight;
- achieve the 5280 foot altitude requirement.

These objectives will be achieved by thorough design and testing of the rocket and its engineering payload.

III.1a.1 Mission Performance Criteria

The goals of Team RPG's rocket is to safely deliver the payload to 5280 feet (AGL) 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.1a.2 Detailed Mission Performance Criteria

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

III.1a.3 Major Milestone Schedule: (Appendix A)

III.1b System Level Design Review

III.1b.1 Final Drawings and Specifications

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

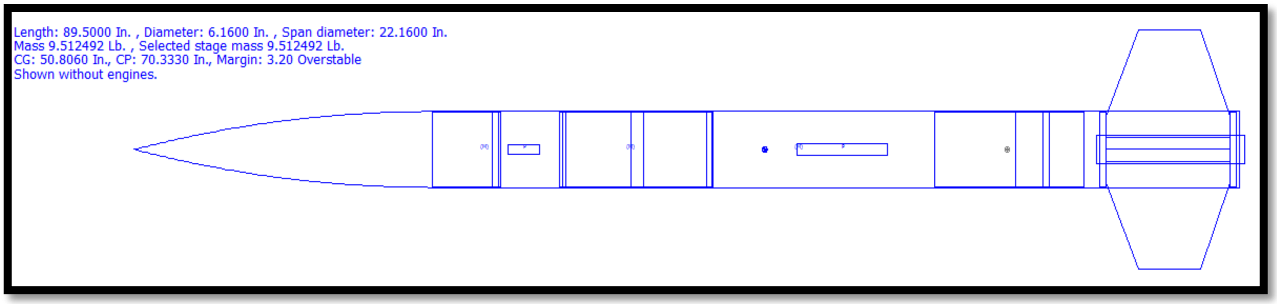


Figure 1 - Rocksim 9 Side View

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.

Figure 2 - Exploded Airframe Component View

III.1b.2 Final Analysis and Model Results, Anchored to Test Data

The dimensions are finalized and the project is committed to this design. The full scale rocket is completely built to these specifications. The dimensions and weights are of the actual rocket.

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 3 and 4, indicate a successful flight and they are within acceptable parameters.

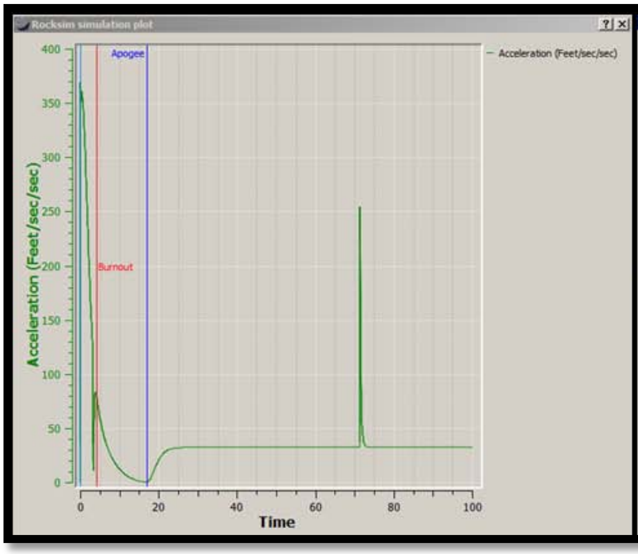


Figure 3 - Acceleration

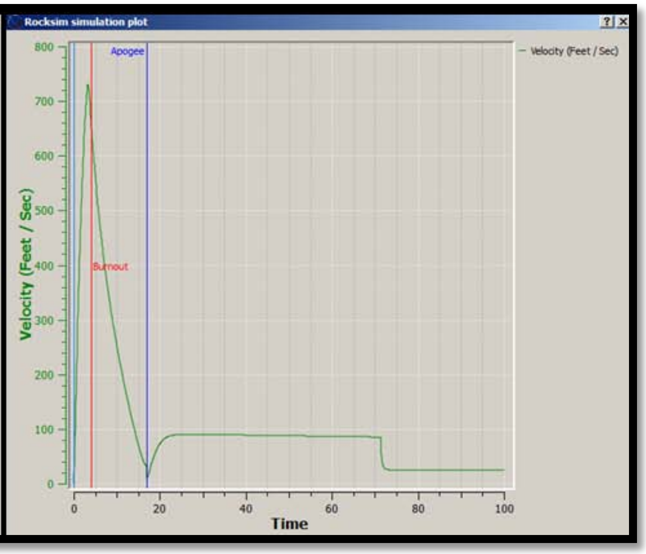
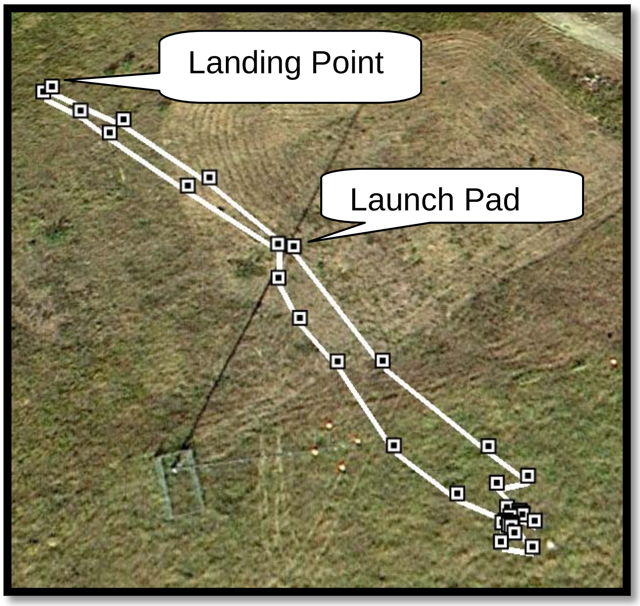


Figure 4 - Velocity

III.1b.3 Test Description and Results

First flight of Salish Star took place on January 13, 2013 at 12:30 pm at the Northwest Indian College Launch Complex. Weather was a high overcast with temperatures in the low 40's, winds 1-2 kts from the SW, and the ground was frozen.



Ground Track of Salish Star

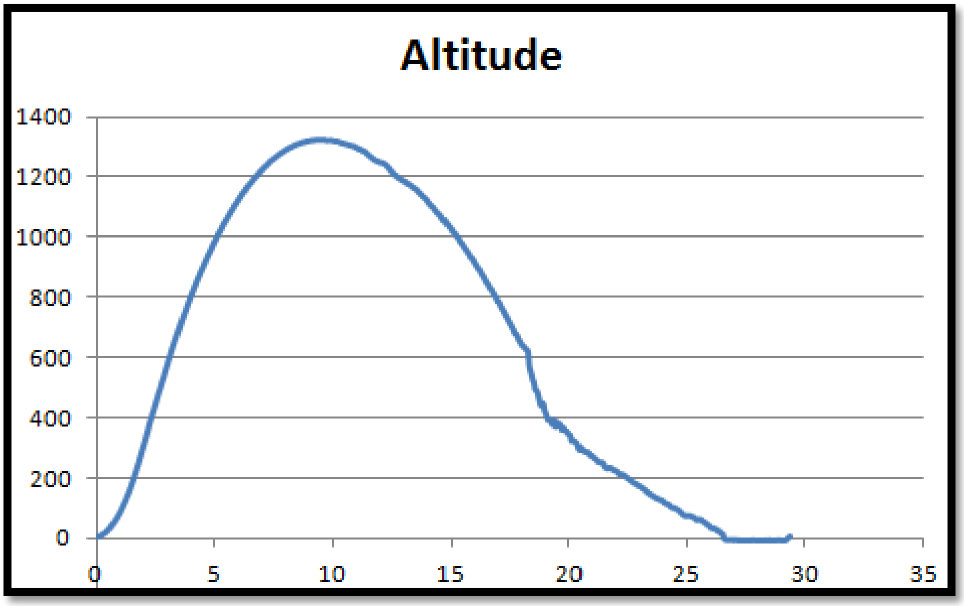
This was a no-payload flight whose intent was to test the rocket's stability and its deployment processes. The flight was very straight and the rocket landed 124 feet from the launch pad.

Motor: CTI I285

Predicted	Predicted	Actual

Altitude w/o payload (f)	1265	1325
Velocity (f/s)	284	
Acceleration (f/s/s)	206	
Time to apogee (sec)	9.32	10.25
Velocity at deployment (f/s)	0	

Table 3, Full Scale Flight Data



Altimeter #1 Data

Altimeter #2 failed and no data was recorded nor were the black powder charges fired. Failure determination will commence on 1/14/13.

III.1b.4 Final Motor Selection

Cesaroni Technology Incorporated (CTI) Pro54 K445 Classic

III.1b.5 Thrust-to-Weight Ratio

The selected motor must provide stable flight for the rocket and enable the rocket to reach the desired altitude. An appropriate thrust-to-weight ratio and sufficient lift-off speed are necessary for a safe flight. The thrust-to-weight ratio is a predictor of flight stability by making certain that the motor has the necessary power to accelerate the rocket to a safe lift-off speed. Sufficient velocity prior to the rocket leaving the stability-inducing guide rail is necessary in order for the air flow over the fins to increase to such a point that the fins are able to act as stabilizers. In general, a minimum thrust-to-weight ratio of five to one is recommended for flight, but a higher ratio may be necessary for stronger winds.

Motor	Max Thrust	Load Weight	Ratio
K445	149.453	15.3	10

Table 4 – Thrust-to-Weight

III.1c System Level Functional Requirements with Satisfying Design Features and Verification

System	Subsystem	Functional Requirement	Design Feature	Evaluation	Verification
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, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	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, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	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

	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, OpenRocket Simulations, NAR Mentor Inspection	Successful Flight

III.1d Approaches to Workmanship Related to 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.1e Planned Additional Component, Functional and Static Testing

Flight tests both with and without the payload are scheduled throughout January to March. After the initial flight test, all additional flights will be conducted to test the MV and refine its capabilities and for fine tuning its autopilot.

We will also be conducting continuous pilot training in case an RC takeover is required.

III.1f Status and Plans of Remaining Manufacturing and Assembly

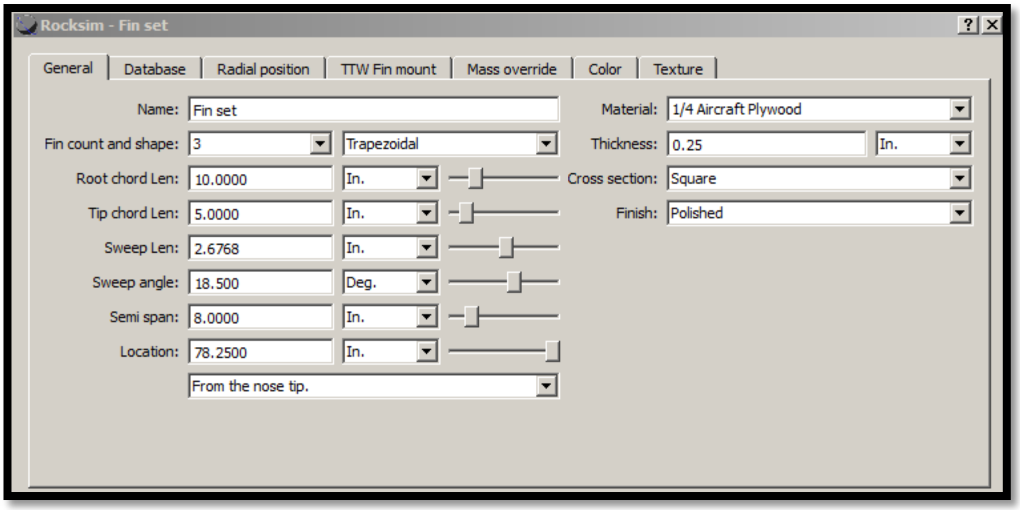
The rocket is finished all but the painting.

The MV flight platform is 85% completed. The motors and flight controller are mounted and have been tested. The autopilot is still under construction, 90% complete and testing is scheduled to begin in mid January.

III.1g Design Integrity

III.1g.1 Mission Suitability of Fin Shape and Style

The fins were designed through Rocksim 9. Their size and shape contribute to the stability of the rocket by ensuring that the Center of Pressure (CP) is well aft of the Center of Gravity (CG). Design data are in Figure 5.



Name: Fin set
Fin count and shape: 3 Trapezoidal
Root chord Len: 10.0000 In.
Tip chord Len: 5.0000 In.
Sweep Len: 2.6768 In.
Sweep angle: 18.500 Deg.
Semi span: 8.0000 In.
Location: 78.2500 In.
From the nose tip.
Material: 1/4 Aircraft Plywood
Thickness: 0.25 In.
Cross section: Square
Finish: Polished

Figure 4 - Fin Design

Three fins constructed from 1/4” aircraft-grade plywood are fastened through the airframe wall (TTW) onto the motor mount tube. The fins are fastened to the motor mount tube and filleted with fiberglass and epoxy. The fin/motor mount tube is then slid into the airframe and epoxied in place. Epoxy fillets complete the attachment.

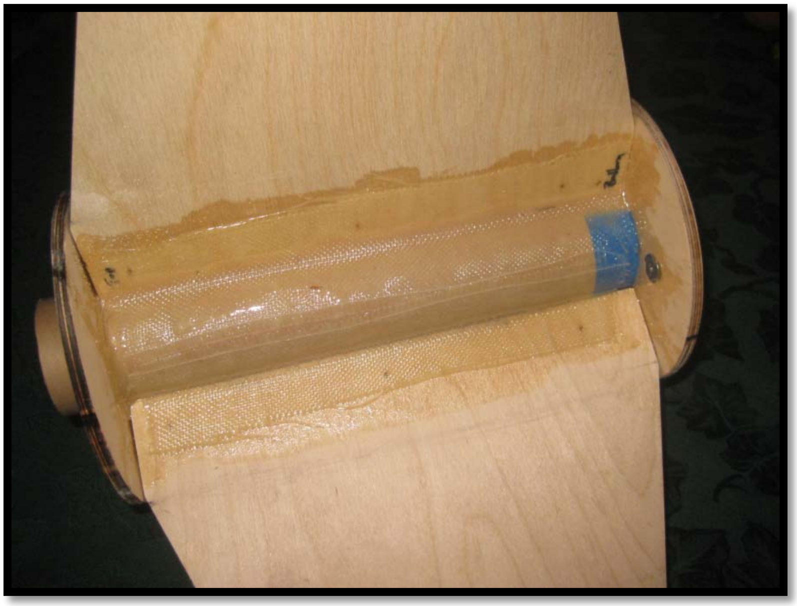


Figure 5 – Through-the-Wall Fin Attachment

III.1g.2 Materials in Fins, Bulkheads, and Structural Elements

Aircraft-grade birch plywood is the material of choice for the fins and bulkheads. If the component is load bearing, it is constructed from ½ inch plywood, otherwise, ¼ inch plywood is used.

III.1g.3 Assembly Procedures, Attachment and Alignment of Elements, Solid Connection Points, and Load Paths

Permanent connections use West System two-part epoxy. Those requiring intermittent access use 8-32 or 10-24 T-nuts and screws.

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.
Alignment notches and keys are built onto each piece of the airframe where any joining is required.

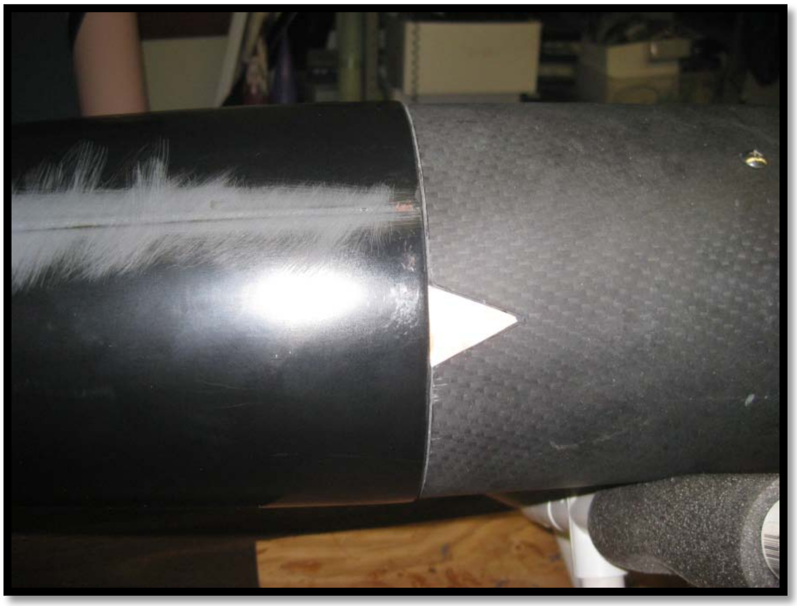


Figure 6 – Alignment Key and Notch

III.1g.4 Motor Mounting and Retention

The motor mount is a 54mm x 12 inch Kraft phenolic tube. It is centered in the airframe by two ½ inch centering rings which in turn butt against the TTW fin tabs. The fins and centering rings are further strengthened by fiberglass and epoxy fillets between them and the motor mount.

Figure 7 – Motor Retention

Three 1/8 inch aluminum brackets with 10-24 T nuts are used to retain the motor. The T nuts are embedded in the backside of the aft motor mount centering ring. The 10-24 bolts cinch the aluminum brackets to the aft enclosure of the motor and the aft centering ring.

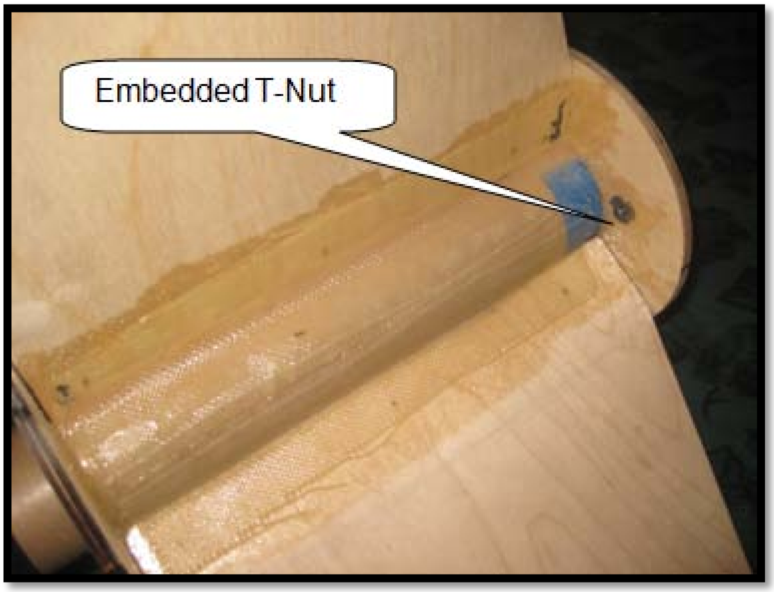


Figure 8 – Interior Anchor Point for Motor Retention Brackets

III.1g.5 Verification Status

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.

Task	Scheduled	Actual	Result
Launch and recovery of scale rocket	10/06 10/20 11/03	10/20	Successful
Black Powder ejection test with altimeters	10/04	10/04	Successful
Flight test of dual deployment recovery system	10/06 10/20 11/03	10/20	Successful
Drogue deployment during flight test	10/06 10/20 11/03	10/20	Successful
Main deployment during flight test	10/06 10/20 11/03	10/20	Successful
Safe main parachute-to-ground descent rate	10/06 10/20 11/03	10/20	Successful
Predicted altitude	10/06 10/20 11/03	10/20	80% Successful
Launch rail and GSE equipment function	10/20	10/20	Successful
Recovery team performance	10/20	10/20	Successful
Range setup	10/20	10/20	Successful
Safety implementation	10/20	10/20	Successful

Table 5, Scale Launch and Verification Plan

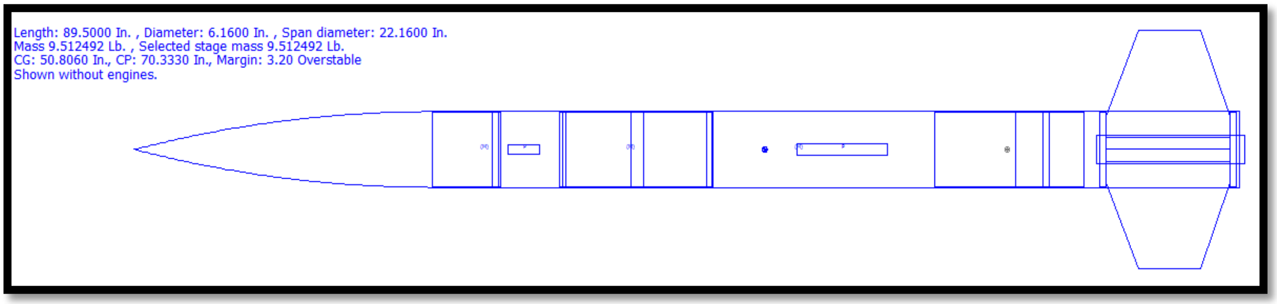
Task	Date	Result
Available Test Dates	~~10/20/12~~ ~~12/01/12~~ ~~12/08/12~~ 01/05/13 01/12/13 01/19/13 01/26/13 02/02/13 02/09/13 02/16/13	
Full Scale Rocket Testing		
Launch and recovery of rocket		
Black Powder ejection test with altimeters	12/05/12	Successful
Flight test of dual deployment recovery system		
Drogue deployment during flight test		
Main deployment during flight test		
Safe main parachute-to-ground descent rate		
Predicted altitude		
MV Testing		
Motor Thrust Test	11/03/12	Successful
Prop Balancing	10/02/12	Successful
Motor Balancing	12/08/12	Successful
RC Ground Test	01/05/13	
Flight Test under RC	01/12/13	
Autopilot Ground Test	01/14/13	
Flight Test under Autopilot	01/21/13	
Manual over ride test	01/22/13	
GSE Testing		
Launch rail and GSE equipment function	10/20	Successful
Recovery team performance	10/20	Successful
Range setup	10/20	Successful
Safety implementation	10/20	Successful

Table 6, Full Scale Launch and Verification Plan

III.1g.6 Launch Vehicle, Subsystems, and Major Components Drawings

Vehicle Drawings

Figure 9 – Paint Scheme Concept



Length: 89.5000 In. , Diameter: 6.1600 In. , Span diameter: 22.1600 In.
Mass 9.512492 Lb. , Selected stage mass 9.512492 Lb.
CG: 50.8060 In., CP: 70.3330 In., Margin: 3.20 Overstable
Shown without engines.

Figure 10 – Line Drawing

Figure 11 – Exploded Rocket Showing Components

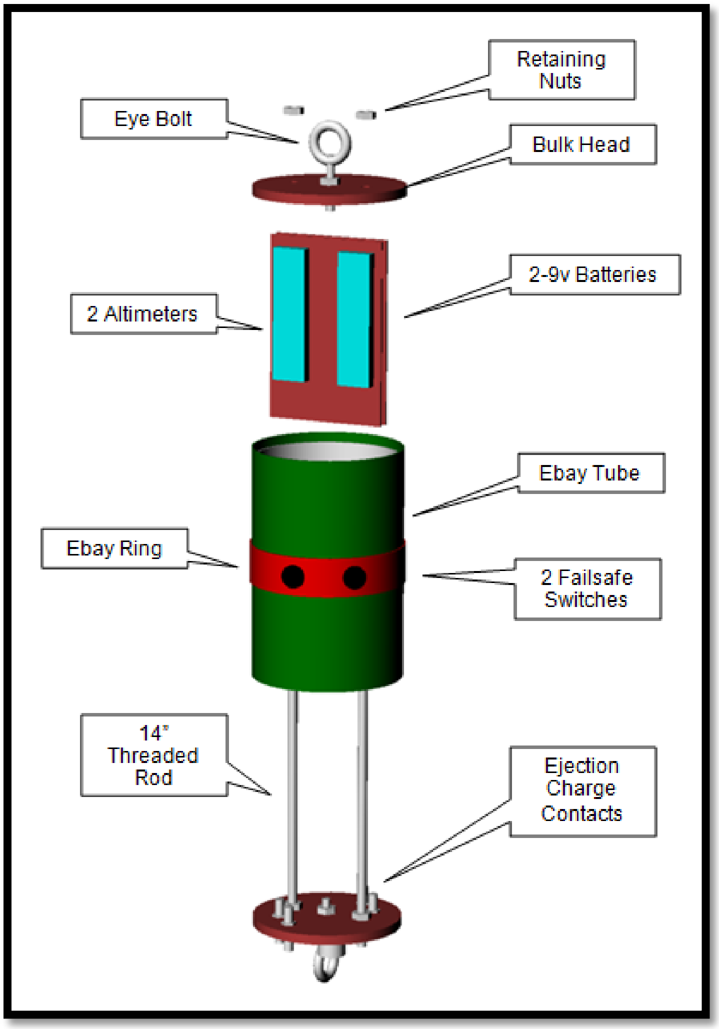


Figure 12 - Ebay Concept

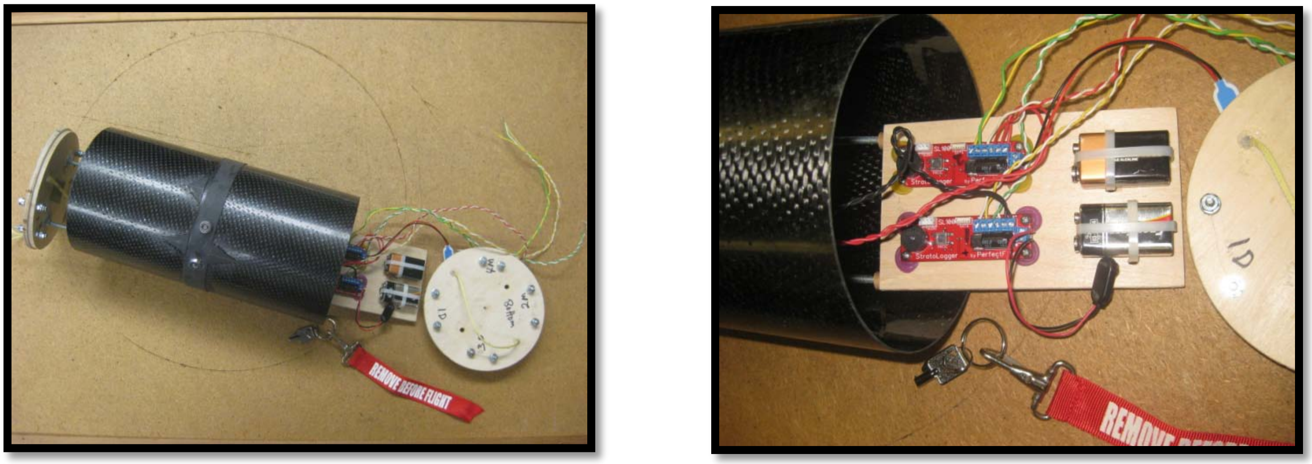


Figure 13 – Ebay and Avionics Layout

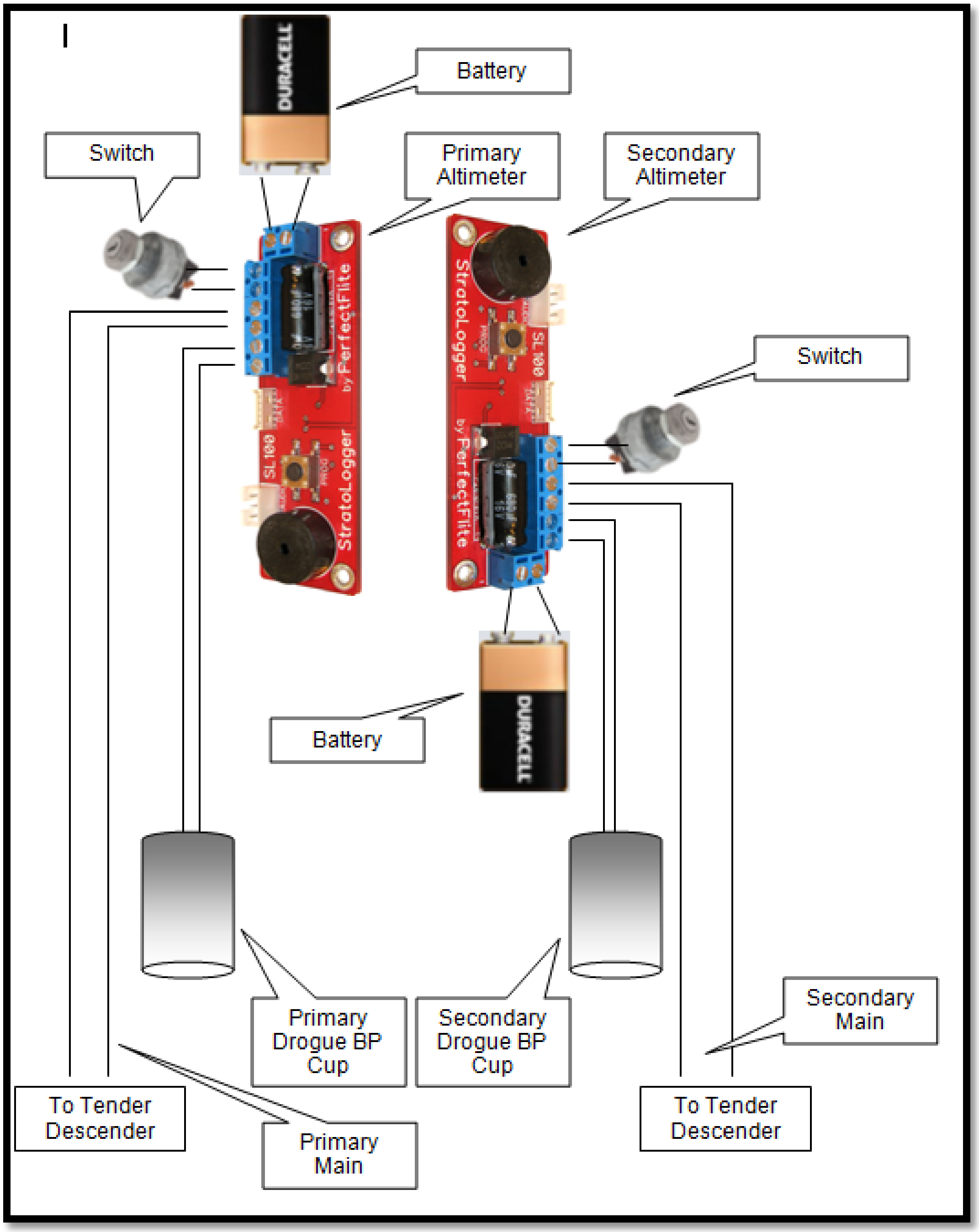


Figure 14 - Redundant Dual Deploy Avionics Block Diagram

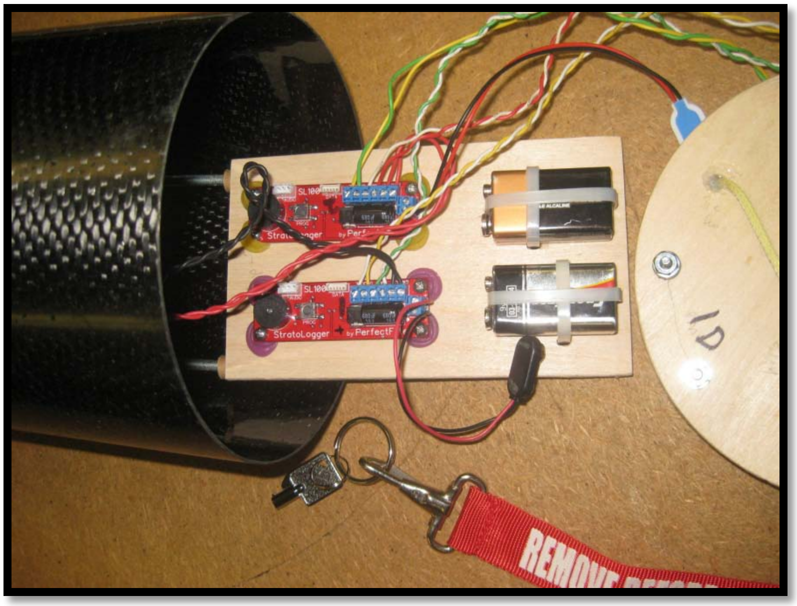


Figure 15 – Avionics Layout (Alt 2, top and Alt 1, bottom)

Fins and Fin Can

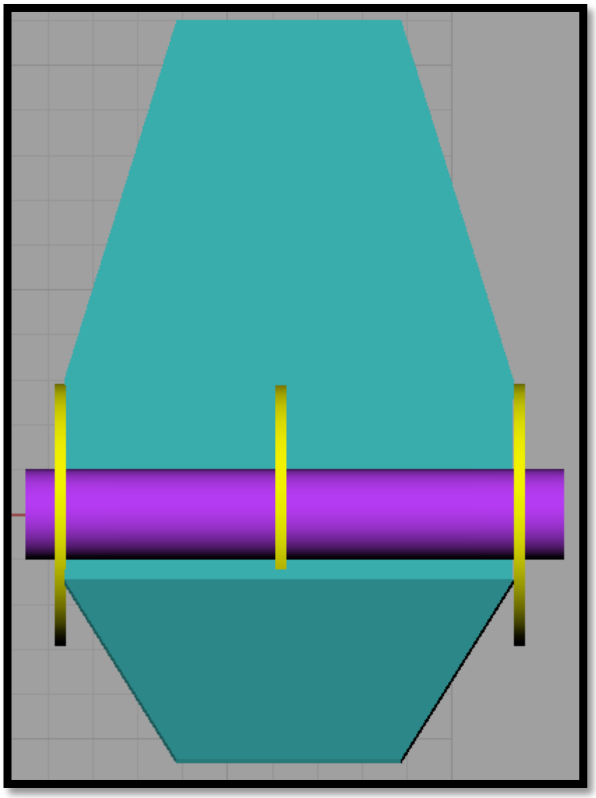


Figure 16 - Fin Can and Motor Mount Concept

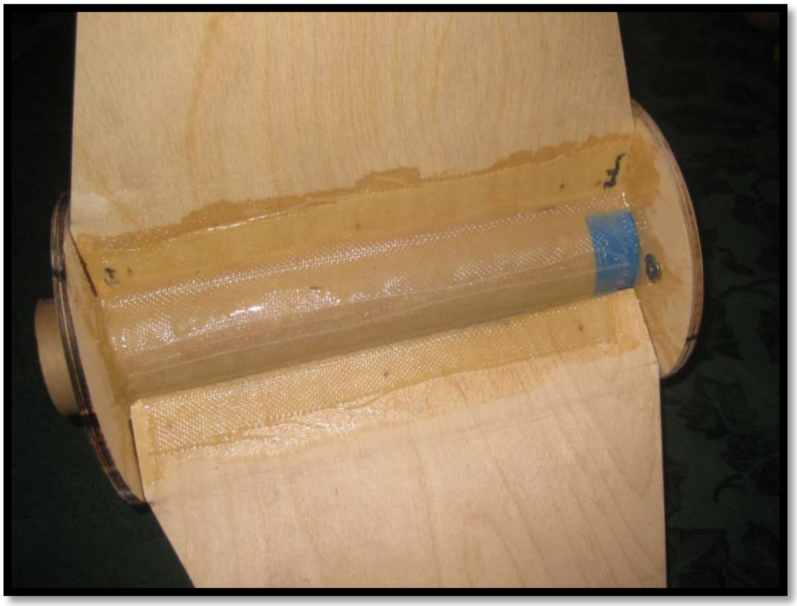


Figure 17 – Fin Can Illustrating Fiberglass Reinforcement

MV Drawings

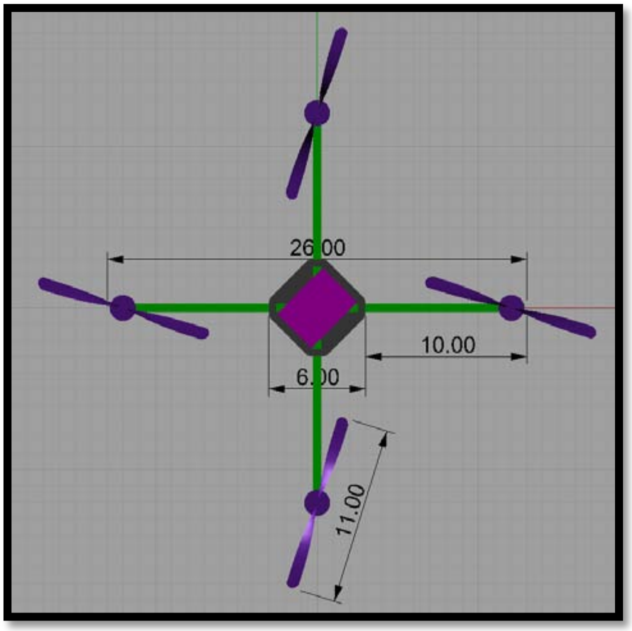


Figure 18 - Plan View

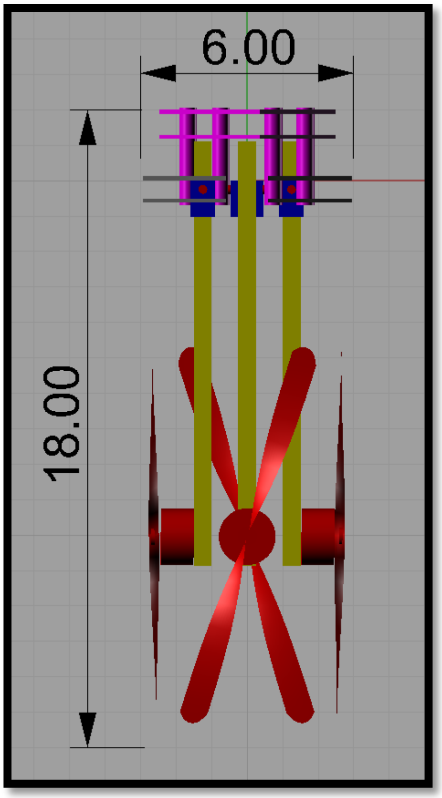
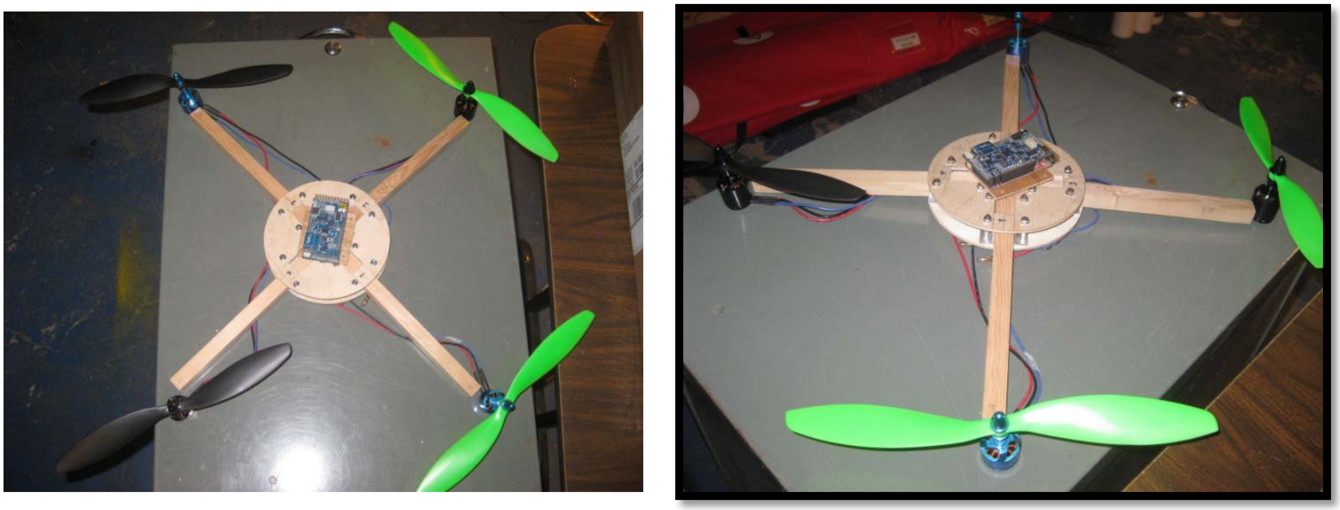


Figure 19 - Folded View



MV in Early Stages of Construction

III.1g.7 Mass Statement99

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 7, Mass Statement

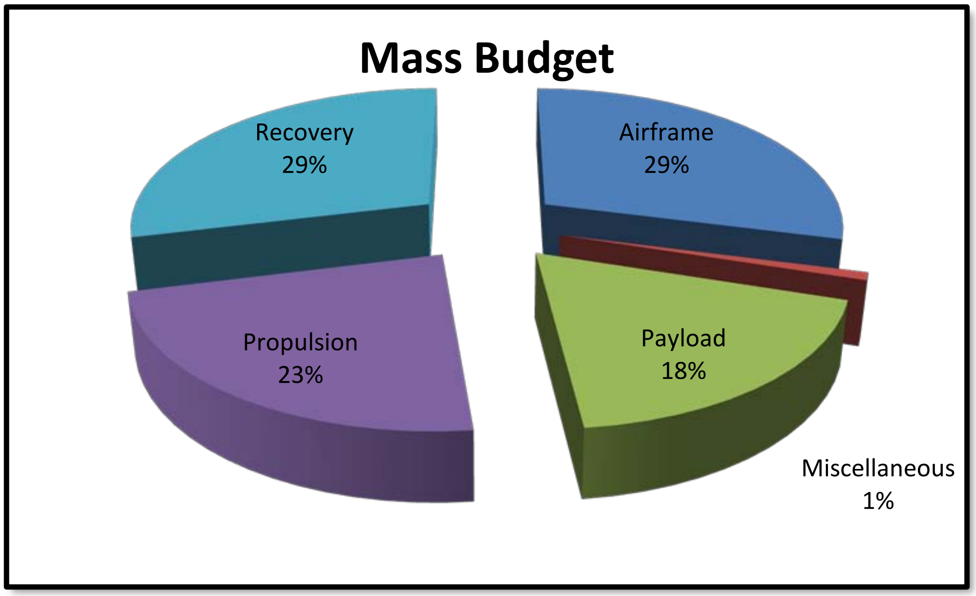


Figure 20 - Mass Budget

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. Rocksim indicates that an increase of three pounds will lower the target altitude which will still be within the 5,180' range.

III.1g.8 Safety and Failure Analysis

Justin 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 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..
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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.
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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 8, Failure, Failure Effects, Failure Mitigation

III.2 Subscale Flight Results

III.2a Flight Data

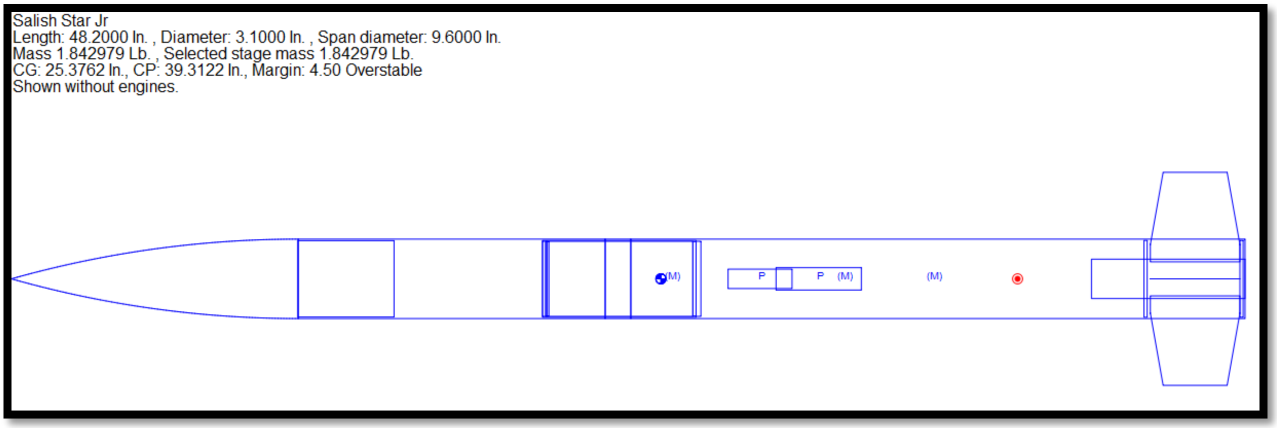
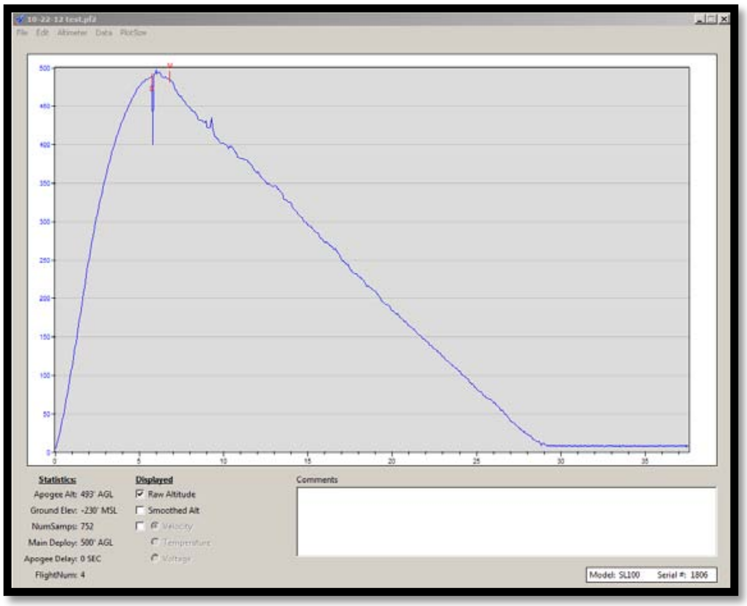


Figure 21 - Subscale Rocket, Salish Star Jr.

We used a Tender Descender as a recovery system in order to test our MV deployment. The rocket flew as expected and the MV deployment occurred as designed.

First the drogue ejected at apogee which extracted the main in its retaining bag and the MV model. The MV model's legs extended as designed. At 500 feet, the main deployed and the rocket descended as we designed it. The only trouble we had was that it landed in the only tree within the area.



Statistics:
Apogee Alt: 493' AGL
Ground Elev: -230' MSL
NumSamps: 752
Main Deploy: 500' AGL
Apogee Delay: 0 SEC
FlightNum: 4

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

Model: SL100 Serial #: 1806

Figure 22 - Subscale Flight Data

Figure 23 - Nicole and Trish with Salish Star Jr.

Figure 24 - Advance Retrieval System

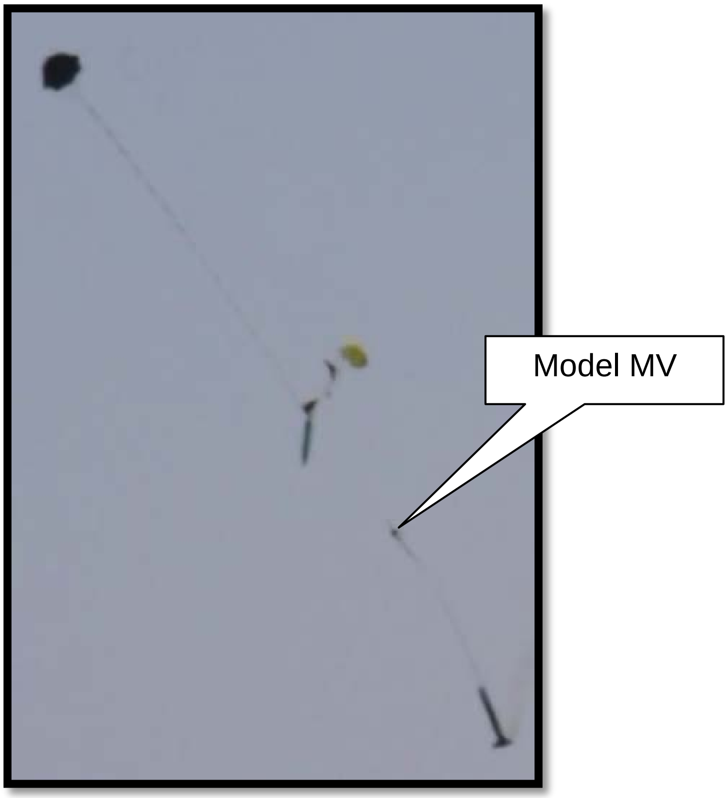


Figure 25 - Full Deployment with Scale MV in proper position

III.2b Predicted Flight Model to Actual Flight Data Comparison/Discussion

The flight data figure shows two interesting items:

1. There appears to be a ejection gas leakage which resulted in the pressure spike at apogee and drogue deployment.
2. The apogee attained (488') was lower than what the altimeter was programmed to eject the main (500)', so the main was deployed slightly more than a second after

apogee/drogue event. The drogue deployed at 5.75 seconds after liftoff and then main deployed at 6.80 seconds after liftoff.

While preparing for launch, the cloud cover increased so we elected to use a slightly smaller motor that would keep the rocket below the perceived cloud ceiling. The simulation placed the apogee slightly above 550' feet so we left the main parachute deployment altitude at 500'. Reality proved otherwise.

III.3 Subscale Flight Data Impact on Full Scale Design Discussion

The Tender Descender allows both the drogue and the main to be housed in a single parachute bay. Although the Tender Descender worked as we had designed it, it became apparent that we would not be able to have a redundant dual deploy recovery system using this recovery method. We have redesigned our recovery system to utilize two parachute bays, one for the drogue and one for the main.

III.3a Recovery Subsystem

We are using two PerfectFlite StratoLoggers as our deployment devices. We want the MV to leave the rocket near drogue deployment in order that the autopilot GPS has sufficient time to achieve its satellite fixes.

The parachutes will provide the primary lift and the MV will tow the rocket back to the launch area. The MV is not responsible for lifting and carrying the rocket. To accomplish the lifting and carrying task, the parachutes would have to be jettisoned, or not deployed unless there is an MV failure. Our interpretation of the USLI safety requirements and our initial beliefs indicate that we cannot have a non-parachute recovery system.

III.3a.1 Parachute, Harnesses, Bulkheads, and Attachment Hardware Descriptions.

The two recovery harnesses, main and drogue, are combination of 1/8" Kevlar and 9/16' tubular nylon. Both harnesses are 24 feet long. A length of tubular nylon provides some protection against zippering from the narrow diameter Kevlar. A Kevlar loop through the bulkhead will fasten the harness to the ebay and to the nose cone and fin can.

	DIA.	TENSILE STRENGTH (lbs.)	WEIGHT (lbs. per 100ft.)
Kevlar	1/8"	1,500	0.650
Tubular Nylon	1/2"	2,000	2.065
	1"	4,000	4.200
Eyebolt	1/4"	500	0.090
	3/8"	1,200	0.190

Table 9, Relative Breaking Strengths and Weights

The eyebolt is the weak link so we decided to use Kevlar, with a tubular nylon section. This combination has comparable tensile strength to the eyebolt and will save space and weight without sacrificing strength.

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" parachute would have a descent rate of 24 fps. We settled on the LOC Precision 50" parachute for the main and a LOC Precision 28" parachute for the drogue. Both are made with Rip-Stop coated nylon fabric with heavy duty braided nylon lines.

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.

Each bulkhead, nose cone, ebay forward end, ebay aft end, firewall is constructed from ¼" aircraft grade plywood. They are fastened to the airframe with West System two-part epoxy. The ebay bulkheads are two layers of the ¼" plywood fastened at each end of the ebay by two ¼" threaded rods. A 1/8" length of Kevlar is looped through the ebay bulkheads to form attachment points for the recovery harnesses. Another Kevlar loop is fastened through the firewall at the base of the airframe and yet a fourth Kevlar loop is fastened to the nose cone bulkhead for recovery harness attachment points.

III.3b Electrical Components and Safe Launch Vehicle Recovery.

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 main ejection charge at 750 feet.

III.3c Drawings/Sketches, Block Diagrams, and Electrical Schematics.

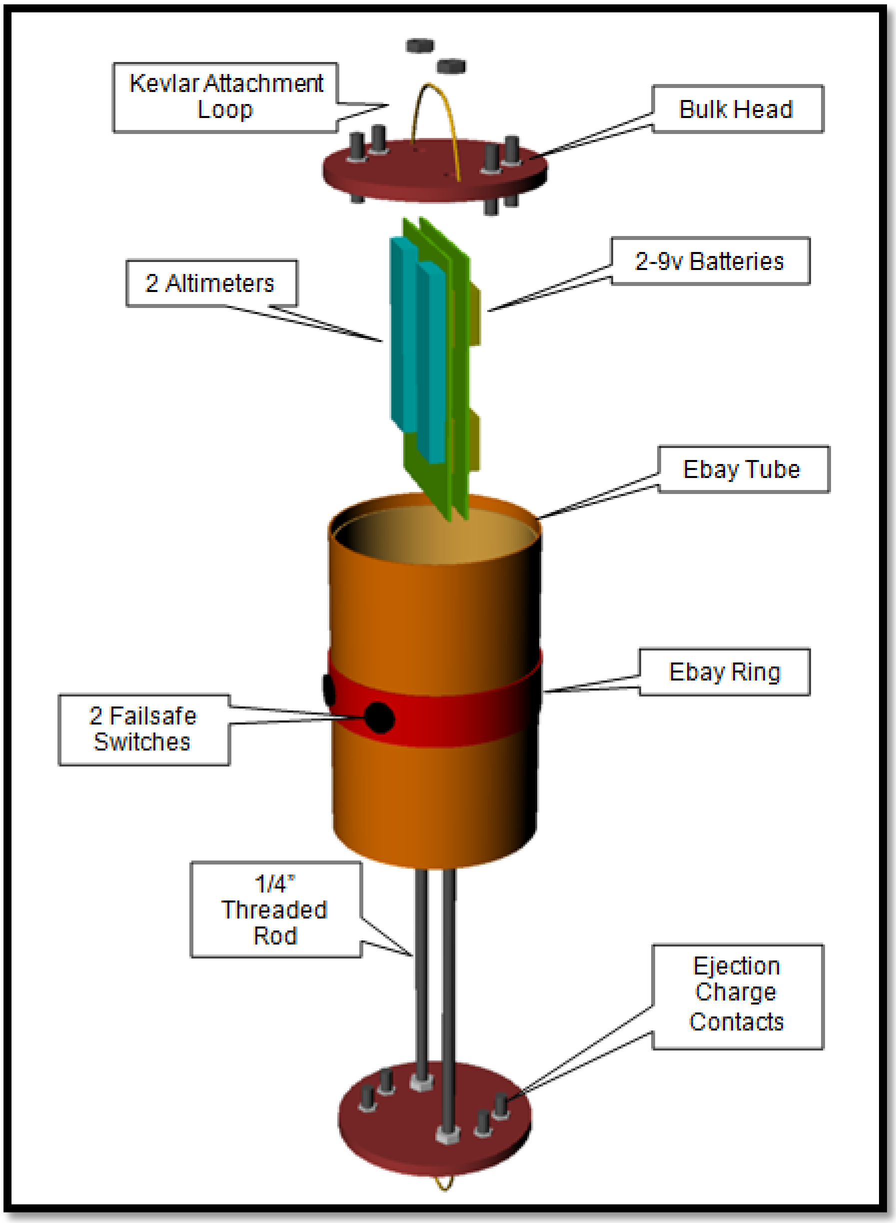


Figure 26 – Ebay, Exploded View

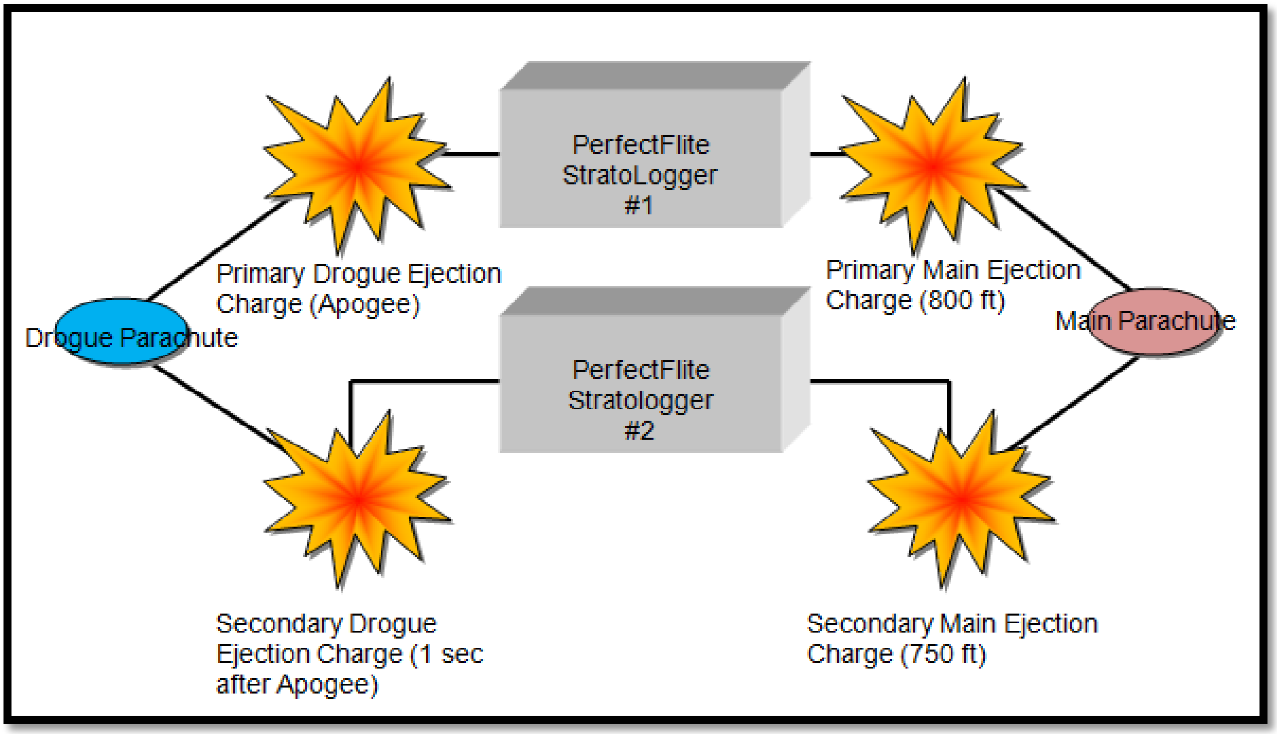


Figure 27 – Avionics Block Diagram

III.3d 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.

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

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

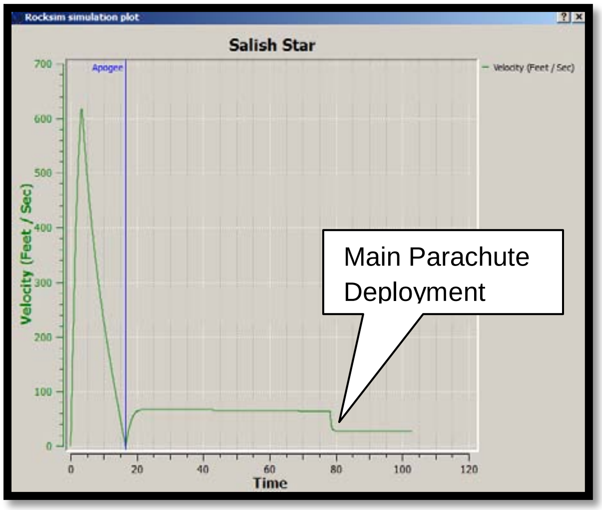
Kinetic Energy by Section		Weight Lb	KE Drogue (fps)	KE Main (fps)
Section 1	Fin Can Aft Airframe MV	7.70	417	67
Section 2	Ebay	1.19	64	10
Section 3	Fwd Airframe Nose Cone	5.98	324	52

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.3e Discuss test results.

As of January 9,2013, the only tests are simulations via Rocksim. These graphs simulate the rocket's flight using a CTI K445 reload.



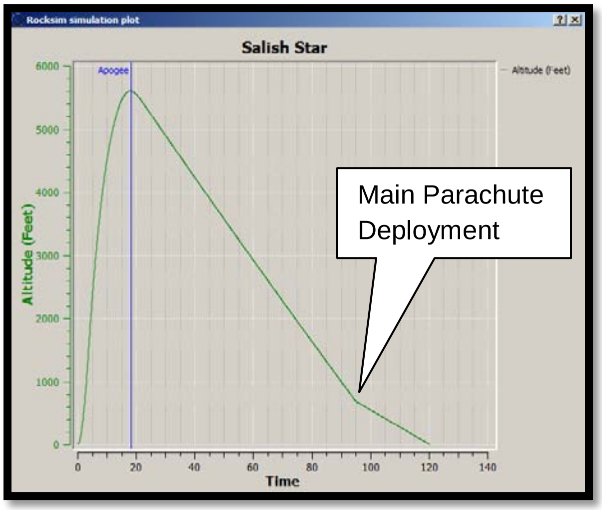
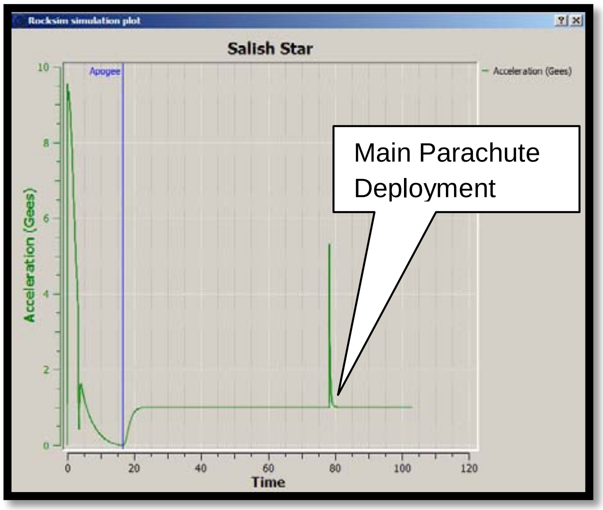


Figure 28 - Velocity Profile *Figure 29 - Altitude Profile*



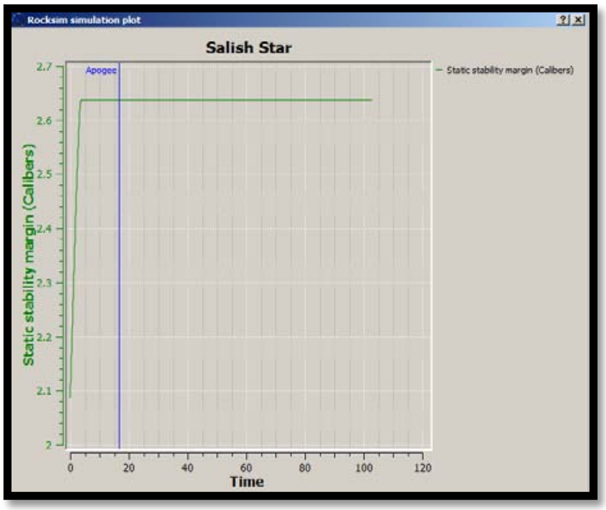


Figure 30 - Acceleration Profile *Figure 31 - Static Stability Profile*

All of the flight profiles appear to fit into nominal profiles based upon previous experiences

III.3f Discuss Safety and Failure Analysis.

Justin 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.

We carefully inspect and analyze our rocket and the MV during construction, pre launch, and post launch activities. Both the lead person and our advisor examine our completed check lists and then conduct a brief inspection of their own. Procedural and operational questioning take place throughout the design, construction, and testing phases.

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.
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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.
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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 criteria.	Test

III.4 Mission Performance Predictions

III.4a State the mission performance criteria.

The goals of Team RPG’s rocket is to safely deliver the payload to 5280 feet (AGL) 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.4a.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.4b Flight Profile Simulations with CIT K445 Reload

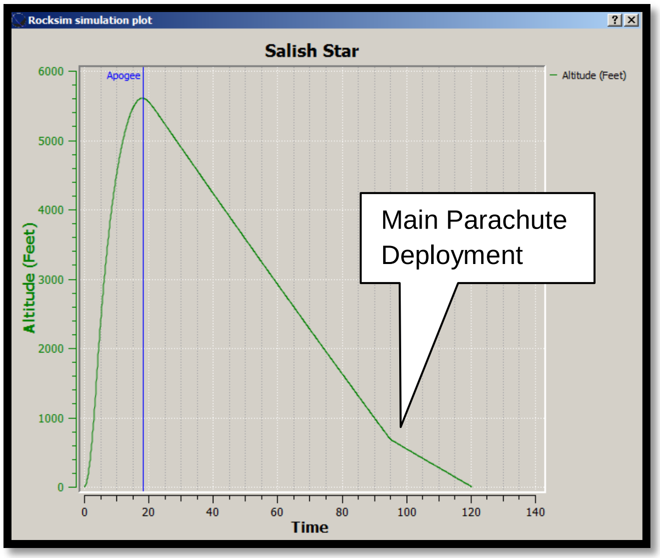


Figure 32 – Altitude Simulation

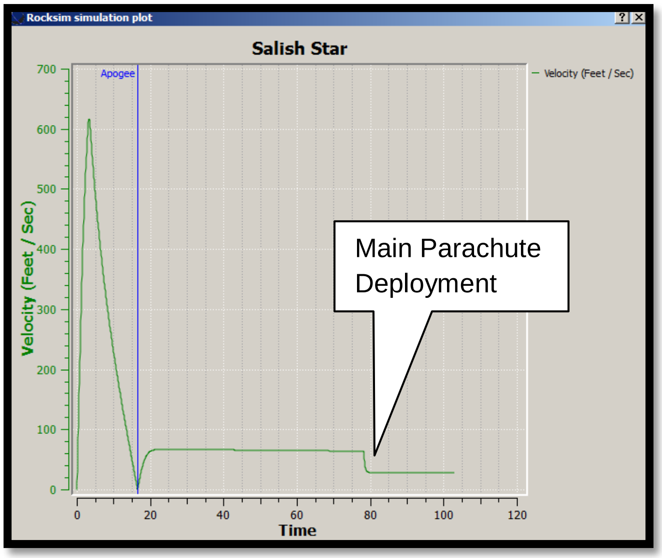


Figure 33 - Velocity Simulation

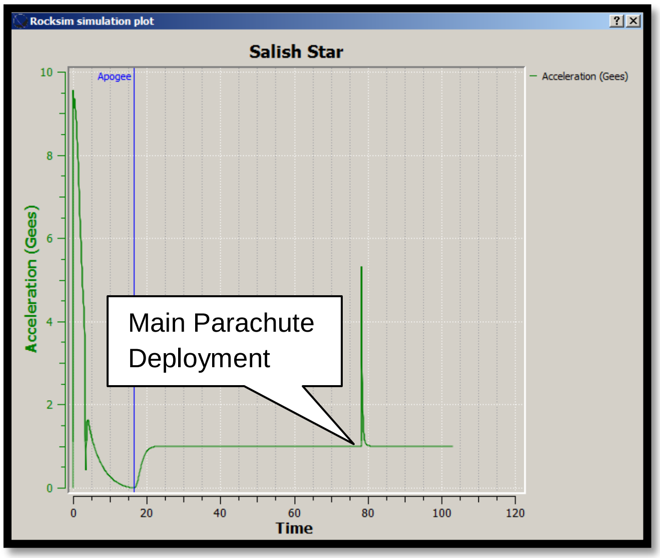


Figure 34 – Acceleration Simulation

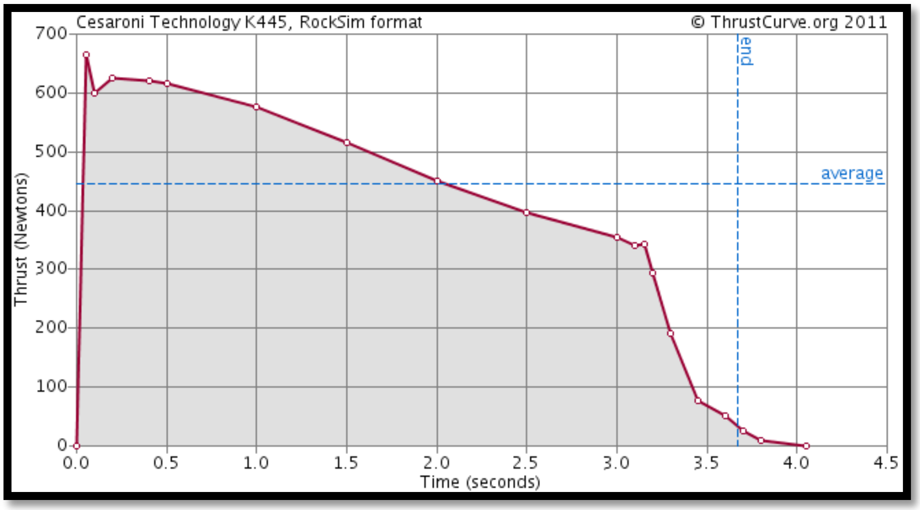


Figure 35 – CTI K445 Thrust Curve

III.4c Static Stability Margin

Static Stability = (Center of Pressure – Center of Gravity)/Diameter

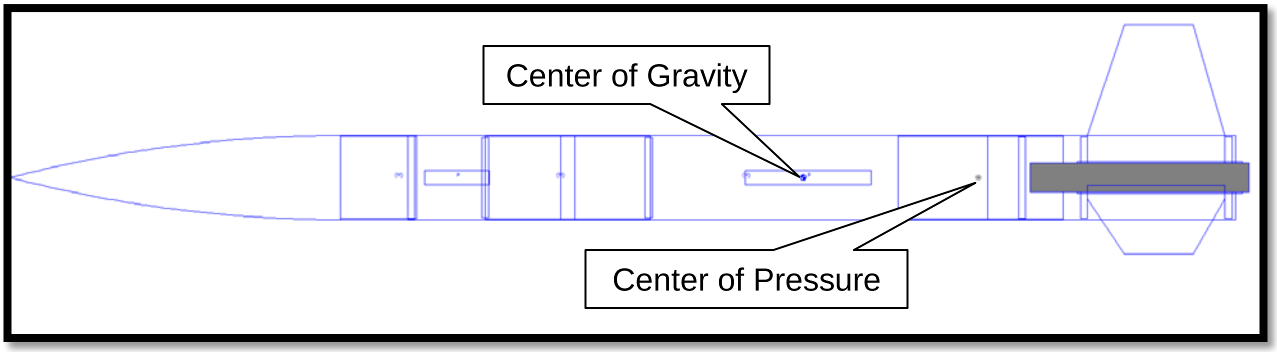


Figure 36 - Static Stability Margin with K445

Center of Gravity	57.60
Center of Pressure	70.33
Static Stability	2.09

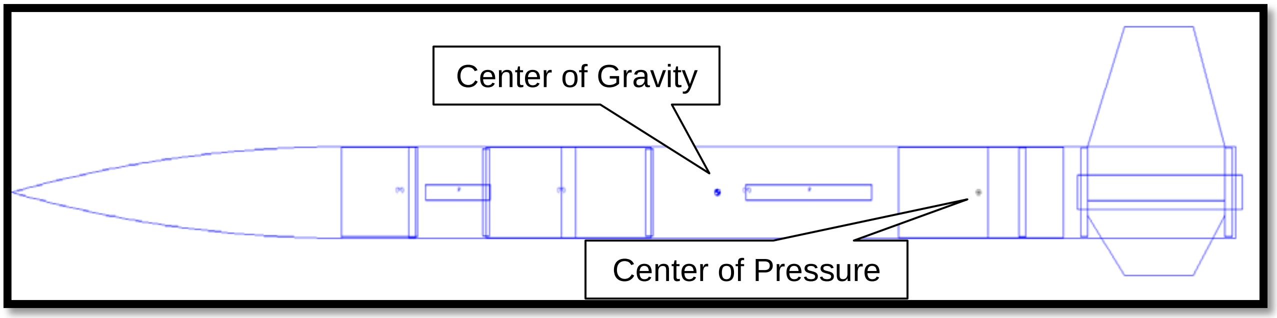


Figure 37 - Static Stability Margin w/o reload

Center of Gravity	51.33
Center of Pressure	70.33
Static Stability	3.11

The Center of Gravity (CG) moves toward the fins 6.27 inches when the loaded motor is installed. This reduces the Static Stability Margin to 2.09 which is still within the recommend Stability Margin of 1-2.

III.5 Payload Integration

Our payload, the MV, is designed to be folded and stowed in the airframe. The rocket is a transport vehicle. The recovery system is the primary interface between the MV and the rocket.

III.5a Describe Integration Plan.

The MV's legs fold down and result in a 5 ½ x 18 inch cylindrical package that is carried in the aft airframe section. It is connected to the aft airframe section with a 10 foot length of 1/8 inch Kevlar. The MV is connected to the aft end of the main parachute recovery harness with an additional 10 feet length of 1/8 inch Kevlar. The forward end of the recovery harness is attached to the aft end of the ebay.

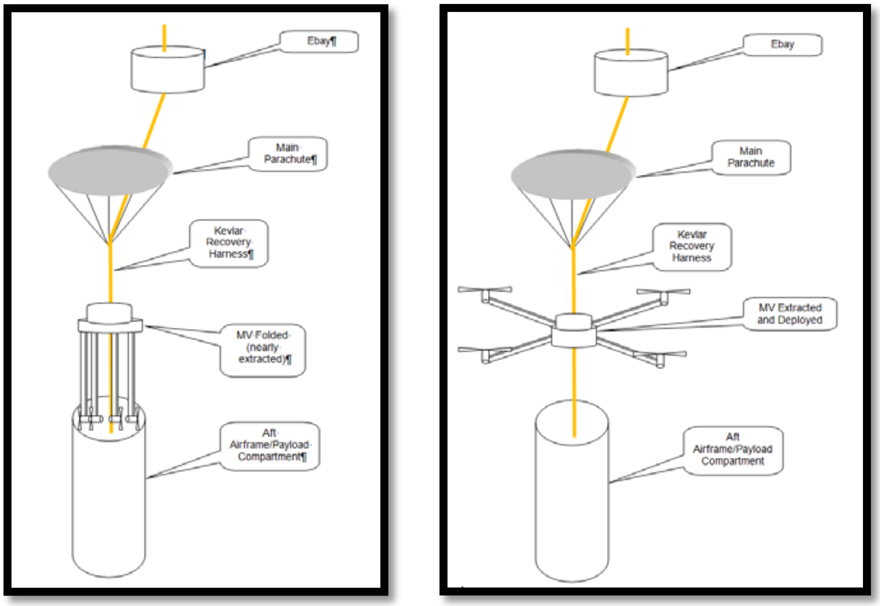


Figure 38– Initial and Final MV Deployment

III.5b Installation and Removal

The MV's four arms fold from the extended position to an arms-down position. The extended MV diameter is 26 inches and the folded diameter is 5.75 inches.

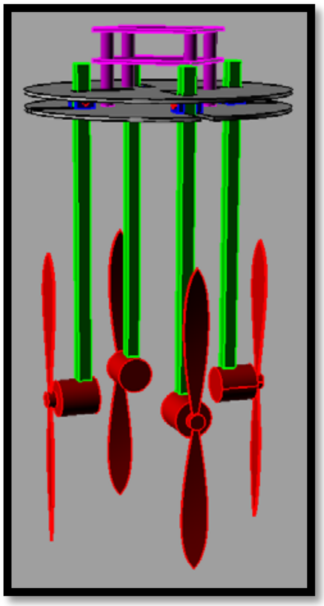


Figure 39 – MV Folded

	Diameter In.	Height In.
Folded	5.75	26.00
Extended	18.00	6.00

The arms are spring-loaded when folded. Extracting from the aft airframe allows the spring mechanism to extend the arms. Each arm has a locking device that engages and locks the arm in its extended position.

The MV is connected to the firewall between the motor and the aft airframe bay with 1/8 inch Kevlar to which a 24” section of ½ inch tubular nylon has been fastened. The tubular nylon reduces the abrasion and potential zippering from the narrower Kevlar. The Kevlar is 10 feet long and is placed in a 1 inch x 3 inch diameter container to assist in keeping it both tangle free and to minimize snaring the MV.

The MV is placed in the aft airframe on a pedestal to prevent damage to the propellers. A cylinder with a closed top is constructed from 3 liter soda pop bottles and is placed over the MV to protect it from the black powder ejection gases.

A 1/8 x 6 inch plywood disk is placed over the protective cylinder to act as a bulkhead between the MV bay and the remaining section of the recovery harness, the main parachute, and the flame-proof protective wadding. The free end of the recovery harness is fastened to the aft end of the ebay.

The protective container and the 1/8 inch bulkhead are fastened to the recovery harness in such as fashion as to be pulled from the aft airframe leaving the MV free and out of reach from possible entanglement with the MV

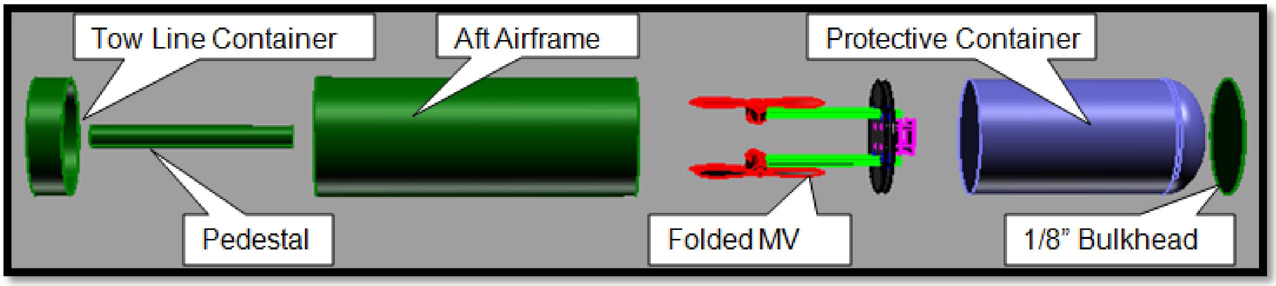


Figure 40 – MV Integration

Figure 41 - Ghosted View of MV Packed for Launch

III.6 Launch Concerns and Operation Procedures

III.6a Final Assembly and Launch Procedures

See Appendices E - J

III.6b Recovery Preparation

See Appendix F

III.6c Motor Preparation

See Appendices G, H, and I

III.6d Igniter Installation

See Appendices G, H, and I

III.6e Setup on Launcher

See Appendix E and Appendix H

III.6f Troubleshooting

See Appendix J

III.6g Post Flight Inspection

See Appendix J

III.7 Safety and Environment (Vehicle)

III.7a Team Safety Officer

Justin is the RPG’s safety officer

1. All members of the team shall adhere to the NAR High Powered Safety Code. The NAR HPRSC is attached as Appendix K
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 L.

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.

Prior to each launch, the RPG’s hold a safety meeting where everyone’s task is outlined and safety measures described.

III.7b Rocket, Payload Integration, and Launch Operations Failure Modes/Mitigation Preliminary Analysis Update

III.7b.1 Failure Modes and Mitigations

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 priorto 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 criteria.	Test

III.7b.2 Payload

Proper static grounding shall be utilized while handling autopilot or any electronic systems. Soldering requires adequate ventilation and safety glasses. None of the battery powered systems use electrical power greater than 11 volts.

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

III.7b.3 Motors and Black Powder

All explosive materials shall be kept in the appropriate storage magazine located off-site on the property of Gary Brandt, the Team Official/Mentor.

All extra black powder, e-matches, igniters, and any unused ejection charges will be stored in the magazine.

Any explosives being handled during launch day will be monitored by the safety officer.

III.7b.4 Launch Operations

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

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

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

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

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

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

III.7b.6 Interaction with Rocket Motors

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

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

III.7c 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 42 - PPE latex gloves while working with epoxy resin

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.

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.

III.7d 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.

IV.0 Payload Criteria

IV.1 Testing and Design of Payload Experiment

IV.1a Design Review at System Level.

System	Functional Requirements
Fuselage	Support arms, motors, flight controller, batteries, autopilot
Propulsion	Provide lift and flight direction
Electronics	Provide autonomous and/or manual flight control
Tow Harness	Provides interface between MV and the upper airfram and the lower airframe
RC Equipment	Provides manual flight control via interface to RC receiver

Table 11, MV Systems

IV.1a.1 Drawings and Specifications

The MV's four arms fold from the extended position to an arms-down position. The extended MV diameter is 26 inches and the folded diameter is 5.75 inches.

	Diameter In.	Height In.
Folded	5.75	26.00
Extended	18.00	6.00

Table 12, MV Dimensions

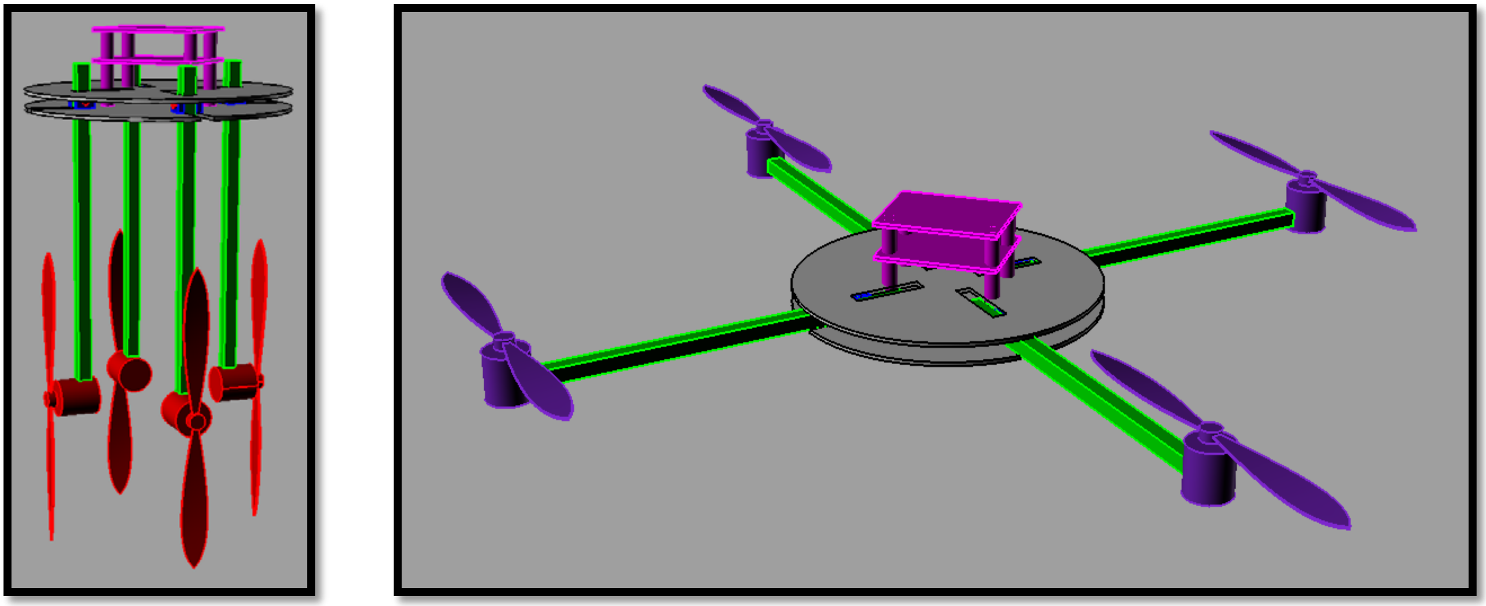


Figure 43 – MV Folded and Extended

The phases to the MV development are:

- Designing and building the MV;
- Designing autopilot electronics;
- Programming the autopilot;
- Designing the MV deployment and towing scheme; and,
- Learning to fly the MV

IV.1a.1 Designing and Building the MV

We have 3 small RC quadrotor vehicles that we have studied extensively to determine optimal airframe size, motor power, and battery size. We have built two experimental multirotor vechicles, a tri-copter and a small quadcopter.

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 motor vibration stand so that we can minimize the vehicles' vibration which may affect the GPS and the stabilization systems.

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.

IV.1a.2 Designing the Autopilot Electronics

We are starting with an ArduoPilot 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.1a.3 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.1a.4 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 38 for a conceptual drawing of this plan.

IV.1a.5 Learning to fly the MV

None of the team members or advisors are 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. The commercial MVs are ready-to-fly multirotor aircraft from hobby shops.

IV.1b Integrity of Design – Subsystems

Each of the subsystems have either gone through or are scheduled to go through a thorough test procedure.

System	Subsystem
Fuselage	Body
	Arms
Propulsion	Motors
	ESC
	Propellers
Electronics	Batteries
	Flight Controller
	Autopilot
Tow Harness	Upper Section
	Lower Section
	Connecting quicklinks
RC Equipment	Transmitter and Receiver

Table 13, Payload Subsystem

IV.1c Demonstrate that the design can meet all system-level functional requirements.

System	Subsystem	Evaluation	Verification
Fuselage	Body	Inspection of construction	Test Flights
	Arms		
Propulsion	Motors	Thrust Tests	
	ESC	Voltage tests	
	Propellers	Balancing	
Electronics	Batteries	Voltage check	
	Flight Controller	Bench testing	
	Autopilot	Bench testing	
Tow Harness	Upper Section	Ground and air testing	
	Lower Section		
	Connecting quicklinks		
RC Equipment	Transmitter and Receiver	Ground and air testing	

Table 14, System/Subsystem Performance Characteristics

IV.1d Specify approach to workmanship as it relates to mission success.

IV.1e Planned Component Testing

Feature	Verification Plan	Status
Construct MV fuselage	Inspection	Work in progress
Arm folding	Inspection	Work in progress
Motor thrust testing	Bench test	Work in progress
Propeller balancing	Bench test	Complete
Flight controller construction	Inspection	Complete
Flight controller testing	Bench test	Work in progress
Autopilot construction	Inspection	Complete
Autopilot testing	Bench test	Work in progress
RC Testing	Flight tests	Work in progress

Table 15, Verification Plan and Status

IV.1f Status and plans of remaining manufacturing and assembly.

The MV and folding arms are complete. The motor mounts need to be added followed by the autopilot and the flight controller board. We plan to have the MV finished and ready for testing by the end of January, 2013.

IV.1g Integration Plan

The MV’s arms fold in a downward position. This allows the MV to slide into the rocket’s lower airframe. The lower harness is placed in the rocket in a cup that will help eliminate fouling between the MV and the harness. The MV is attached 10 feet above the aft attachment point. The upper harness which is 12 feet long, is attached to the top of the MV and continues to the aft end of the ebay. The protective cylinder is attached 2 feet above the MV followed by the bulkhead.

IV.1a Instrumentation Precision

The GPS is an Astro 200 and accuracies to within 15 meters can typically be obtained. This depends on the number and position of the satellites.

The MediaTek MT3329 GPS unit that is the main instrument in the autopilot has a position accuracy of < 3m CEP (defined as the radius of a circle centered on the true value that contains 50% of the actual GPS measurements).

IV.1h Discuss the payload electronics with special attention given to transmitters.

Figure 44 - Complete Arduopilot

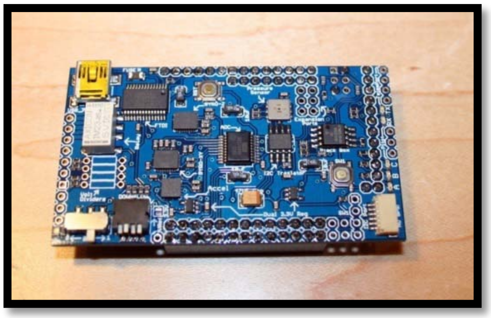


Figure 45 - Complete Flight Controller Board

The flight controller board was assembled from a kit whereas the Arduopilot came as a fully fabricated item.

The MV, autopilot, and RC receiver are all powered by a single 11.4v lipo battery. The battery has a 2 hour standby life and will power the MV at full power for 9-12 minutes depending upon how long the rocket remains on the launch pad.

The RC transmitter operates at 2.4 GHz in a frequency hopping spread spectrum whose operating frequency band is between 2.400-2.4835GHz. The Garmin GPS frequencies are 151.82, 151.88, 151.94, 154.57, and 154.60 MHz.

Flight testing and autopilot testing are on a weekly basis and more if weather permits.

IV.1i Provide a safety and failure analysis.

These are the potential hazards and their mitigations:

Payload Failures	Potential Effects of Failure	Failure Mitigation
MV fails to unfold	Payload experiment fails.	Testing and careful packing.
MV becomes entangled during	Payload experiment fails.	Testing and careful packing.

deployment.		
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 Keeping the MV clear of all the parts of the rocket during the landing phase initiated by the fin can coming in contact with the ground
MV lands further than the 100 feet mission criteria.	Failure of that mission criterion.	Test
One or more propellers striking the recovery harness during the towing phase	MV's motor may stall Payload experiment fails.	Careful planning and multiple test flights.

IV.2 Payload Concept Features and Definition

IV.2a Creativity and Originality

This is an entirely new project for us. We have no experience in RC flying or MVs. Building an MV and learning about the propulsion systems and the electronics to control the MV has proven to be an interesting challenge.

IV.2b Uniqueness or Significance

Our payload will be an autonomous UAV that will tow our rocket back to the launch area. This is a unique project in that we are learning about aerodynamics, flight controls, and UAVs. We are also learning how to fly a RC vehicle. The engineering is proving to be very interesting and rewarding to the students.

IV.2c Suitable Level of Challenge

This is a totally new process for most of the students. We've had little to no experience working on a project of this magnitude. That being said, the RPGs are confident that we can complete this project successfully. Our advisors, Gary and Dave, are totally supportive and help us find answers and encourage us to figure out how to find solutions to our challenges.

IV.3 Science Value

The objective of the payload is to learning some 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 success.

IV.3a Payload Success Criteria

- MV deploys as designed
- MV tows rocket vehicle to launch area
- MV lands with rocket within 100 feet of launch tower

IV.3b Experimental Logic, 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.

IV.3c Preliminary Experimental Procedures

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 push the altitude to 5000 feet. Data collection and analysis will allow us to make any programming changes or other modifications necessary to obtain consistent and accurate results. Test, evaluate, modify, and repeat as necessary.

A typical 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.4 Payload Safety and Environment Plan

IV.4a Safety Officer

Justin is the safety officer.

IV.4b 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 42 and 57 for more details.

IV.4c Personnel Hazards

Personnel hazards have discussed elsewhere. Please see page 48 for more details.

IV.4d Payload Environmental Concerns

Nothing in the payload constitutes an environmental hazard.

V.0 Project Plan

V.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

V.2 Funding Plan

We are currently seeking funds from neighboring tribe’s Community Action Grants.

V.3 Timeline

Please see Appendix C.

V.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

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

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

VI.0 Conclusion

The RPGs are confident in the design that we have created to meet the overall mission requirements in the USLI competition. 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 safe as well as successful.

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

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

The overall success of the 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	CDR

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	Top Flite			
Size	28			
Altitude at Deployment (ft)	5,280			
Velocity at Deployment (ft/s)	0.0024			
Terminal Velocity (ft/s)	59.41			
Recovery Harness Material	Kevlar			
Harness Size/Thickness (in)	1/8”			
Recovery Harness Length (ft)	24			
Harness/Airframe Interfaces	1/8” Kevlar Loops			
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	Kevlar			
Harness Size/Thickness (in)	1/8”			
Recovery Harness Length (ft)	24			
Harness/Airframe Interfaces	1/8” Kevlar Loops			
Kinetic Energy Upon Landing (ft-lb)	Section 1	Section 2	Section 3	Section 4
	67	10	52	

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

Recovery System Properties	
Electronics/Ejection	
Rocket Locators (Make, Model)	Garmin Astro
Transmitting Frequencies	2.4 GHz frequency band is between 2.400-2.4835GHz. The Garmin GPS frequencies 151.82, 151.88, 151.94, 154.57, and 154.60 MHz.
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	12/1, 12/8, 12/15, 1/7, 1/13, 1/20

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

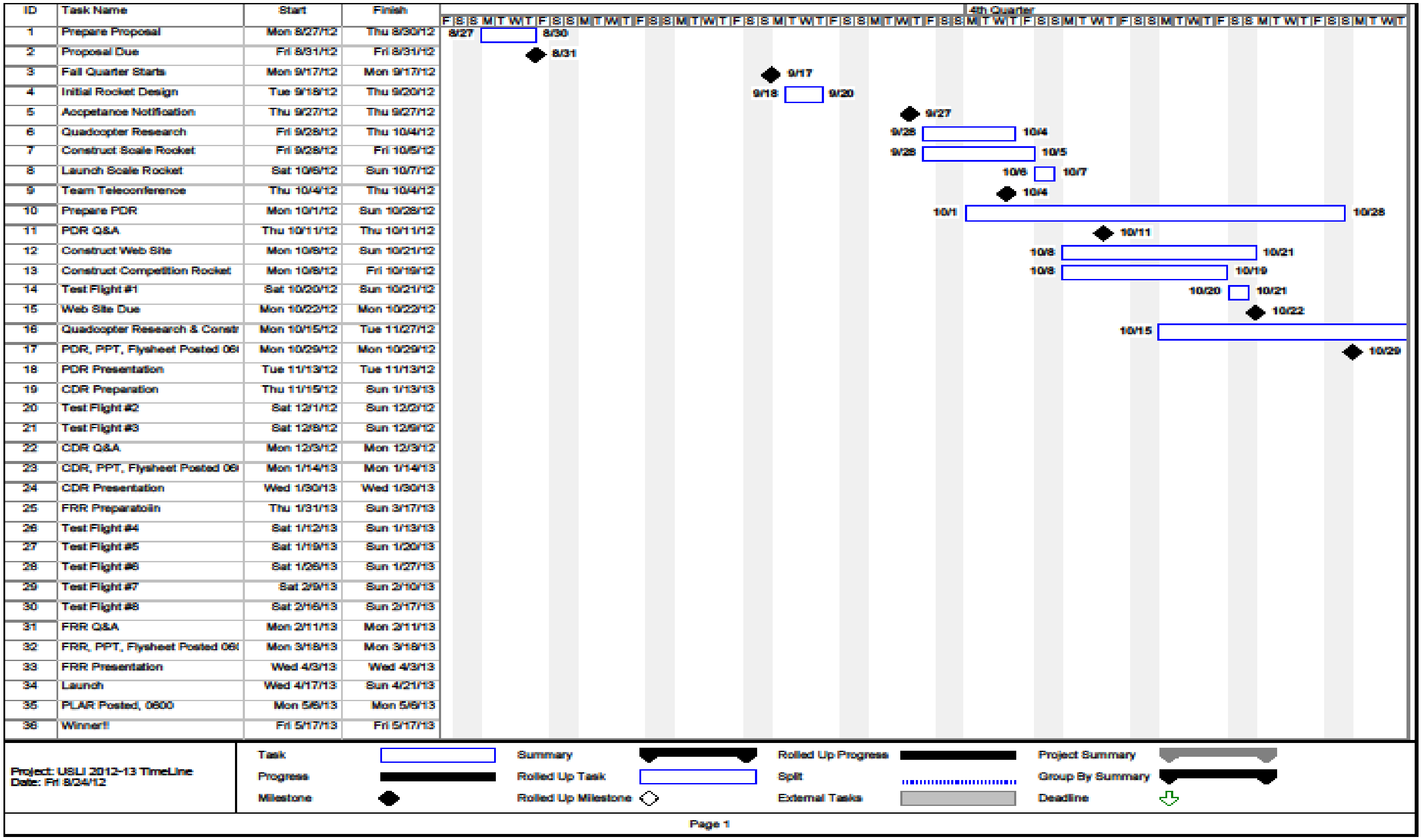
7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Simulation	Complete
8. The launch vehicle shall stage the deployment 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		Work in Progress
c. The payload does not have to be flown during the full-scale test flight.			
▪ If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Measured mass of actual payload will be either substituted or the payload will be flown	Test flight	Work in Progress
▪ If the payload changes the external surfaces of the launch vehicle (such as with camera housings and/or external probes), those devices must be flown during the full scale demonstration flight.	Test flight will be with rocket as its designed		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		Work in Progress
e. The success of the full scale demonstration flight shall be documented on the flight certification form, by a Level 2 NAR/TRA observer.	Our mentor and 2 other NAR L2 individuals are available		Work in Progress
f. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer.	No changes will be made.		Work in Progress
20. The following items are prohibited from use in the launch vehicle:			

a. Flashbulbs. The recovery system must use commercially available low-current electric matches.	None of these have been included in the rocket design	Inspection	Complete
b. Forward canards.	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:			In Progress
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	Acceptance Notification	Thu 9/27/12	Thu 9/27/12
6	Quadcopter 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	Quadcopter Research & Constr	Mon 10/15/12	Tue 11/27/12
17	PDR, PPT, Flysheet Posted 06(	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 06(	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 06(	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, 0600	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

Task	☐	Summary	▬	Rolled Up Progress	▬	Project Summary	▬
Progress	▬	Rolled Up Task	☐	Split	┈	Group By Summary	▬
Milestone	◆	Rolled Up Milestone	◇	External Tasks	▨	Deadline	⇩

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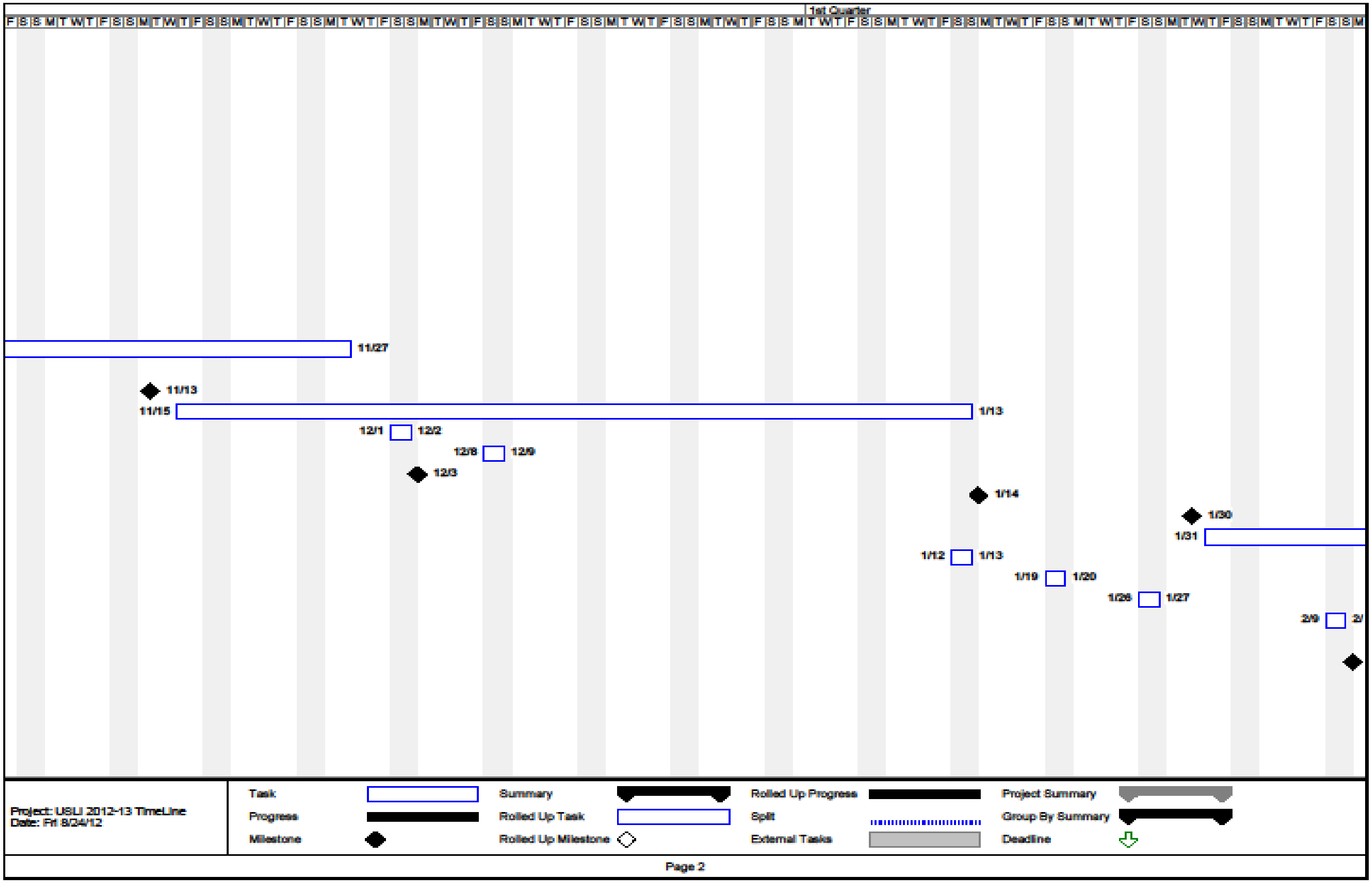
1st Quarter
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Project: USLI 2012-13 TimeLine
Date: Fri 8/24/12
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Rolled Up Milestone
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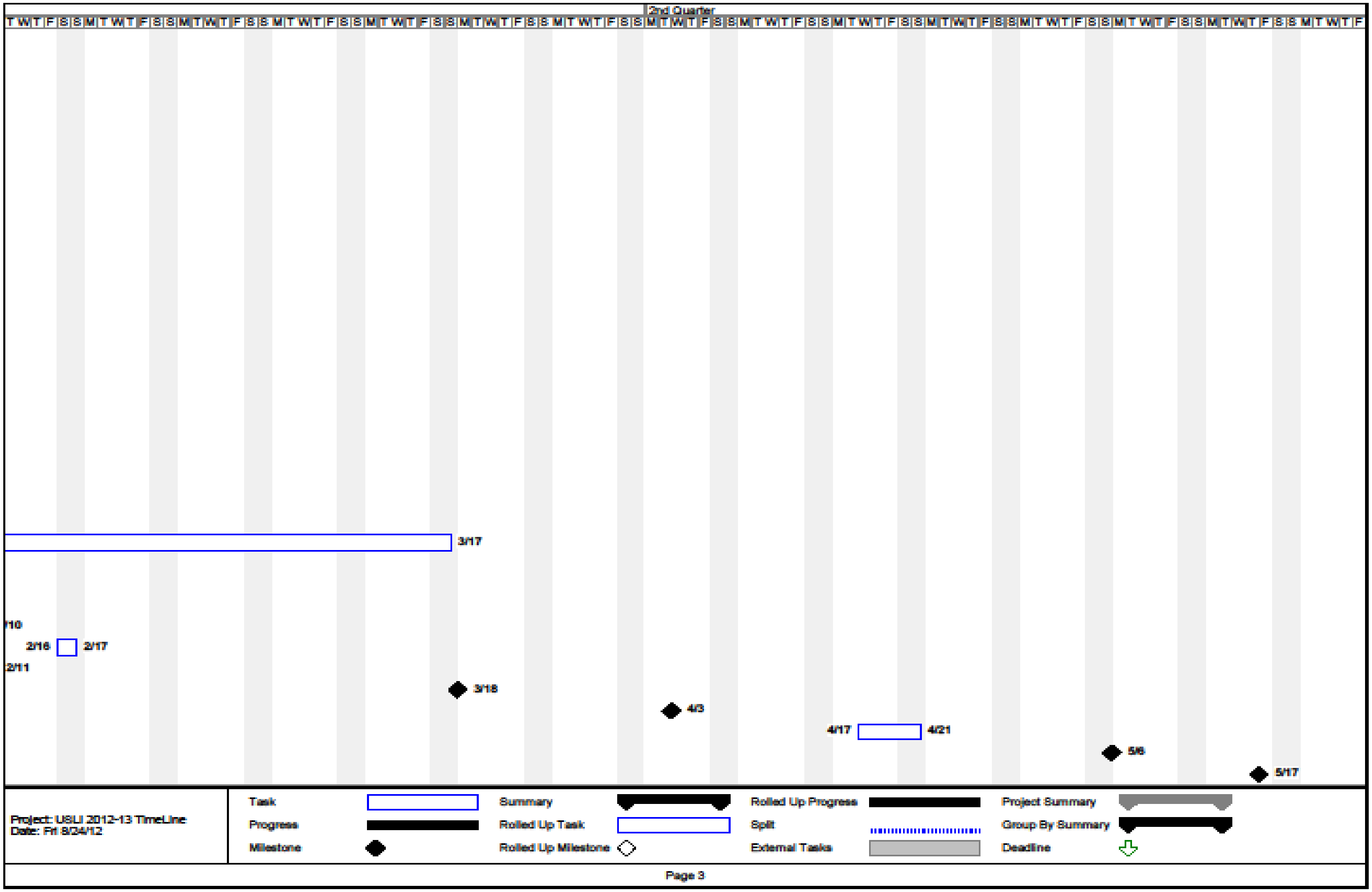
External Tasks
Project Summary
Group By Summary
Deadline
Page 2


2nd Quarter
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2/11
3/18
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Project: USLI 2012-13 TimeLine
Date: Fri 8/24/12
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
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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

- ☐ Fold MV arms
- ☐ Power-on system
- ☐ Power on RC transmitter
- ☐ Check for RC connection between transmitter and receiver
- ☐ 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
- ☐ 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

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.
- ☐ Safe all ejection circuits.
- ☐ Remove any non-discharged pyrotechnics.

Flight Failure Checklist

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

Appendix 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:

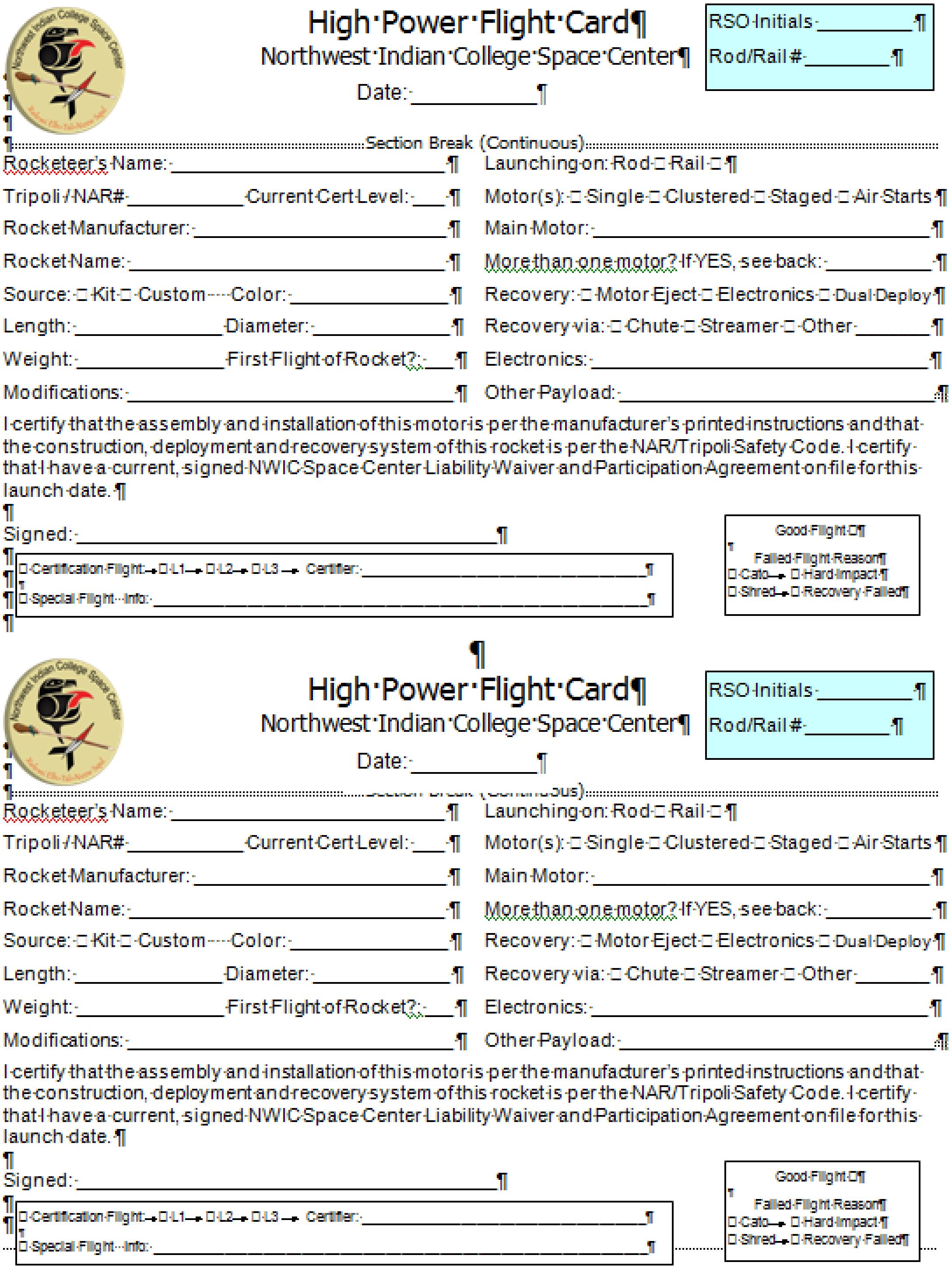
____

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 # ________

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 # ________

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