NORTHWEST INDIAN COLLEGE
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2012-2013

Northwest Indian College Space Center USLI Preliminary Design Review

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I. Preliminary Design Review Summary

I.1 School Information

Organization Name: Northwest Indian College Space Center
Northwest Indian College, 2522 Kwina Road, Bellingham, WA, 98226
Team Name: RPGs
Team Mentor: Gary Brandt, National Association of Rocketry (NAR) Level 2, gbrandt@nwic.edu
NAR Section: #730 NWIC-SC Northwest Indian College Space Center

I.2 Launch Vehicle Summary

Preliminary investigation has the rocket diameter at 6 inches with a length of 85 inches. The rocket airframe will be carbon fiber, the nosecone will be fiberglass and the fins will be aircraft-grade plywood. The fins will be mounted through-the-wall (TTW). Water integrity and minimal weight are two of the requirements for our rocket; carbon fiber and fiberglass satisfy 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. Initial design discussions and Rocksim planning has resulted in this preliminary design:

I.2a Size and Mass

Airframe: Carbon Fiber

Length	83.00	Diameter	6.00
Weight	5.00	Fin Span	22.00
Center of Gravity	41.55	Center of Pressure	65.49
Static Stability	3.92		

I.2b Motor Choice

Diameter: 54 mm
Cesaroni Technology Inc. K

I.2c Recovery System

Parachute Type	Circular	Main – 52”	Drogue – 12”
Harness	9/16” Tubular Nylon		
Avionics	Dual PerfectFlite StratoLogger Altimeters		

I.2d Milestone Review Flysheet (Appendix A)

I.2e Payload Summary

The rocket will carry a multirotor vehicle (MV) that will become a tow tug after the rocket achieves a certain altitude. The MV will be deployed at a yet to be determined altitude and will be autonomous with Radio Control (RC) backup. The MV as an Unmanned Aerial Vehicle (UAV) will tow the rocket back to the launch area prior to landing.

II. Changes Made Since Proposal

None

III. Vehicle Criteria

III.1 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.

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

III.1a Mission Requirements

Our mission is to lift an MV within or on our rocket with the intent to have the MV tow the rocket back to or near the launch site. The MV will utilize a GPS-based autopilot. This will provide the guidance from the MV's deployment back to the launch site. We will also have anRC connection that will allow us to override the autopilot if necessary. The MV and its tow will descend under the drogue and main parachutes to ensure safety. This configuration, of course, adds several layers of complexity: 1) the MV will have to fight the additional drag from the parachutes and wind; 2) the potential for entanglement with the recovery harness and parachutes during descent and landing is increased; and, 3) the MV deployment becomes a an exercise in keeping everything from being entangled.

III.1b Mission Success Criteria

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

Additional Flight success criteria are listed below:

- rocket launches as designed;
- attains an altitude within 10% of 5,280 feet;
- drogue parachute deploys at apogee;
- main parachute deploys at 500 feet above ground level;
- descent rates are within design parameters;
- rocket is recovered with minimal damage and able to be launched again within four hours.
- rocket and electronics sustain no damage from a damp landing
- MV deploys as designed
- MV tows rocket vehicle to launch area
- MV lands with rocket within 100 feet of launch tower

III.2 System Level Design Review

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 83 inches tall with an airframe diameter of 6 inches. The airframe is constructed from carbon fiber while the fins are aircraft-grade birch plywood and the nose cone is fiberglass. 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 2 list the dimensions.

Length	83.00	Diameter	6.00
Weight	5.00	Fin Span	22.00
Center of Gravity	41.55	Center of Pressure	65.49
Static Stability	3.92		

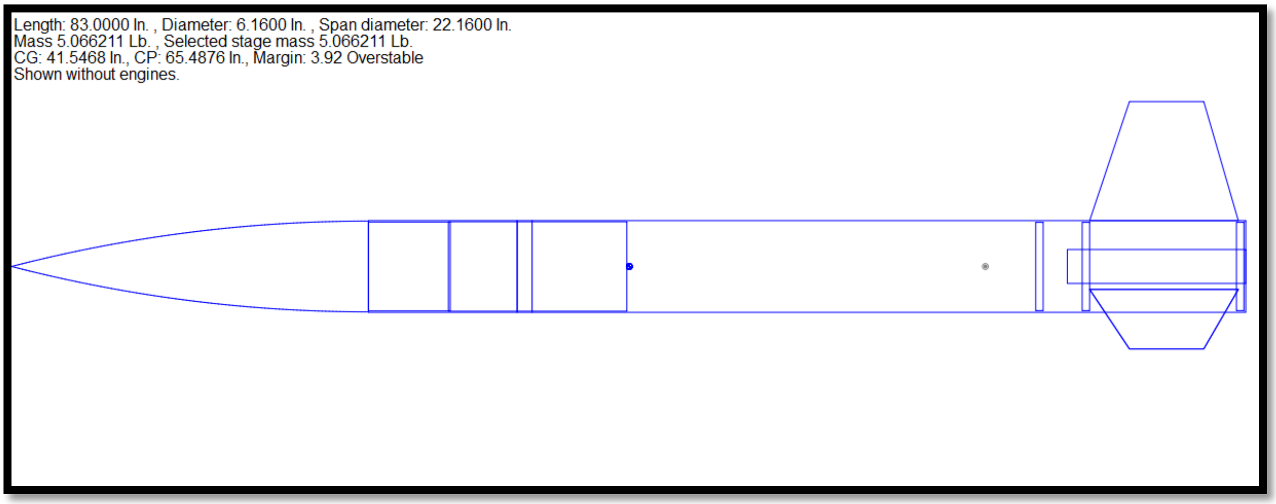


Figure 1, Rocksim 9 Side View

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

1. It is large enough to house our MV;
2. It is light enough so that the MV can tow it;
3. It is light enough that we can use a lower power, longer burn motor to reduce acceleration and velocity;
4. It has a high strength to weight ratio; and,
5. 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.

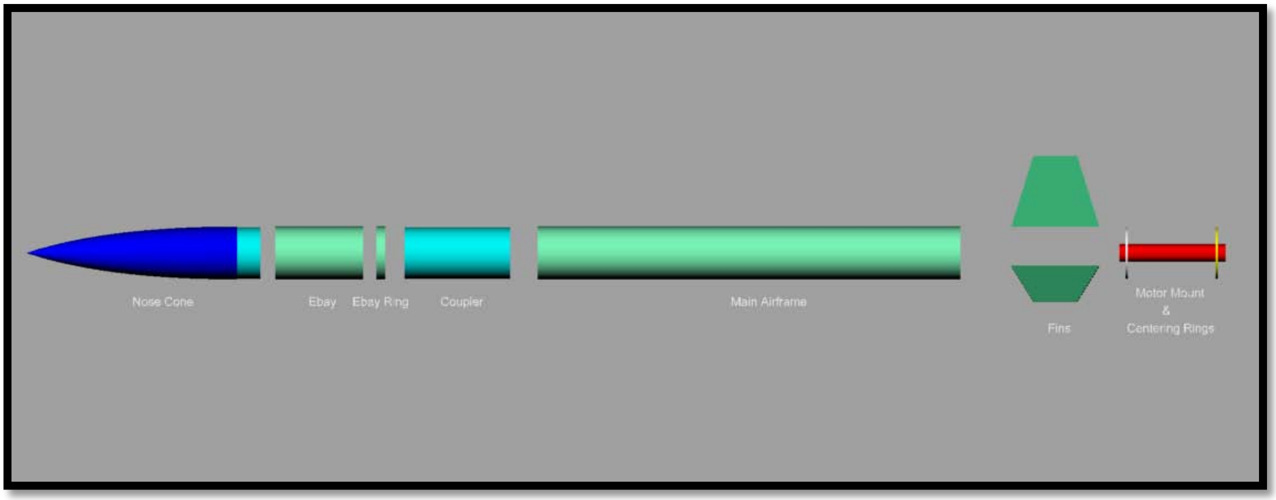


Figure 2, Airframe Component View

III.2a Nosecone

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

Figure 3, GPS Tracker on nose cone insert with hand-held GPS receiver

III.2b Electronics Bay (Ebay)

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

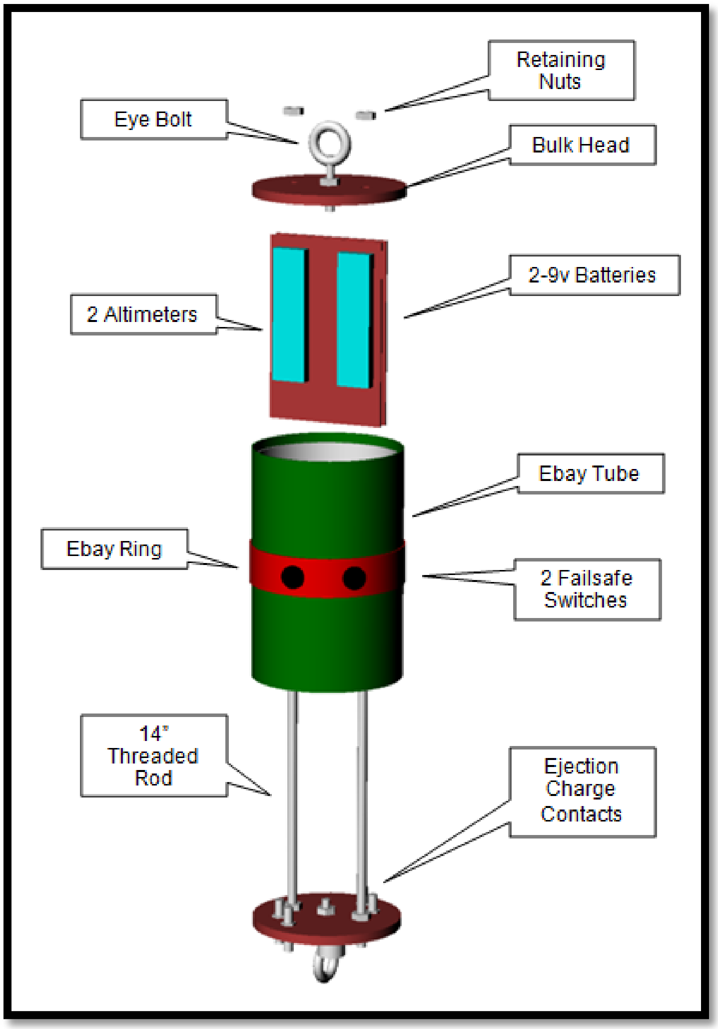


Figure 4, Ebay Concept

Figure 6 depicts the altimeter and ejection charge connections and layout.

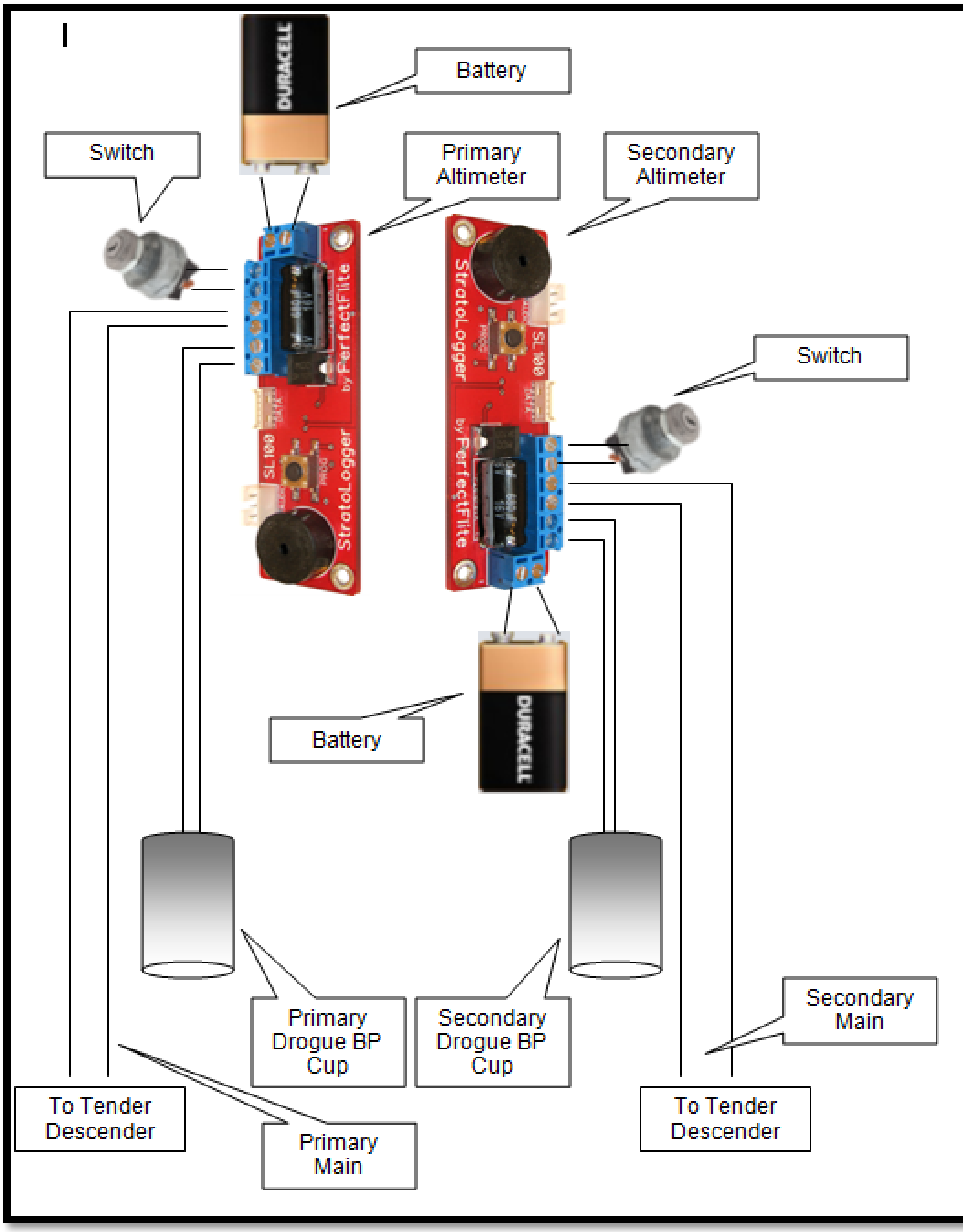


Figure 5, Redundant Dual Deploy Avionics Block Diagram

III.2b.1 Ebay Ring

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

III.2c Tube Coupler

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

III.2d Main Airframe

The main airframe is 6 x 48 inches of lightweight carbon fiber. The tube coupler, detailed in III.2c, above connects the upper portions of the rocket to the main airframe. This section houses the drogue and main parachutes, the Tender Descender with the appropriate recovery harnesses, the MV, the fins, and the motor mount. Usable space is 25 inches. The parachutes and recover harness occupy about 9 inches; this leaves 17 inches for the MV and the eye bolt that connects the harness to the rocket.

III.2d.1 Firewall

A 6 x ¼ inch aircraft-grade plywood bulk head is fastened 32 inches from the top of the airframe with West Systems two part epoxy. This forms a firewall between the motor mount area and the remainder of the airframe.

III.2d.2 Motor Mount and Motor Retention

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

III.2d.3 Fins

Three fins constructed from 3/16" aircraft-grade plywood are fastened through the airframe wall (TTW) onto the motor mount tube. The fins are fastened to the motor mount tube, filleted with a fiberglass and epoxy fillet. The fin/motor mount tube is then slid into the airframe and epoxied in place. Epoxy fillets complete the attachment.

Figure 6, Typical Through the Wall Fin Attachment

III.2e Connecting the Components

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

III.3 Subsystems Required to Accomplish the Overall Mission.

Subsystems
Airframe is carbon fiber, nose cone is fiberglass, fins are plywood
Nose Cone

Fiberglass with plywood bulkhead. Contains the GPS tracking unit used to locate the rocket after landing and to provide flight data.	
Recovery	
Ebay	Contains deployment electronics
Parachutes	Housed in the airframe
Harnesses	Sufficient length & strength to absorb deployment shock loads
Tender Descender	Dual deploy device from one compartment
Engineer Payload	
Multirotor vehicle designed to be a tow tug Autonomous navigation via GPS Radio Control override of autopilot	
Propulsion	
Contains the motor casing and the reload used for flight.	
Ground Support Equipment	
Launch platform, guide rail and launching electronics	
Safety System	
Check lists, fire suppression equipment, cell phones	

Table 1, Subsystems

III.4 System/Subsystems Performance Characteristics and Evaluation/Verification Metrics.

III.4a Scale Rocket

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

Table 2, Subscale Rocket Performance Characteristics

III.4b Competition Rocket

Competition Rocket		Characteristic			Metrics	
System	**Subsystem**	**Design**	**Structure**	**Materials**	**Evaluation**	**Verification**
Airframe	Nose Cone	Designed in Rocksim 9	Public Missiles Limited product	Carbon fiber	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	Ebay Ring					
	Airframe					
	Fins			Aircraft-grade plywood		
Recovery	Main Parachute	Designed in Rocksim 9	Sky Angle parachute	Nylon	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Test Flights
	Ebay		Public Missiles Limited product	Carbon Fiber		
	Drogue Parachute		TopFlight Parachute	Ripstop Nylon		
	Avionics	Designed to High Power Rocketry standards	2 Perfect Flight StratoLogger Altimeters, G10 sled, zinc plated 1/4" threaded rod	Various	Multiple Ground Tests that demonstrate successful parachute ejection	Successful Ground Tests and Successful Flight
Engineer Payload	Science Payload Bay	Integration Designed with Rhino 3D	Public Missiles Limited product	Carbon Fiber	Team & Advisor Visual Inspection, Rocksim 9, OpenRocket Simulations, NAR Mentor Inspection	Successful Flight
	Multirotor Vehicle		Quadrotor with GPS based autopilot. 2.54 Ghz Radio Control as backup	Various	Multiple Ground Tests	
	Cameras		Meritline Mini Camera			
Propulsion		Designed in Rocksim 9	CTI Commercial Motors	Aluminum. ACP	Rocksim 9 Simulation	Successful Flight

Table 3, Competition Rocket Performance Characteristics

III.4c Engineering Payload Subsystem

III.4c.1 Considerations:

Legal Requirements from FAA AC 91-57

- 400 foot maximum altitude for a unmanned aircraft system (UAS);
- Human control throughout the flight;
- Human observation throughout flight.

These are the operating parameters for our USLI payload that have flight restrictions from the FAA. We are referring to our MV as a UAV because it is a more common term than the FAA's nomenclature of UAS.

III.4c.2 MV Design

- Motors big enough to drag rocket with parachutes extended;
- Folding the MV into the rocket;
- Unfolding the MV when it is out of the rocket;
- Getting the MV out of the rocket;
- Ensure not fouling with anything;
- Protect motors from ejection charge;
- Protect electronics from ejection charge.

III.4c.2 Electronics/Programming

- Batteries large enough capacity to accomplish task;
- Arming before launch;
- Starting motors at appropriate time/altitude;
- Programming waypoints;
- Stopping motors at or slightly before landing.

III.4c.3 Unknowns

- Wind

III.4c.4 Engineering

- Propeller size;
- Propeller balancing;
- MV weight;
- Motor thrust;
- MV construction materials;
- Electronic Speed Controller (ESC) size;
- ESC wiring.

The MV's motors, RC receiver, and autopilot will be armed just prior to launching. The MV will be deployed when the drogue parachute is deployed. The arms will extend upon deployment. At 400 feet (FAA requirement), the motors will engage via the autopilot's command and the rocket will be towed back to the launch area. In the event of an autopilot failure, manual RC control will be engaged and the ground-based pilot will fly the vehicles back to the launch area. The MV is designed to tow the rocket, not lift and carry it. This allows us to use smaller motors and therefore, a smaller battery, both of which save weight.

The phases to the MV development are:

1. Designing and building the MV;
2. Designing autopilot electronics;

3. Programming the autopilot;
4. Designing the MV deployment and towing scheme; and,
5. Learning to fly the MV

III.4c.4a 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 a motor stand to measure the motor thrust in order that the combined thrust of the motors will accomplish flying the MV and towing the rocket. 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.

III.4c.4b 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.

III.4c.4c Programming the Autopilot

Programming considerations included:

- waking the autopilot at 400 feet;
- navigating to the set waypoints;
- controlling the altitude descent rate so that the MV can bring the rocket back to the launch area prior to grounding; and,
- having the MV land the rocket and itself without entanglement with the parachutes/recovery harnesses or the rocket.

III.4c.4d Designing the MV Deployment and Towing Scheme

We have ascertained that using the Tender Descender as our dual deploy parachute device will allow us to "string" the rocket components and the MV in a single line. See Figure 17 for a conceptual drawing of this plan. These are the potential hazards:

1. MV becoming entangled in the recovery harness during deployment;
2. MV becoming entangled in the recovery harness during descent;
3. One or more propellers striking the recovery harness during the towing phase; and,
4. 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.

III.4c.4e Learning to fly the MV

None of the team members or advisors are RC pilots. We have three quadcopters ranging in size from 4 inches between motors to 10 inches between motors. The 4 inch quad is the Ladybird and we have 2 MQX quadcopters. All are ready-to-fly multirotor aircraft from hobby shops.

Figure 7, Ladybird Quadcopter

Figure 8, MQX Quadcopter

Several team members are leaning to fly them quite successfully both indoors and outdoors. MV orientation at a distance is proving to be one of the major problems as there is no physical differentiation as to port, starboard, front, or back in the MV design.

III.4d Propulsion Subsystem

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 an 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.

III.4d.1 Launch Guide Rail Requirements

Launch guide length: 96.0000 inches
User specified minimum velocity for stable flight: 43.9882 ft/s.

For the rocket to lift off with sufficient speed for the fins to have a stabilizing effect, the rocket's velocity by the time it reaches the end of the launch guide rail must be 43.9882 ft/s or faster.

III.4d.2 Motor Selection

Several motors were analyzed and considered for use with Rocksim 9. Cesaroni Technology Incorporated (CTI) K-size motors will be used for the competition flight. We will use Aerotech and CTI motors for low altitude testing.

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

Thrust-to-Weight Ratio = Pounds of Thrust/Weight of Salish Star

Table 4 illustrates the spectrum of motor choices given the information available. Test launches will be used to refine the motor selection. The simulation indicates that the motors are big enough to get the rocket safely off the launch rail. We do not and will not know how close the predicted altitude will be to actual altitude; until we get some actual flight data, our motor choice is based on the Rocksim 9 simulation using the best information that we have available which, at this point, is the CTI K445 or CTI K500.

Motor	Maximum Thrust		Loaded Weight (lbs)	Ratio	Propellant Weight	RocSim Altitude	Lift Off (fps)
	Newtons	Pounds					
I100RL_LB	358.4	80.6	10.24	8	350	2592	45.93
J140-WH_LB	221.8	49.9	11.29	4	680	4808	39.32
J210-Classic	335.0	75.3	10.32	7	396	2714	51.00
J240-RL	299.4	67.3	10.39	6	446	2372	49.74
J293BS	386.1	86.8	10.32	8	416	3309	53.60
J295-Classic	450.5	101.3	10.93	9	594	4052	64.15
J325TT	540.3	121.5	10.93	11	537	3634	67.20
J355-RL	434.3	97.6	11.05	8	669	4368	60.76
K160-CL	282.5	63.5	11.71	5	772	5237	44.97
K500-GR	484.5	108.9	11.88	9	924	5280	63.83
K445	664.8	149.5	11.55	13	792	5523	77.46
K500-RL	607.9	136.7	11.72	12	892	5275	69.79

Low Level Tests

Potential Competition

Table 4, CTI Motor Selection

III.5 Verification Plan

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 will provide 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		
Black Powder ejection test with altimeters	10/04	10/04	Successful
Flight test of dual deployment recovery system	~~10/06~~ ~~10/20~~ 11/03		
Drogue deployment during flight test	~~10/06~~ ~~10/20~~ 11/03		
Main deployment during flight test	~~10/06~~ ~~10/20~~ 11/03		
Safe main parachute-to-ground descent rate	~~10/06~~ ~~10/20~~ 11/03		
Predicted altitude	~~10/06~~ ~~10/20~~ 11/03		
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

III.6 Risks and Risk Reduction Plans

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

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

Winter weather in the Pacific Northwest has moderate temperatures, moderate winds, and many days of low clouds and precipitation. This definitely impacts our testing ability. Fortunately, our launch area is only 2 miles from the college and we can activate our 5000' FAA and Canadian AA waivers for any Friday, Saturday, or Sunday morning from 9:00 through 13:00. However, flights higher than 5000 feet require a 6 hour drive into Washington's interior which means weather can severely affect our higher altitude test schedule. Given this, we may forego a test flight using the full-scale motor.

Table 6, Risk Tables

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

Personal Safety Hazards	***Potential Effects of Failure***	***Failure Prevention***
Individual health issues when working with epoxy, fiberglass, paint, etc.	Person will become sick or experience discomfort.	Wear appropriate safety clothing/equipment such as gloves and clothing to cover skin, face masks, etc. Have adequate ventilation. Have MSDS prominently posted.
Accidental injuries such as lacerations, bruises, etc.	Harm to team members (possible hospitalization).	Be attentive to task at hand. First aid kit is available.
Potential fire when working with flammable substances	Harm to team members (possible hospitalization).	Be aware of locations of nearest first-aid kit, fire extinguisher, and eye wash station
Untidy work area	Harm to team members (possible hospitalization). Loss of tools, hazardous working conditions	Everything has a place and everything in its place. Clean up debris during and after working.

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

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

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

Multirotor Vehicle Failures	***Potential Effects of Failure***	***Failure Prevention***
Fails to deploy	Rocket does not get towed back to launch area	Test launches and careful packing
Becomes entangled in recover harnesses and/or tow line	Harness may be severed or motors malfunction	Test launches and careful packing
Motors fail to start	Rocket doesn't get towed back to launch area	Testing
Autopilot fails	Rocket gets towed somewhere other than the launch area	Testing, Radio Control backup
Unable to conduct a Radio Control Override	Rocket doesn't get towed back to launch area if autopilot fails	Testing, Radio Control backup
Motor batteries fail before mission end	Rocket is only towed partially to launch area	Ensure batteries are fresh and large enough, testing at full power for calculated flight duration plus 20% extra
GPS fails to lock prior to launch	Rocket gets towed somewhere other than the launch area	Testing, Radio Control backup

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

Propulsion Failures	***Potential Effects of Failure***	***Failure Prevention***
Propellant fails on the launch pad.	Launch will be unsuccessful.	Test the ignition system and ensure that the connection points and the installation of the igniters are correct.
Igniter fails on the launch pad.	Motor of the rocket will fail to ignite.	Ensure that the igniter is secure before attempting ignition. Have spare igniters on hand
Motor centering rings fail.	Thrust vector is will not be aligned with the axis of symmetry, causing erratic and unpredictable flight.	Use strong centering rings that are well mounted and have holes in the true center.
Motor mount fails.	Rocket and the payload might be destroyed by the motor traveling up through the rocket body.	Test the motor mount system for correct construction. The team shall also conduct an inspection of the mounting system prior to launch.
Motor retention system fails.	Free-falling ballistic objects could be produced, possibly harming people around the launch site.	Use an adequate motor retention system to ensure that the motor will remain in the rocket.
Motor explodes on the launch pad.	Rocket will explode and the mission will be a failure.	Use appropriate casings for motors and stand an appropriate distance away from the launch pad at the time of ignition.

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

III.6 Planning

The general planning has been complete since the proposal. We constantly modify and update the plan as circumstances warrant. We have plans as well contingency plans in place. Our thinking is flexible enough that we can make most changes without causing a mission failure.

III.6a Manufacturing

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

We are on very good terms with the major component vendors and they have responded very quickly to our purchase requests. Constructions of both the subscale and competition rockets are proceeding smoothly. Working with carbon fiber airframe and rocket components is new to us.

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

III.6b Verification

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

III.6b.1 Integration

We verify, through design and model building, that each component and subassembly will physically fit as planned.

Airframe: all components fit and are soundly constructed.

Recovery: parachutes, parachute bay, and avionics (including BP charges) are designed to function together.

Propulsion: careful simulations, calculations, and prior experience ensures that the propulsion subsystem is fully integrated.

Engineering Payload: this is a stand-alone system that uses the rocket as a means of transportation. The MV is independent of the rocket. It will be deployed and used as a tow vehicle to return the rocket to the launch area. It will be used in conjunction with the parachutes, which will provide 70% of the lift forces, and will use its autopilot capabilities to “home” the rocket back to the launch area.

III.6b.2 Operations

Because this is a class, operation planning is straight forward. A majority of the time consensus is reached about who does what, when in accordance with our timeline.

III.6b.3 Component Testing

Stress tests, ground tests, and multiple simulation runs, all figure into planning for component testing.

III.6b.4 Functional Testing

The rocket’s functionality will be tested first through simulations and then through actual flights. The avionics and recovery system will be tested through ground testing of the electronics and the black powder charges. The MV payload will be tested by flying independently of the rocket under both radio control and with its autopilot.

III.6b.5 Static Testing

Stress testing of the airframe and fins will be performed. We will do no motor testing other than through test flights. This is a financial decision. Static testing of the MV deployment system is a key feature of the testing program. We have to be assured that the MV will deploy without becoming entangled with the recovery harness. We have to be assured that a GPS lock takes place while the MV is encased in the rocket.

III.7 Confidence and Design Maturity

Our Space Center members have built a cumulative total of 38 high-powered rockets over the past three years. Most of the team members are NAR L1 certified. We are therefore very confident in the designing, building, launching, and recovery of any rocket that we design. We also have very good support from many NAR members who are not part of our team.

The design phase began with process of identifying and defining the project goals. We elected to carry a multirotor UAV and use it to tow the rocket back to the launch area.

The next step in the design was choosing materials with which to construct the rocket. We know that we have to deal with a very wet recovery area. This dictated a water-resistant rocket. We also knew that we needed a light rocket because of the MV limitations. We examined fiberglass, blue tube, and carbon fiber. Carbon fiber had the best qualities that would meet our stated mission.

Electing to use a 6 inch airframe that was long enough to hold the parachutes, the tracking device, and the MV, we then utilized Rocksim 9 to design the rocket and run simulations based upon estimates of the payload. Motors were “flown” to verify target altitude acquisition. Parachute calculations were run to determine the appropriate sized parachute to meet the USLI design parameters. The proper relationship between the Center of Pressure and the Center of Gravity was maintained throughout the design process.

A similar design process was followed when designing the sub-scale launch vehicle. This allowed newer team members to become more integrated into the USLI project and its processes. The goal was to team-build a smaller rocket launch a small model of the MV to test the deployment system as well as the “unfolding” of the MV.

The design process has given the team confidence in the construction and the reliability of the competition rocket.

III.8 Dimensional Drawings

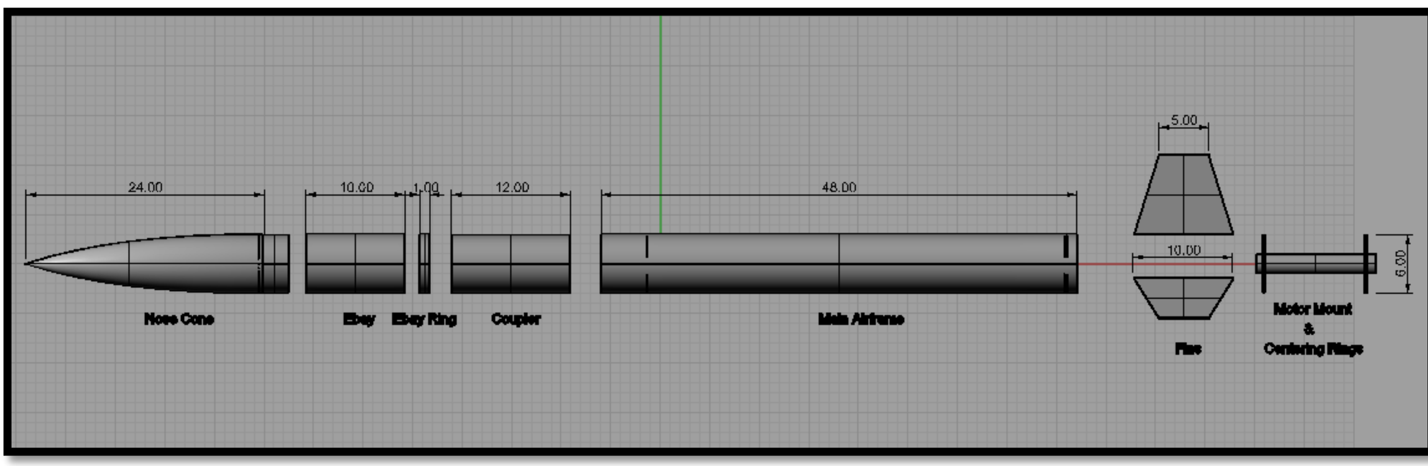


Figure 9, Exploded View, Launch Vehicle

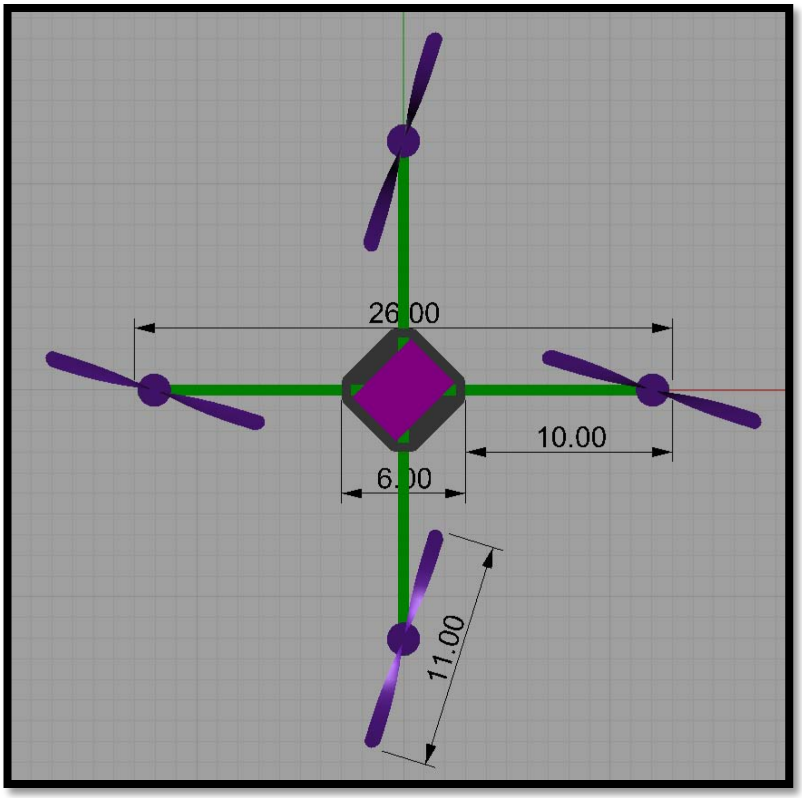


Figure 10, Multirotor Vehicle, Top View, Arms Extended

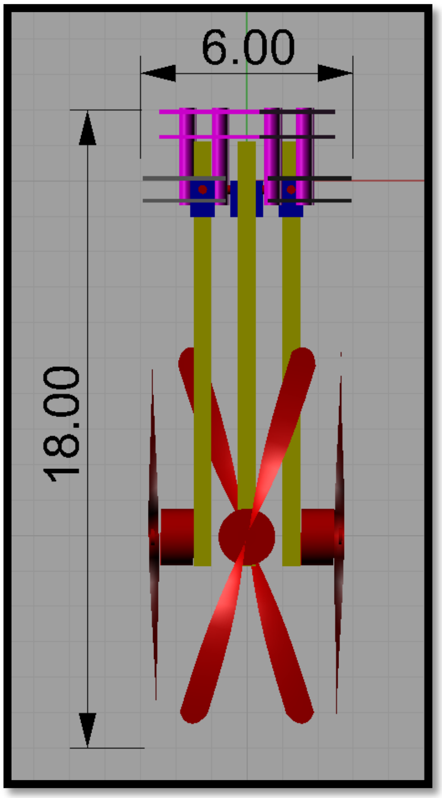


Figure 11, Multirotor Vehicle, Side View, Arms Folded

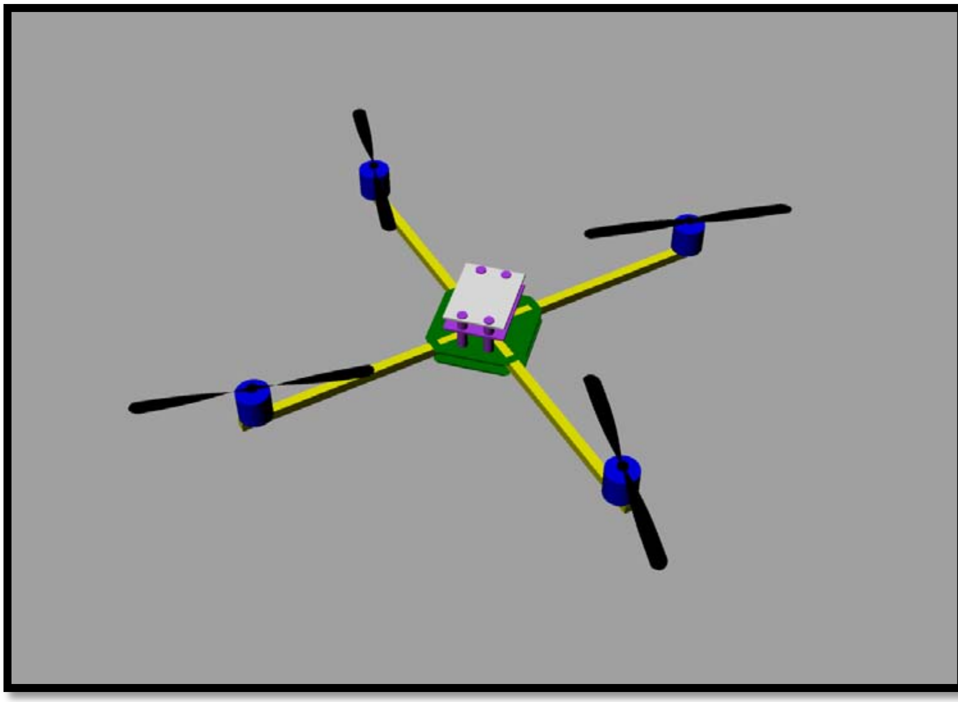


Figure 12, Multirotor Vehicle, Perspective

III.9 Recovery System Electrical Schematics

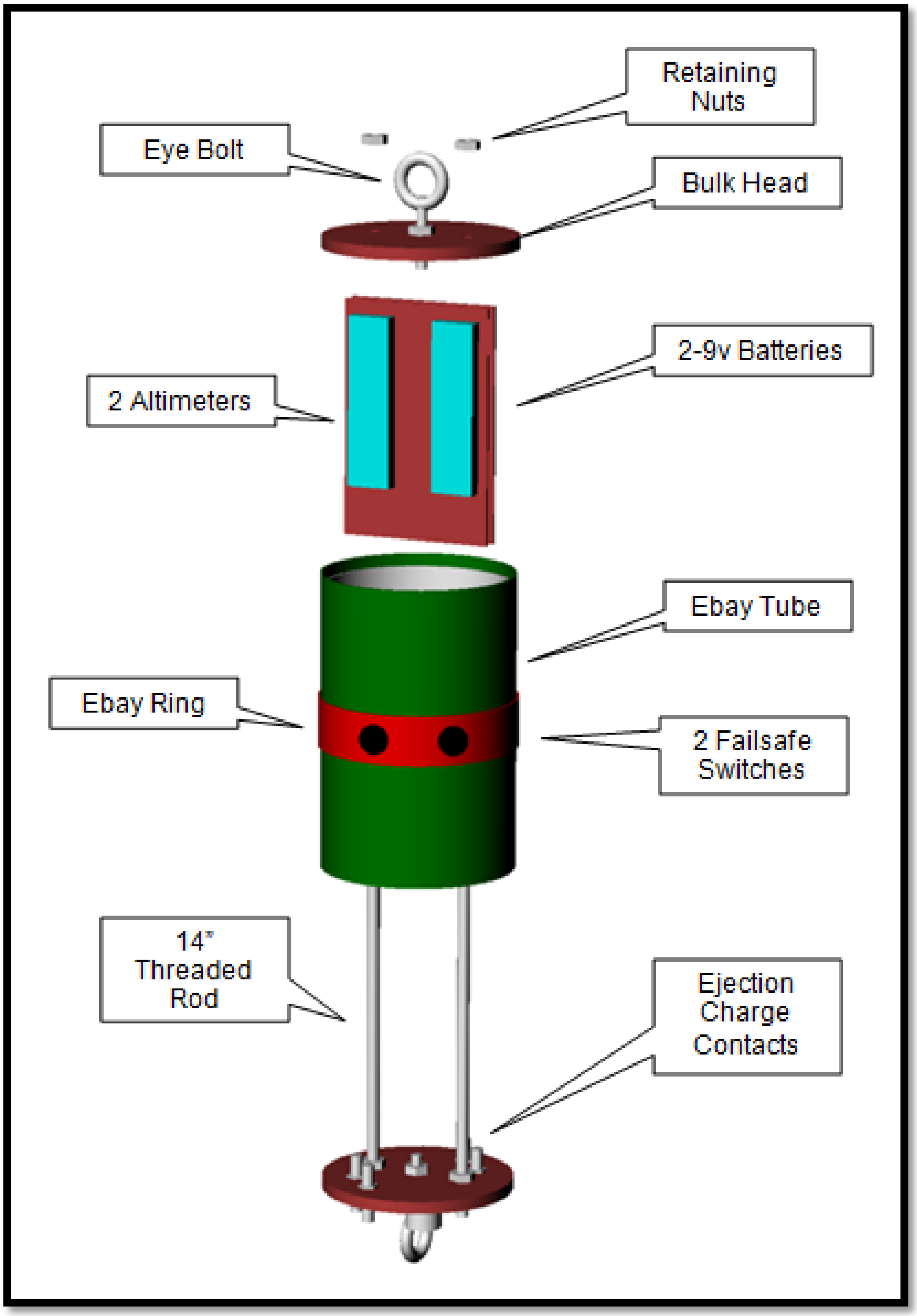


Figure 13, Ebay Construction

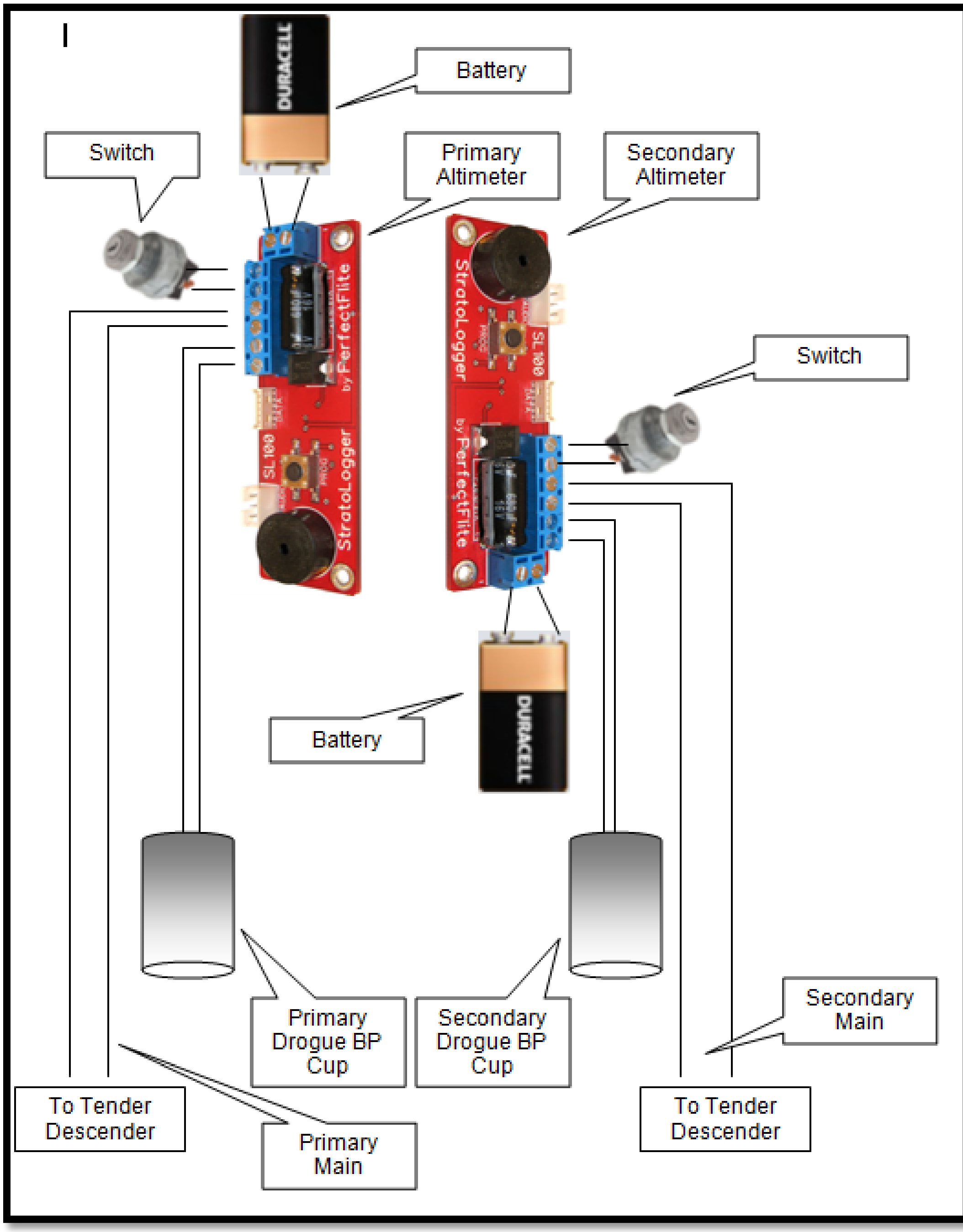


Figure 14, Block Diagram of Recovery Electronics

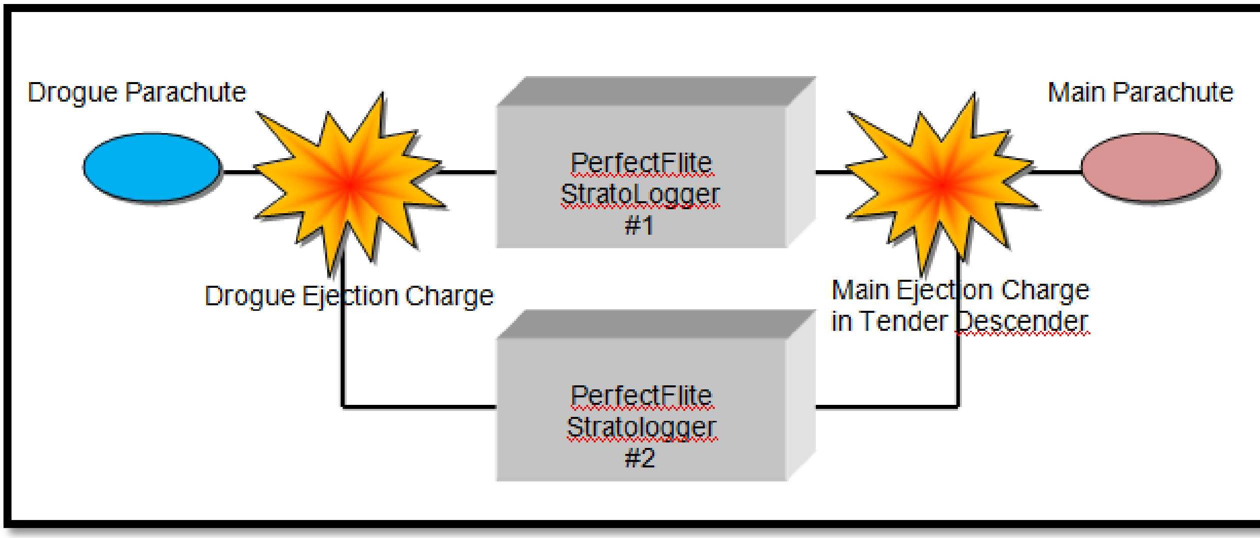


Figure 15, Block Diagram Recovery System

III.10 Mass Statement

Mass Statement		
Material	**Component**	**Mass (lb)**
Carbon Fiber	Aft Airframe	1.75
Carbon Fiber	Fwd Airframe	0.03
Fiberglass	Nose Cone	1.75
Carbon Fiber	Ebay Ring	0.05
Carbon Fiber	Ebay Coupler	0.25
Steel	Threaded Rod	0.16
Steel	Aft Ebay Eyebolt	0.06
Nylon	Main Parachute	0.56
Nylon	Drogue Parachute	0.25
	Avionics (altimeters, batteries)	0.75
	Multirotor Vehicle	2.50
Tubular Nylon	Main Recovery Harness	0.44
Tubular Nylon	Drogue Recovery Harness	0.44
	GPS Unit	1.00
Plywood	Nose Cone Bulk Head	0.02
Plywood	Fwd Ebay Bulk Head	0.02
Plywood	Aft Ebay Bulk Head	0.02
Plywood	Fwd Motor Mount Center Ring	0.01
Plywood	Aft Motor Mount Center Ring	0.01
Plywood	Fin Set	0.28
	Epoxy	0.13
	Paint	0.13
	Total Mass=	**10.60**

Table 7, Mass Statement

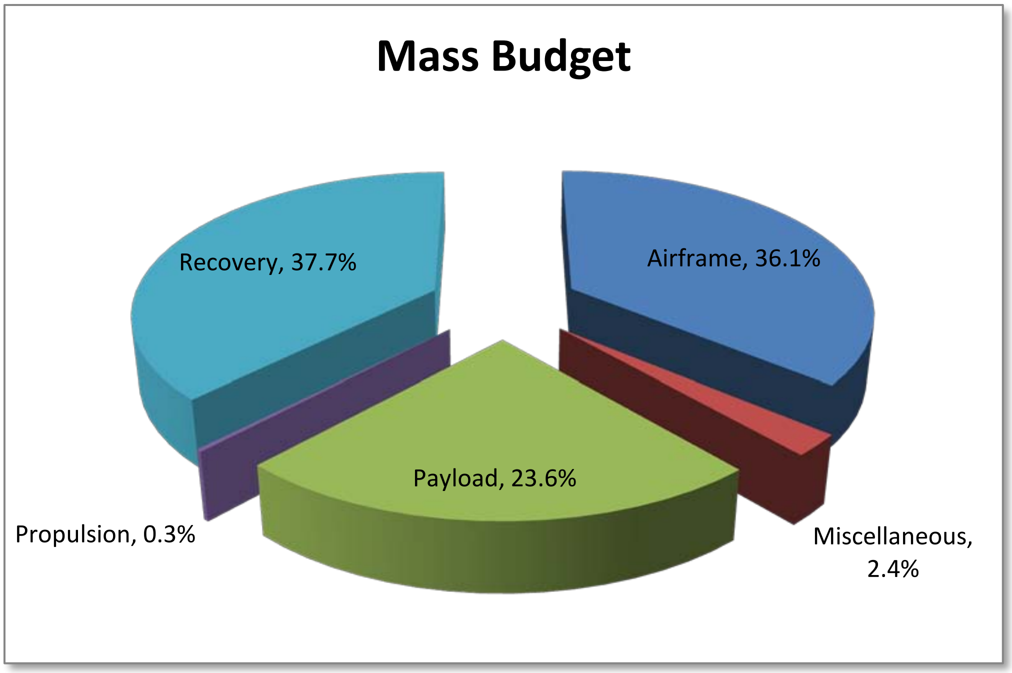


Figure 16, Mass Budget

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

The selected motors have reserve power for up to 15 extra pounds and still deliver a safe liftoff and flight. The 15 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 not adversely affect the target altitude.

IV. Recovery Subsystem

We are using a Tender Descender as our deployment device. This eliminates the space and weight that separate parachute bays require. Figure 17 is a conceptual drawing of the drogue deployment (right) and the main deployment (left). We want the MV to leave the rocket upon 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.

We have used, the parachutes, tubular nylon recovery harness, ¼ inch aircraft-grade plywood bulk head, and ¼ inch closed eye bolts in many previous launches and we are confident in the strength and reliability of our choices.

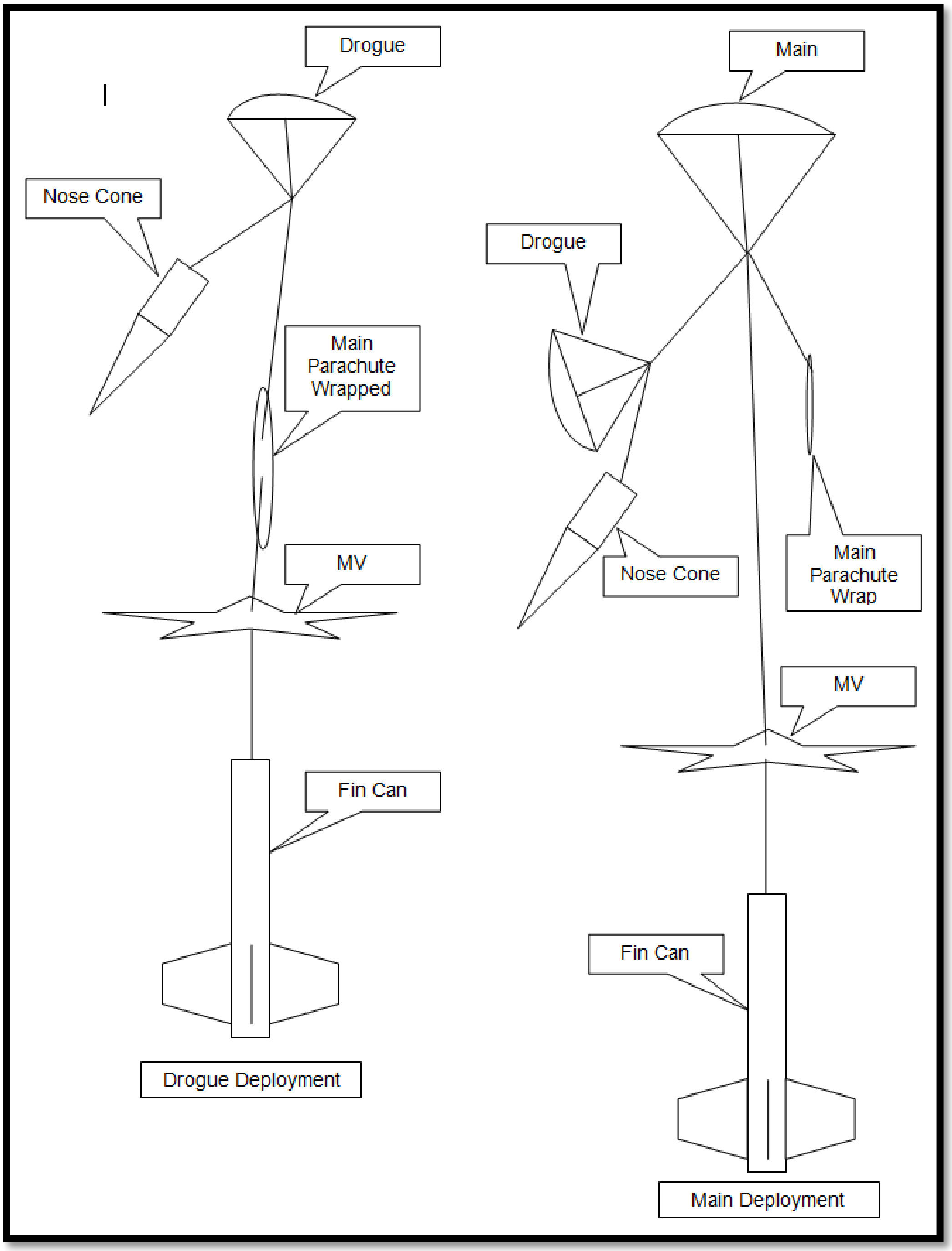


Figure 17, Parachute and MV Deployment Concept

IV.1 Ebay

This subsystem consists of the parachute bay and the ebay (Figure 4) that contains the avionics which control the parachute deployment. 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. A ¼ inch closed eyebolt is fastened at the lower end of the ebay. A second eyebolt is fastened to the firewall at the base of the airframe. These are the fastening points for the recovery harnesses.

IV.2 Recovery Harness

The two recovery harnesses, main and drogue, are 9/16' tubular nylon. Both harnesses are 24 feet long. Since we are using a Tender Descender, the harnesses are linked to each other, the parachutes, the eyebolt at the aft end of the ebay and the eyebolt in the firewall with stainless steel quicklinks.

IV.3 Parachutes

Rocksim calculated the fully loaded weight for the rocket at 9.78 pounds while descending. USLI requires a 75 lb/ft^3 Kinetic Energy impact for each section of the rocket. We used this formula to calculate the KE for a 44 inch Sky Angle Classic main parachute and a 15 inch Top Flight drogue parachute.

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

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

		Lb	KE Drogue fps	KE Main fps
Section 1	Fin Can	5.126	691	45
	Aft Airframe			
	MV			
Section 2	Ebay	4.664	639	41
	Fwd Airframe			
	Nose Cone			

Table 18, KE Impact Forces

IV.4 Bulkheads and Eye Bolts

The bulkheads are constructed from ¼ inch aircraft-grade plywood. They are fastened to the airframe with West System two-part epoxy. The eye bolts are ¼ inch closed forged steel. Similar items have been successfully used in previous high-powered rockets launches including one that experienced a high-speed demolition shortly after launch. The bulkheads and eyebolts have withstood the rigors of flight.

V. Mission Performance Predictions

V.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.

V.1a Detailed Mission Performance Criteria

1. Successful motor ignition
2. Successful liftoff
3. Successfully drogue parachute deployment

4. Successfully MV deployment
5. Successfully main parachute deployment
6. Successful autopilot-controlled MV back to launch area
7. Successful landing
8. Successfully reaching the target altitude within ±30 feet

V.2 Flight Profile Simulations with CTI K500 Reload

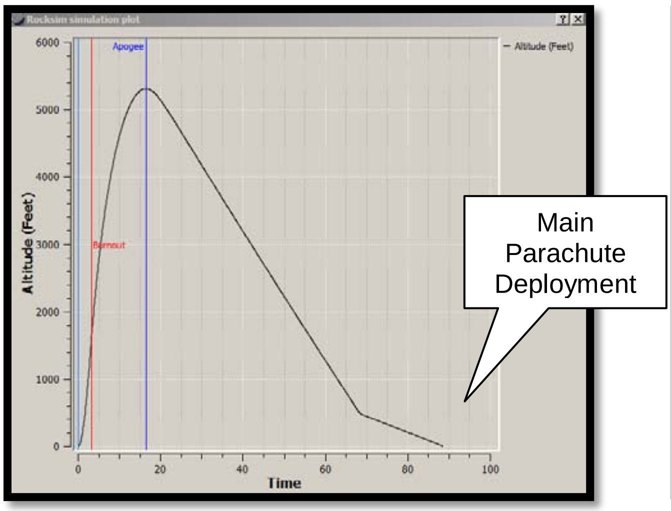


Figure 18, Altitude Profile

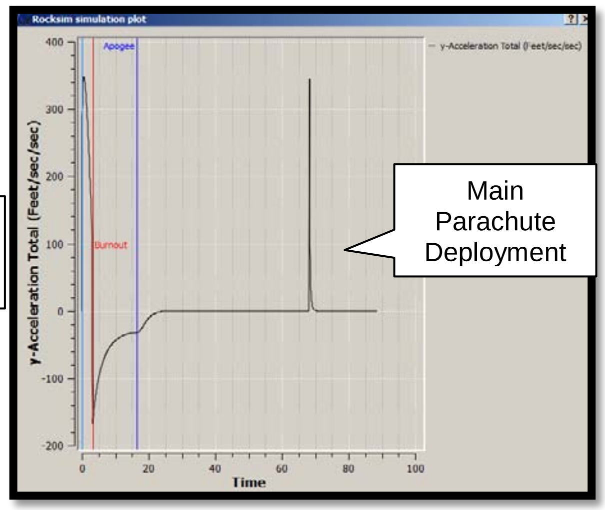


Figure 19, Vertical Acceleration Profile

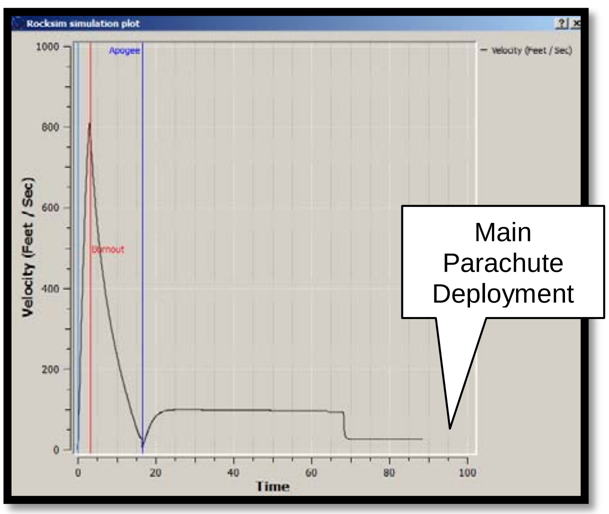


Figure 20, Velocity Profile

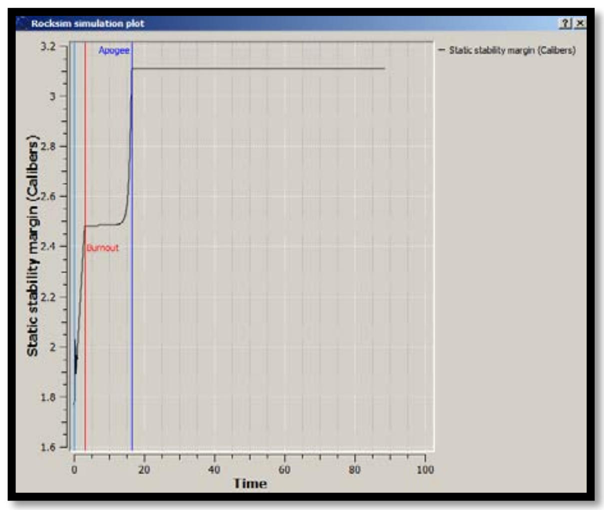


Figure 21, Static Stability Profile

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

V.2a Altitude Predictions

We are predicting an altitude at or near (±30 feet) the target altitude of 5,280 feet above ground level. While reaching the target altitude is one of the mission criteria, we are primarily interested in the MV functioning as designed.

V.2b Component Weights (lbs)

Subsystem	Mass
Airframe	3.83
Miscellaneous	0.26
Payload (MV)	2.50
Propulsion	0.03
Recovery	3.99
	10.61

Table 19, Component Weights

V.2c Motor Thrust Curve

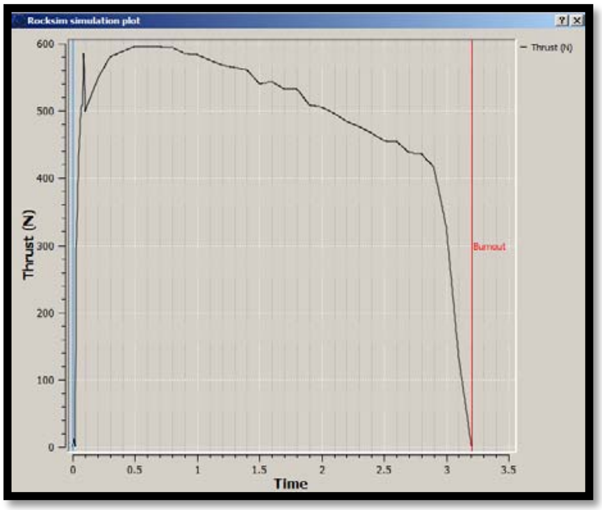
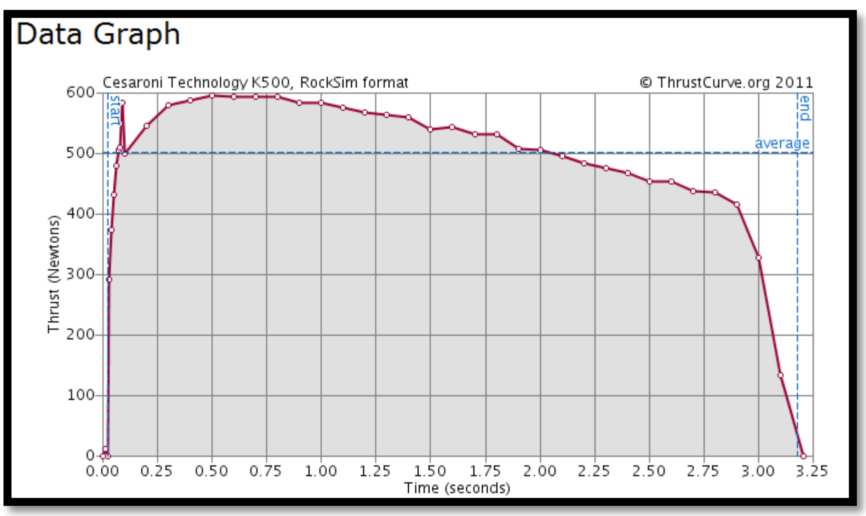


Figure 22, Rocksim K500 Simulated Thrust Curve



Fixture 23, CTI K500 Thrust Curve from thrustcuve.org

V.2d Robustness

The CTI K500 reload has a burn time of 3.2 seconds which contributes to moderate acceleration. The moderate acceleration and long burn allows the rocket's velocity to be held to a maximum of mach 0.72. These numbers will not produce extremely high forces on the carbon fiber rocket or its components.

V.3 Stability Margin from Rocksim Simulation

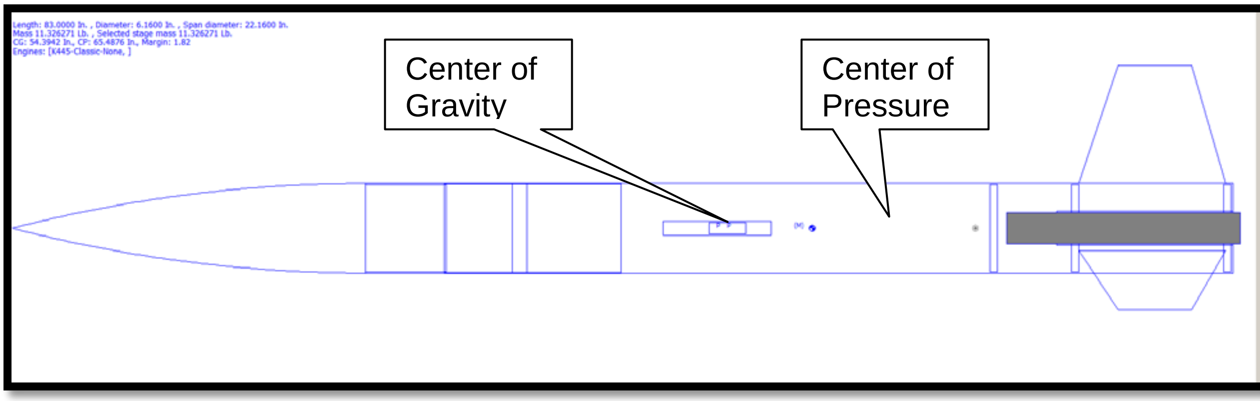


Figure 24, Static Stability Margin with K500

Center of Gravity	53.39
Center of Pressure	65.49
Static Stability	1.82

Static Stability = (Center of Pressure – Center of Gravity)/Diameter
=(65.49-53.39)/6
=1.82

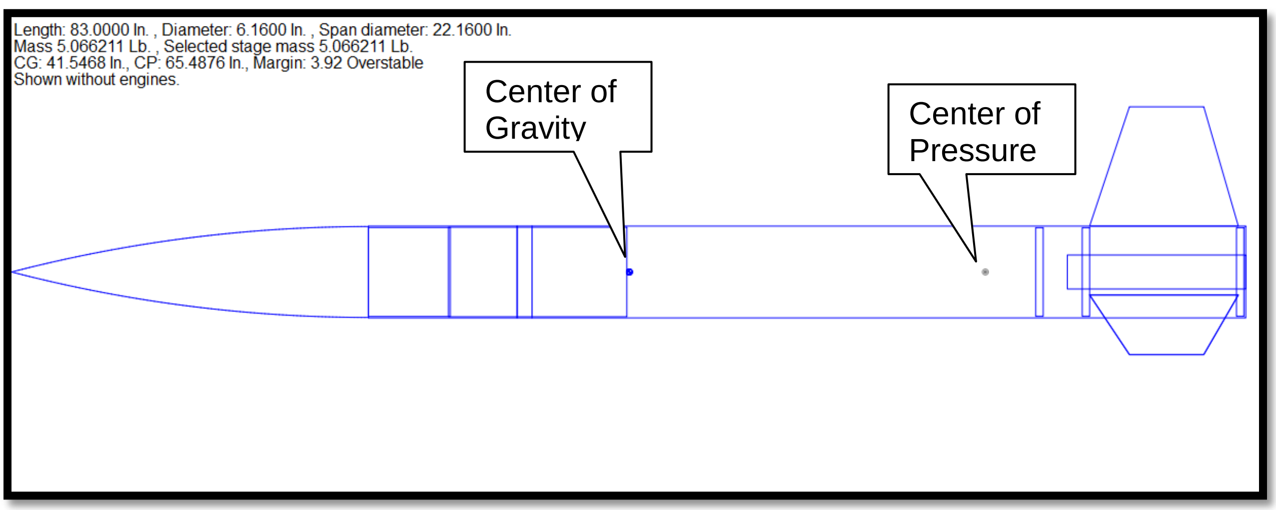


Figure 25, Static Stability Margin of Empty Rocket

Center of Gravity	41.55
Center of Pressure	65.49
Static Stability	3.92

V.4 Kinetic Energy at Landing

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

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

		Mass (lbs)	KE (fps)
Section 1	Fin Can	5.126	45
	Aft Airframe		
	MV		
Section 2	Ebay	4.664	41
	Fwd Airframe		
	Nose Cone		

Table 20, KE Impact Forces

The USLI requirements want the Kinetic Energy of each section to be 75 foot pounds/second or less. The two rocket sections have a calculated Kinetic Energy force well below the maximum KE allowed.

V.5 Drift Calculations

Our mission is to have the MV tow the rocket back to the launch area. We are including a drift chart to provide information in the event that the MV fails to accomplish its task.

Latitude: 34° 38' 50" N

Longitude: 86° 33' 11" W

Elevation: 827 feet

Wind Speed is Constant

Relative humidity: 77 %

Temperature: 65 Deg. F

Pressure: 30.27 In.

	Wind Speed (Kts)				
Guide Rail Angle	0-2	3-7	8-14	15-25	20-30
0	0	47	153	309	421

Our rocket is over stable which causes it to weathercock a small amount into the wind. The wind causes it drift back toward the launch area while descending. The above chart does not illustrate the effect of the MV towing the rocket back to the launch area. We anticipate that the MV will tow the rocket to within 100 feet of the launch pad.

VI. Interfaces and Integration

VI.1 Payload Integration Plan

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.

VI.2 Internal Interfaces

VI.2a Recovery Subsystem Interface

Figure 15 is a schematic of the recovery system interfaces

The nosecone and the forward end of the ebay are connected to the airframe with ¼ inch t-nuts and bolts. The lower end of the ebay is connected to the airframe with nylon screws that serve as shear pins during drogue parachute deployment.

The forward end of the drogue recovery harness is connected to the aft end of the ebay via a ¼ inch quicklink to a ¼ inch closed-eye eyebolt while the aft end is connected to the upper harness of the MV with a quickline. The drogue parachute is connected to the mid point of the drogue recovery harness with a ¼ inch quicklink.

The forward end of the main recovery harness is connected to the main parachute with a ¼ inch quicklink, whereas the aft end of the main recovery harness is connected to the upper harness of the MV.

The upper harness of the MV is connected to both recovery harnesses with a ¼ inch quicklink. The lower harness of the MV is connected to the fin can via a ¼ inch quicklink to a ¼ inch closed-eye eyebolt mounted to the firewall in the fin can.

VI.2b Airframe Internal Interfaces

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

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

VI.3 Launch Vehicle and Ground Facilities Interface

The rocket uses standard e-matches and a commercially available motor that will utilize the NAR ground equipment without any modifications.

RC contact with the MV will commence while setting up on the launch pad and will continue throughout the flight duration.

VI.4 Rocket and Launch Rail Interface

Two 0.5 inch rail guide buttons are bolted and fiber glassed to the fin can. These serve to guide the rocket up the 96 inch long T-Slotted Aluminum Extrusion Framing.

VI.5 Launch Vehicle and the Ground Launch System Interface

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

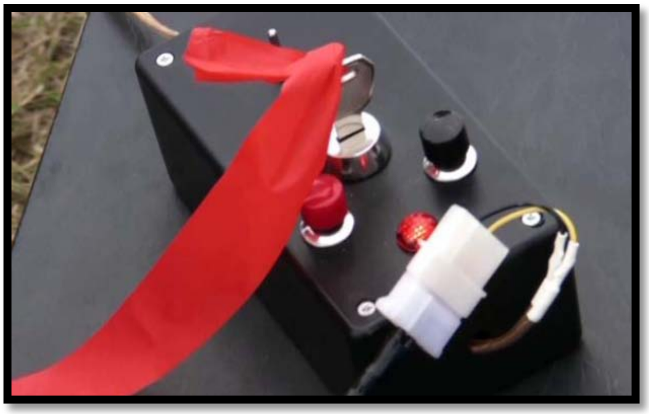


Figure 26, Launch Control Box

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

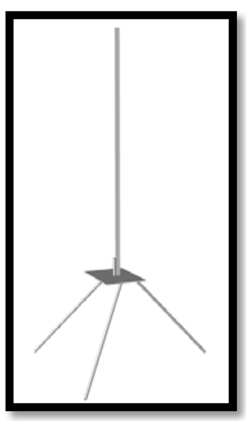


Figure 27, Light Launch Pad

Our larger launch pad is constructed from 1 ¼” galvanized pipe that is in the form of an H. It is staked to the ground with 4 – ¼ inch rebar hoops. Two 0.630” x 0.680” (large) rail guide buttons are bolted and fiber glassed to the fin can that will guide the rocket up the 96 inch long 80/20 15 Series 1515 1.5" X 1.5" T-Slotted extrusion.

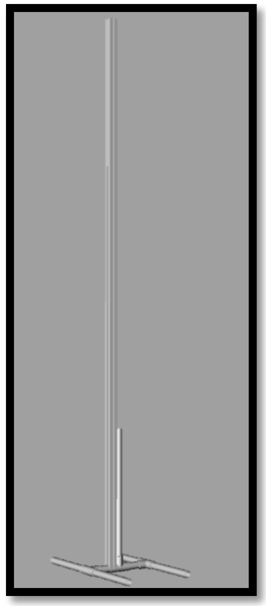


Figure 28, Large Launch Pad

VII. Launch Operation Procedures

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

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

VII.1 Documents On Hand at Each Launch

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

VII.2 Checklists

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

VIII. Safety and Environment (Vehicle)

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.

VIII.1 Failure, Failure Effects, Failure Mitigation

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

At this time the rocket and MV are still in the construction stages and there are no completed mitigation steps.

VIII.2 Personnel Hazards and Hazard Mitigations

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

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

http://blogs.nwic.edu/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 29, PPE latex gloves while working with epoxy resin

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

VIII.3 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.

VIII.4 Motors and Black Powder

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

VIII.5 Launch Operations

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

VIII.6 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”

VIII.7 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.

VIII.8 Environmental Safety at the Northwest Indian College Launch Complex

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

IX. Payload Criteria

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

IX.1a System and Subsystem Level Analysis

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 21, System/Subsystem Analysis Table

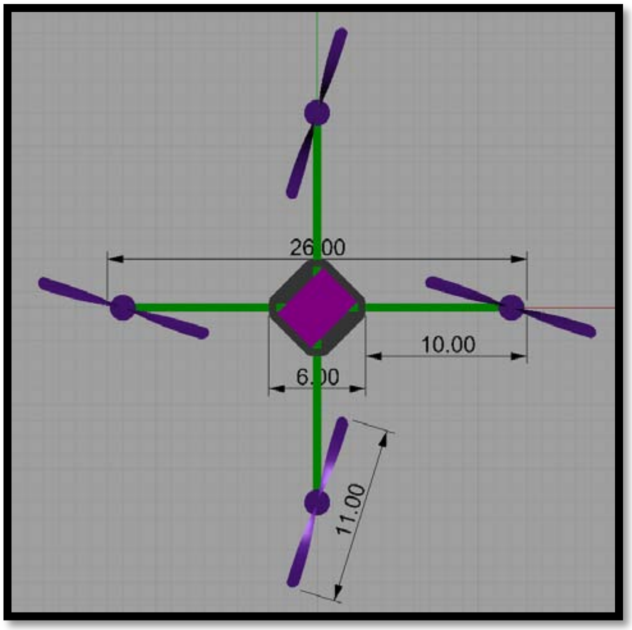


Figure 30, Plan View

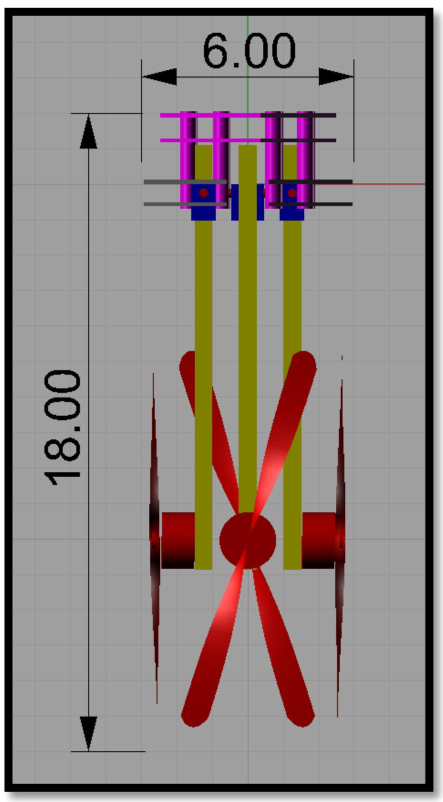


Figure 31, Folded View

The phases to the MV development are:

1. Designing and building the MV;
2. Designing autopilot electronics;
3. Programming the autopilot;
4. Designing the MV deployment and towing scheme; and,
5. Learning to fly the MV

IX.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 a motor stand to measure the motor thrust in order that the combined thrust of the motors will accomplish flying the MV and towing the rocket. 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.

IX.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.

IX.1a.3 Programming the Autopilot

Programming considerations included:

- waking the autopilot at 400 feet;
- navigating to the set waypoints;
- controlling the altitude descent rate so that the MV can bring the rocket back to the launch area prior to grounding; and,
- having the MV land the rocket and itself without entanglement with the parachutes/recovery harnesses or the rocket.

IX.1a.4 Designing the MV Deployment and Towing Scheme

We have ascertained that using the Tender Descender as our dual deploy parachute device will allow us to "string" the rocket components and the MV in a single line. See Figure 17 for a conceptual drawing of this plan. These are the potential hazards:

- MV becoming entangled in the recovery harness during deployment;
- MV becoming entangled in the recovery harness during descent;
- One or more propellers striking the recovery harness during the towing phase; and,
- 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.

IX.1a.5 Learning to fly the MV

None of the team members or advisors are RC pilots. We have three quadcopters ranging in size from 4 inches between motors to 10 inches between motors. The 4 inch quad is the Ladybird and we have 2 MQX quadcopters. All are ready-to-fly multirotor aircraft from hobby shops.

Figure 32 Ladybird Quadcopter *Figure 33, MQX Quadcopter*

IX.2 Payload Subsystems Required to Accomplish Payload Objectives.

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 22, Payload Subsystem

IX.3 Performance Characteristics, Evaluation and Verification Metrics for the System and Subsystems

System	Subsystem	Evaluation	Verfication
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 23, System/Subsystem Performance Characteristics

IX.4 Verification Plan and Status.

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 24, Verification Plan and Status

IX.5 Preliminary Integration Plan.

The MV's arms will fold in a downward position. This will allow the MV to slide into the rocket's lower airframe. The lower harness will be placed in the rocket, followed by the MV and the upper harness., Next comes the wrapped main parachute with the Tender Descender followed by the drogue harness and the drogue parachute. The ebay and nosecone complete the assembly.

IX.6 Instrumentation Precision

The GPS precision is

IX.7 Drawings for Key Electronics of the Payload

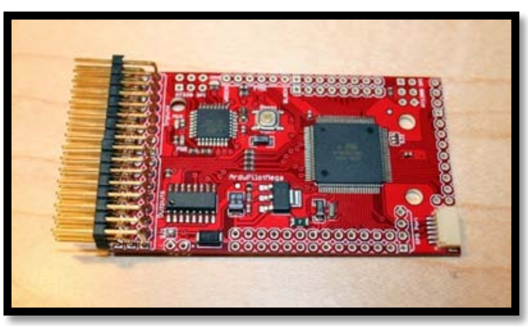


Figure 34, Complete Arduopilot

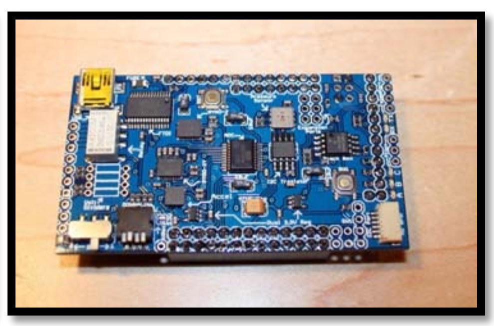


Figure 35, Complete Flight Controller Board

IX.8 Payload Key Components Functioning to Achieve the Desired Results

Once the MV is deployed and the 400 foot altitude is reached, the autopilot's programming will start the 4 motors. The GPS unit will orient the MV toward the launching area and commence the flight back to the launch area.

The GPS unit feeds the location information to the flight controller which in turn controls the appropriate motors's rpm to direct the MV back to the launch area.

X. Payload Concept Features and Definition

X.1 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.

X.2 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.

X.3 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, ROGs are confident that we can complete this project successfully. Our advisors, Gary and Dave, are totally supportive and help us find answers, figure out how to find solutions to our challenges.

XI. 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.

XI.1 Payload Success Criteria

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

XI.2 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.

XI.3 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 test session follows this order:

1. Test battery voltages
2. Power up the system
3. Fly the MV manually
4. Fly the MV under autopilot
5. Power down the system
6. Analyze the data
7. Trouble shoot mechanical, electrical and/or programming issues.

XII. Payload Safety and Environment Plan

XII.1 Safety Officer

Justin is the safety officer.

XII.2 Failure Modes

Payload failure modes can be hazardous or nonhazardous. Hazardous failures may result injury to personnel or damage to property. Non-hazardous failures are failures affecting the success of the mission, but not resulting in injury to personnel or damage to property (other than that of the team). See page 16 for more details.

XII.3 Personnel Hazards

Personnel hazards have discussed elsewhere. Please see page 46 for more details.

XII.4 Payload Environmental Concerns

Nothing in the payload constitutes an environmental hazard.

XIII. Activity Plan

XIII.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	60" Parachute	$79.95	$79.95
1	18" Parachute	$16.75	$16.75
1	RDAS-Tiny altimeter	$300.00	$300.00
2	StratoLogger Altimeter	$99.95	$199.90
			$696.60

Payload and Tracking System			
1	GPS Unit	$295.00	$295.00
1	FPV Camera	$195.00	$195.00
1	Science Payload	$2,300.00	$2,300.00
1	Arduino Uno	$19.95	
1	Arduino Pro Mini	$29.95	
1	Adafruit Data Logger	$29.95	
			$2,790.00
		Total	**$4,979.92**

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	$696.60
Electronics & Payload	$2,790.00
	$4,979.92

Travel & Lodging	$9,676.00

Project Income	
	$19,000.00

XIII.2 Funding Plan

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

XIII.3 Timeline

Please see Appendix C.

XIII.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.

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 the 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	PDR

Vehicle Properties	
Diameter (in)	6
Length (in)	83
Gross Liftoff Weight (lb)	8.12
Launch Lug/button Size	0.630" x 0.680" (large)
Motor Retention	10-24 Tie Down Bolts

Motor Properties	
Motor Manufacturer	CTI
Motor Designation	K500
Max/Average Thrust (N/lb)	607.9/136.7
Total Impulse (N-sec/lb-sec)	1595.6/358.7
Mass pre/post Burn (lb)	3.25/1.97

Stability Analysis	
Center of Pressure (in from nose)	65.49
Center of Gravity (in from nose)	53.39
Static Stability Margin	1.82
Thrust-to-Weight Ratio	13:01
Rail Size (in) / Length (in)	1.5" X 1.5"/96"

Ascent Analysis	
Rail Exit Velocity (ft/s)	70.46
Max Velocity (ft/s)	808.93
Max Mach Number	0.72
Max Acceleration (ft/s^2)	380
Peak Altitude (ft)	5,343

Recovery System Properties

Drogue Parachute

Manufacturer/Model	Top Flite
Size	18
Altitude at Deployment (ft)	5,280
Velocity at Deployment (ft/s)	0.03
Terminal Velocity (ft/s)	93.66
Recovery Harness Material	Tubular Nylon
Harness Size/Thickness (in)	9/16
Recovery Harness Length (ft)	24
Harness/Airframe Interfaces	1/4 inch closed eye eyebolt

Kinetic Energy During Descent (ft-lb)	Section 1	Section 2	Section 3	Section 4
	691	639		

Recovery System Properties

Main Parachute

Manufacturer/Model	SkyAngle
Size	50
Altitude at Deployment (ft)	500
Velocity at Deployment (ft/s)	93.66
Landing Velocity (ft/s)	21.22
Recovery Harness Material	Tubular Nylon
Harness Size/Thickness (in)	9/16
Recovery Harness Length (ft)	24
Harness/Airframe Interfaces	1/4 inch closed-eye eyebolt

Kinetic Energy Upon Landing (ft-lb)	Section 1	Section 2	Section 3	Section 4
	45	41		

Recovery System Properties

Electronics/Ejection

Altimeter(s) Make/Model	PerfectFlite StratoLogger

Recovery System Properties

Electronics/Ejection

Rocket Locators (Make, Model)	Garmin Astro

Redundancy Plan	Redundant Dual Recovery with 2 PerfectFlite StratoLogger altimeters with independent power supplies	Transmitting Frequencies	***Required by CDR***
		Black Power Mass Drogue Parachute (gram)	9g
Pad Stay Time (Launch Configuration)	2 hrs	Black Power Mass Main Parachute (gram)	Tender Descender - 0.2g

Milestone Review Flysheet

PDR, CDR, FRR

Institution Name	Northwest Indian College	**Milestone**	PDR

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
Sub-scale Test Flights	3-Nov
Full-scale Test Flights	1-Dec

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 MAWD altimeters	Inspection	Complete
a. The official, marked altimeter is damaged and/or does not report an altitude after the team's competition flight.	Safe Recovery will preclude this	Inspection	Work in Progress
b. The team does not report to the NASA official designated to record the altitude with their official marked altimeter by 5:00 pm on the day of the launch.	Check list will preclude this		Work in Progress

4. The recovery system electronics shall have the following characteristics:			
a. The recovery system shall be designed to be armed on the pad.	Locking key switches installed	Inspection	Work in Progress
b. The recovery system electronics shall be completely independent of the payload electronics.	Payload electronics in separate science by		
c. The recovery system shall contain redundant altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	Designed with two independent systems		
d. Each altimeter shall be armed by a dedicated arming switch.	Locking Key Switches		
e. Each altimeter shall have a dedicated battery.	Designed with two independent systems including batteries		
f. Each arming switch shall be accessible from the exterior of the rocket airframe.	Locking switches located on ebay ring		
g. Each arming switch shall be capable of being locked in the ON position for launch.	Switches that lock with a key are installed		
h. Each arming switch shall be a maximum of six (6) feet above the base of the launch vehicle.	Switches located 64 inches from base of rocket		
5. The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system by the transmitting device(s).	Ebay lined with aluminum foil	Inspection	Work in Progress
6. The launch vehicle and science or engineering payload shall remain subsonic from launch until landing.	Designed with Rocksim 9 to stay subsonic	Simulation	Work in Progress

7. The launch vehicle and science or engineering payload shall be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	Designed with Rocksim 9	Simulation	Work in Progress
8. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery from apogee to main parachute deployment is permissible, provided that the kinetic energy is reasonable.	Designed with Rocksim 9, using drogue at apogee and main at 700 feet	Simulation	Work in Progress
9. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	2 - #2-56 nylon screws will be shear pins	Ground Testing	Work in Progress
10. The launch vehicle shall have a maximum of four (4) independent or tethered sections.	Designed with three	Inspection	Work in Progress
a. At landing, each independent or tethered sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Designed via calculations	Simulation	Complete
b. All independent or tethered sections of the launch vehicle shall be designed to recover with 2,500 feet of the launch pad, assuming a 15 mph wind.	Designed with Rocksim 9	Simulation analysis	Complete
11. The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the waiver opens.	Designed as required	Check lists	Work in Progress
12. The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any onboard component.	Battery power calculated to last at least 2 hrs for each device using a battery	Simulation analysis	Work in Progress

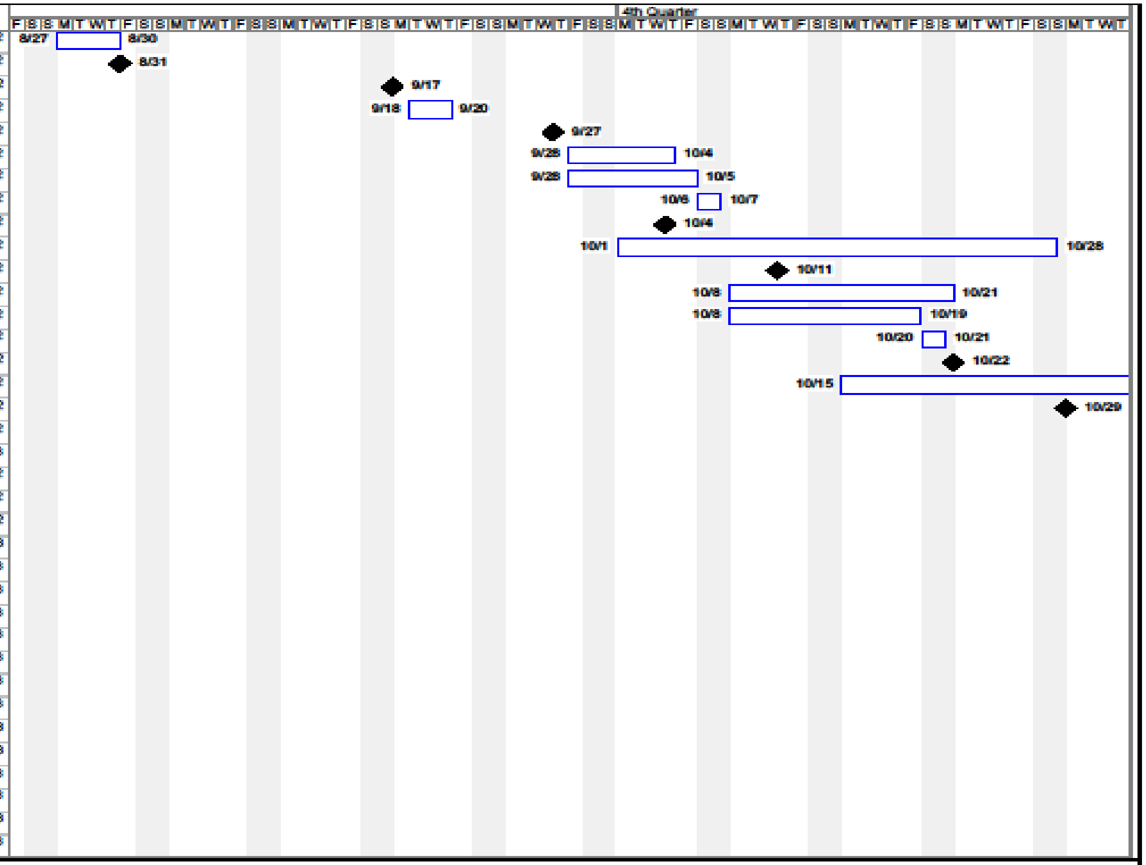
13. The launch vehicle shall be launched from a standard firing system (provided by the Range) using a standard 10 - second countdown	Designed as required	Test	Work in Progress
14. The launch vehicle shall require no external circuitry or special ground support equipment to initiate the launch (other than what is provided by the Range).	None are necessary as designed	Inspection	Work in Progress
15. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	Data analysis will be examined post flight	Testing will follow payload completion prior to the competition flight	Work in Progress
16. An electronic tracking device shall be installed in each independent section of the launch vehicle and shall junction with an electronic, transmitting device, but shall not replace the transmitting tracking device.	Garmin GPS unit in nose cone	Ground tested complete. Flight test to follow	Work in Progress
17. The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA) and/or the Canadian Association of Rocketry (CAR).	Designed to use CTI reloadable motor	Inspection	Work in Progress
18. The total impulse provided by the launch vehicle shall not exceed 5,120 Newton-seconds (L-class). This total impulse constraint is applicable to any combination of one or more motors.	Designed as required, L motor largest permissible	Inspection	Work in Progress
19. All teams shall successfully launch and recover their full scale rocket prior to FRR in its final flight configuration.			

a. The purpose of the full scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight.	Test flights scheduled prior to FRR	Test flight	Work in Progress
b. The vehicle and recovery system shall have functioned as designed.	Extensive ground testing where possible, test flights for the vehicle		Work in Progress
c. The payload does not have to be flown during the full-scale test flight.			
▪ If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Measured mass of actual payload will be either substituted or the payload will be flown	Test flight	Work in Progress
▪ If the payload changes the external surfaces of the launch vehicle (such as with camera housings and/or external probes), those devices must be flown during the full scale demonstration flight.	Test flight will be with rocket as its designed		Work in Progress
d. The full scale motor does not have to be flown during the full scale test flight. However, it is recommended that the full scale motor be used to demonstrate full flight readiness and altitude verification.	Both smaller and a full scale motor will be used in test flights		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.			
c. Forward firing motors.			
d. Rear ejection parachute designs.			
e. Motors which expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).			
f. Hybrid motors.			
21. Each team shall use a launch and safety checklist. The final checklist shall be included in the FRR report and used during the flight hardware and safety inspection and launch day.	Check lists are designed	Inspection and actual testing	Complete
22. Students on the team shall do 100% of the work on the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder charges.	Implemented as required	Inspection	Work in Progress
23. The rocketry mentor supporting the team shall have been certified by NAR or TRA for the motor impulse of the launch vehicle, and the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 15 flights in this or a higher impulse class, prior to PDR.	Implemented as required	Inspection	Complete
24. The maximum amount teams may spend on the rocket and payload is $5000 total. The cost is for the competition rocket as it sits on the pad, including all purchased components and materials and the fair market value of all donated components and materials. The following items may be omitted from the total cost of the vehicle:			
a. Shipping costs.	Implemented as required	Inspection	Complete
b. Ground Support Equipment.			
c. Team labor.			

Appendix 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 08(	Mon 10/29/12	Mon 10/29/12
18	PDR Presentation	Tue 11/13/12	Tue 11/13/12
19	CDR Preparation	Thu 11/15/12	Sun 1/13/13
20	Test Flight #2	Sat 12/1/12	Sun 12/2/12
21	Test Flight #3	Sat 12/8/12	Sun 12/9/12
22	CDR Q&A	Mon 12/3/12	Mon 12/3/12
23	CDR, PPT, Flysheet Posted 08(	Mon 1/14/13	Mon 1/14/13
24	CDR Presentation	Wed 1/30/13	Wed 1/30/13
25	FRR Preparatoiin	Thu 1/31/13	Sun 3/17/13
26	Test Flight #4	Sat 1/12/13	Sun 1/13/13
27	Test Flight #5	Sat 1/19/13	Sun 1/20/13
28	Test Flight #6	Sat 1/26/13	Sun 1/27/13
29	Test Flight #7	Sat 2/9/13	Sun 2/10/13
30	Test Flight #8	Sat 2/16/13	Sun 2/17/13
31	FRR Q&A	Mon 2/11/13	Mon 2/11/13
32	FRR, PPT, Flysheet Posted 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 | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

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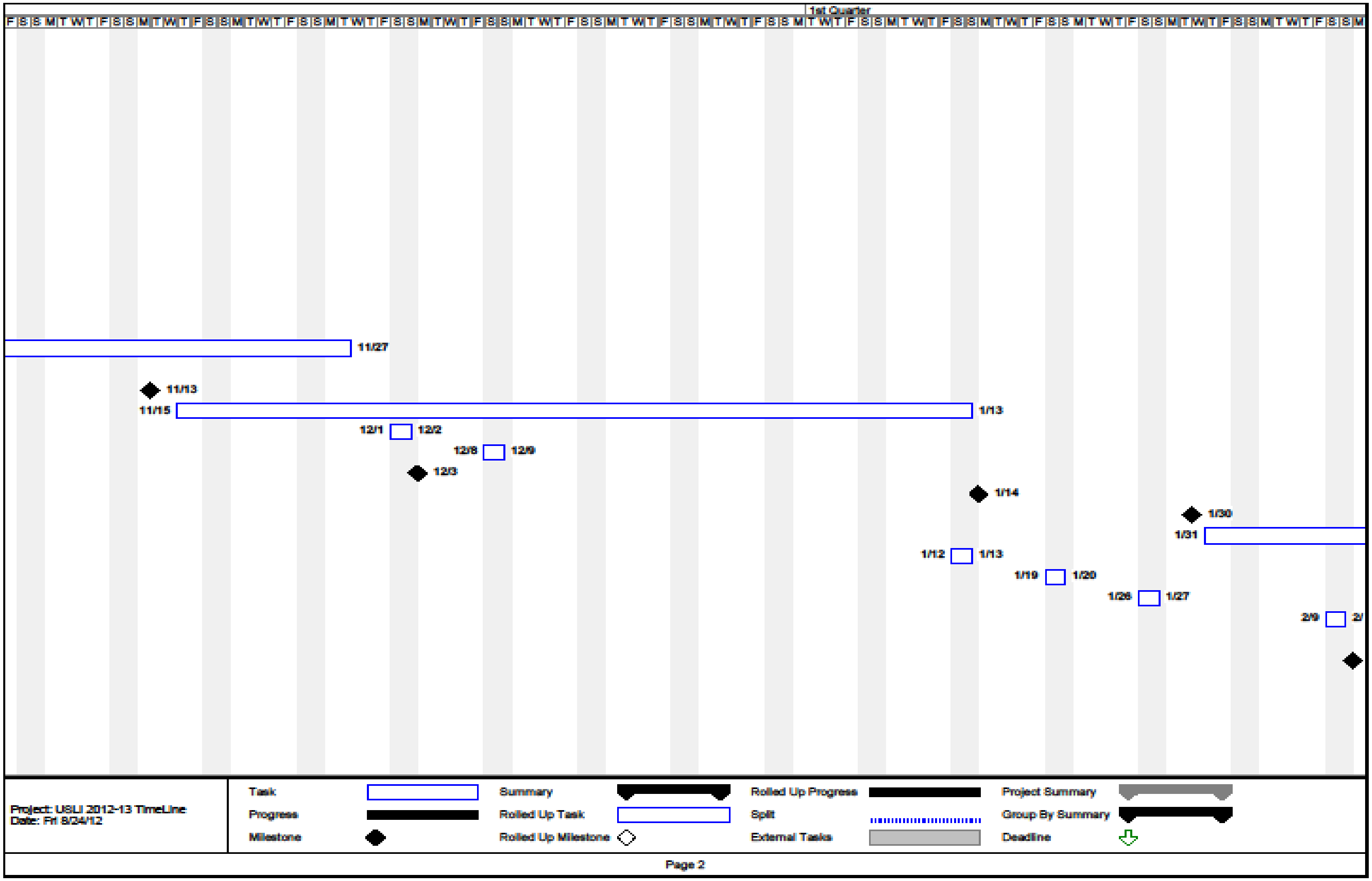
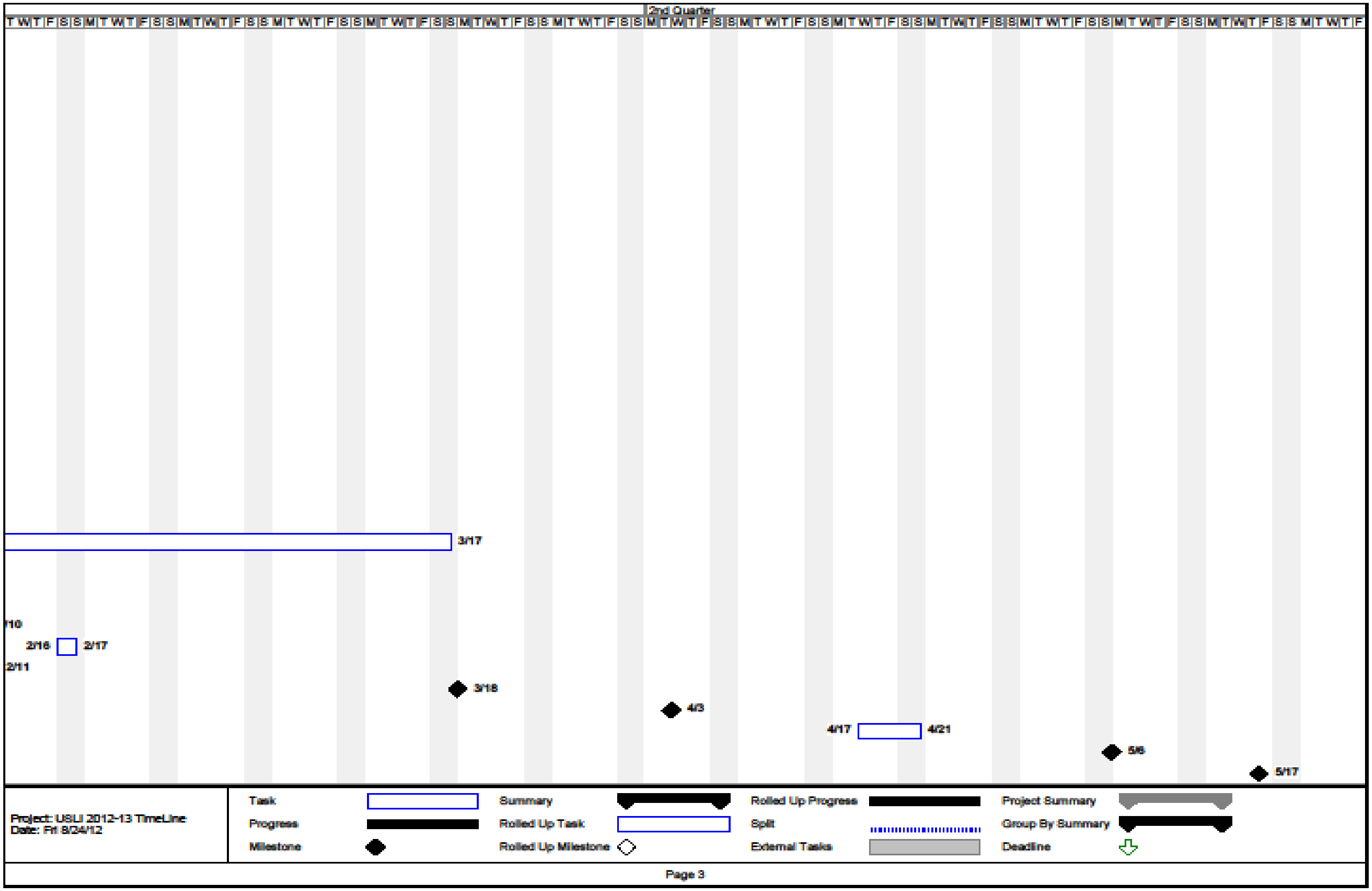

1st Quarter
11/27
11/13
11/15
1/13
12/1
12/2
12/8
12/9
12/3
1/14
1/30
1/31
1/12
1/13
1/19
1/20
1/26
1/27
2/9
Project: USLI 2012-13 TimeLine
Date: Fri 8/24/12
Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress
Split
External Tasks
Project Summary
Group By Summary
Deadline
Page 2


2nd Quarter
3/17
/10
2/16
2/17
2/11
3/18
4/3
4/17
4/21
5/6
5/17
Project: USLI 2012-13 TimeLine
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Task
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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:*

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

Recovery System, Main Chute

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

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

EBay & Black Powder Ejection Charges

Wear eye protection whenever working with Black Powder!

Prepare avionics #1

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

Prepare avionics #2

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

- ❑ Connect forward pyrotechnic leads to electronic deployment device

Black Powder, drogue

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

Black Powder, main

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

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

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
- ❑ Pack main recovery harness on top of MV
- ❑ Connect main recovery harness to main parachute burrito
- ❑ Place main parachute burrito in airframe
- ❑ Pack Tender Descender into airframe
- ❑ Connect drogue harness to Tender Descender
- ❑ Pack drogue harness into airframe
- ❑ 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 tail cone
- ❑ Tape igniter to rocket airframe
- ❑ Discard trash properly

Launch team transports rocket to assigned launch pad

Appendix I - Final Launch Preparation Checklist

Tools to launch pad

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

Setup on launcher

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

Section Break (Continuous)

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

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

Rocket Manufacturer: ________________________ Main Motor: ________________________________

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

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

Length: ____________ Diameter: _____________ Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Weight: ____________ First Flight of Rocket?: ___ Electronics: ________________________________

Modifications: _____________________________ Other Payload: ______________________________

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

Signed: ____

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

☐ Special Flight Info: ____

Good Flight ☐

Failed Flight Reason

☐ Cato ☐ Hard Impact

☐ Shred ☐ Recovery Failed

High Power Flight Card

Northwest Indian College Space Center

Date: ____________

RSO Initials ________

Rod/Rail # ________

Section Break (Continuous)

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

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

Rocket Manufacturer: ________________________ Main Motor: ________________________________

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

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

Length: ____________ Diameter: _____________ Recovery via: ☐ Chute ☐ Streamer ☐ Other ________

Weight: ____________ First Flight of Rocket?: ___ Electronics: ________________________________

Modifications: _____________________________ Other Payload: ______________________________

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

Signed: ____

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

☐ Special Flight Info: ____

Good Flight ☐

Failed Flight Reason

☐ Cato ☐ Hard Impact

☐ Shred ☐ Recovery Failed