2012-2013

Northwest Indian College Space Center USLI Post Launch Assessment Review

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Northwest Indian College Post Launch Assessment Review

I. Team Summary

Team Name: Northwest Indian College RPGs

Project TOR (Tow Our Rocket)
Northwest Indian College, 2522 Kwina Road, Bellingham, Washington, 98226

II. Launch Vehicle Summary

Rocket Data

Rocket height: 89.5 inches
Rocket diameter: 6 inches
Rocket mass: 14.7 pounds with K445 motor and payload

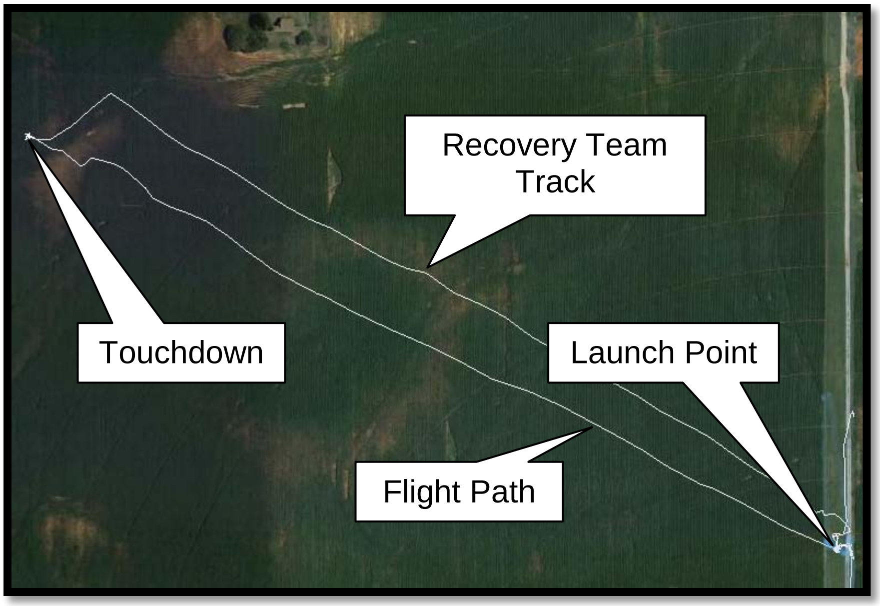
Motor used: Cesaroni Technologies Incorporated (CTI) K445

Altitude reached: 2999 feet

Flight Performance

Salish Star passed the Flight Hardware and Safety Check on Wednesday, April 17, 2013 with only three minor items on its punch list: make certain that igniter wire nuts were tight; include that note in the check list; and, use Duracell 9v batteries. Needless to say, we were very pleased with our responses to the NAR officials and the soundness of our rocket's design and construction.

Our rocket was the third to launch on Sunday, April 21, 2013. It launched from a vertical launch rail, deployed both the main and drogue at apogee and drifted downwind to a gentle landing. Because the main deployed at apogee, the landing distance from the launch pad was greater than the predicted <200 feet. It was 2,253 feet (from GPS unit and Google Earth); however, it was still within the 2,500 USLI requirements.



The altitude was within our predicted range of 3044 feet (3-7 Kts wind speed) and the actual altitude of 2999/3000 feet (0.09%). The below figures of Altimeter #1 and #2 are from that flight. Total flight time from launch until touchdown was approximately 128 seconds.

Altitude and Drift Predictions from FRR and Presentation

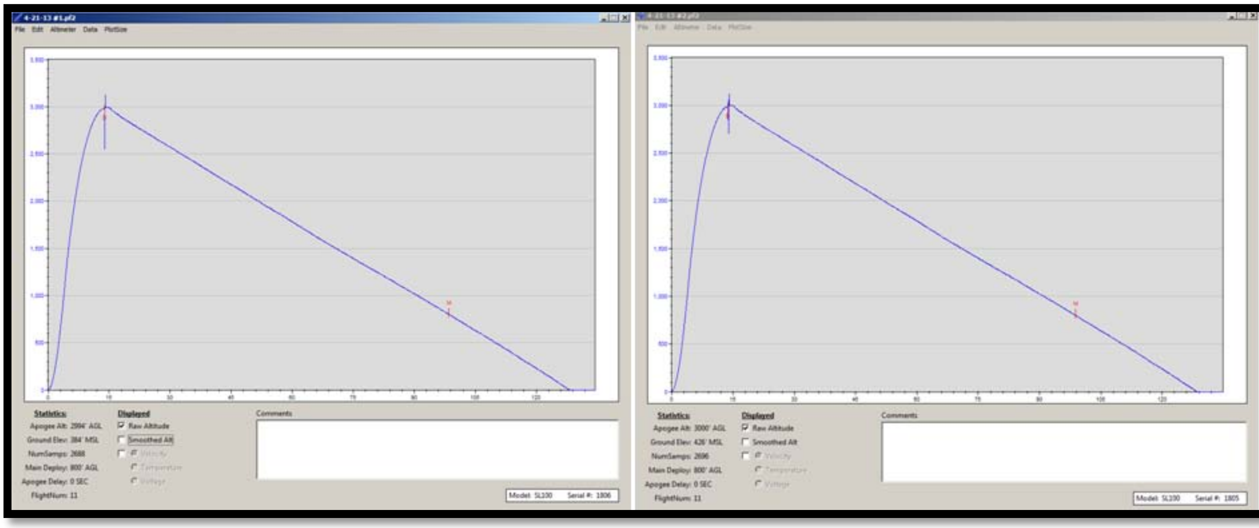
Typical seasonal weather at Braggs Farm

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.

Launch Rail is Vertical (0^o)	**Wind Speed (Kts)**				
	0-2	**3-7**	**8-14**	**15-19**	**20-30**
Downwind from Pad(ft)	159	174	614	735	1,329
Altitude	3,344	3,044	2,935	2,924	2,831

Altimeter Data



Altimeter #1 *Altimeter #2*

Recovery System

Our rocket was equipped with a redundant recovery system consisting of two PerfectFlite StratoLogger altimeters that were electrically independent of each other. This subsystem consisted of the ebay which contained the avionics that controled parachute deployment. We used two PerfectFlite Stratologger altimeters to record the altitude and to deploy the parachutes. Each altimeter had its own power supply and having two altimeters provided redundant parachute deployment. The primary altimeter was programmed to deploy the drogue parachute at apogee and the main parachute at 800 feet, whereas the secondary altimeter activated the drogue charge 1 second after apogee and activated the secondary main ejection charge at 750 feet.

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

RockSim 9 indicated that the descent rate under drogue was to be 66.01 ft/s and 22.02 ft/s while descending under the main parachute. The data from the last test launch had the descent rates at 61.03 ft/s under drogue and 22.97 ft/s under main with the fin can impacting the ground at 20.53 ft/s. The calculated data from the Huntsville launch was 21.83 ft/s under both main and drogue and an impact of 20 ft/s.

The main and drogue recovery harnesses were both 24 feet long made of ½ inch tubular Kevlar. The connections between ebay and the aft airframe and the ebay and the forward airframe were ¼ inch U-bolts.

Brief Payload Description

The designed payload was a multirotor vehicle (MV) that was a quadcopter. Its purpose was to stay tethered to our vehicle, deploy at 800 feet and tow the rocket back to the launch area. The MV was designed as a tow vehicle and not as a vehicle capable of carrying the rocket vehicle.

Vehicle Construction Summary

Salish Star was built from 6 inch light weight carbon fiber tubing and a carbon fiber ogive nose cone. Its fins were constructed from 1/4 inch aircraft grade birch plywood. All bulkheads and centering rings were built from ½ inch aircraft grade birch plywood. Recovery harnesses were ½ inch tubular Kevlar whose attachment points were ¼ inch U-bolts. The rocket's initial weight and estimated payload weight resulted in us choosing a 4 grain motor casing. This was large enough to reach the required 5,280 foot altitude. We then used a solid bulkhead to seal off the payload bay from any stray motor gasses. What this did was, was eliminate any possibility of using a motor larger than a 4 grain and weight creep dictated that we could have used a larger motor to realize our altitude goal. Lesson learned, allow for more weight while designing.

A Garmin Astro 220 Dog Tracker was located in the carbon fiber nose cone to provide location information as well as tracking data for later analysis. The antenna needed to be located externally because of the carbon fiber being RF opaque. Lesson learned, use some other material than carbon fiber where RF ability is necessary.

Two external camera pods were located on opposing sides of the fin can. They were mounted below the ebay and 1 inch above the CG. Each held a high definition video camera. One camera pointed up and one camera pointed down. The up-facing camera collected MV deployment and flight data, and the down-facing camera recorded ground features that we could analyze for vehicle flight characteristics.

Data Analysis Vehicle Results

Salish Star has successfully flown and has been recovered for each of its seven launches. No flight resulted in any damage to the vehicle. We used progressively larger motors to test all systems and flew the last two test flights with the K445 motor that we used in the competition launch. *Salish Star's* reliability gave us total confidence in its flight and payload carrying capabilities. The launch from Pad 13 on 4/21/13 was nearly vertical throughout the powered and coasting phases.

On board cameras showed a roll rate of approximately once per second during ascent and descent.

Apogee was reached in approximately 14.65 seconds and the drogue was successfully deployed. The main also deployed at apogee which resulted in a hike for the recovery crew. It landed approximately 1,973 feet downwind from the launch pad. The vehicle descended and landed approximately 128 seconds after liftoff. No damage incurred. A “souvenir” of Alabama soil was left on the nose cone tip and one of the fins. The MV landed untangled in an upright position between its recovery harness attachment points.

Subsystem Arrangement at Touch Down

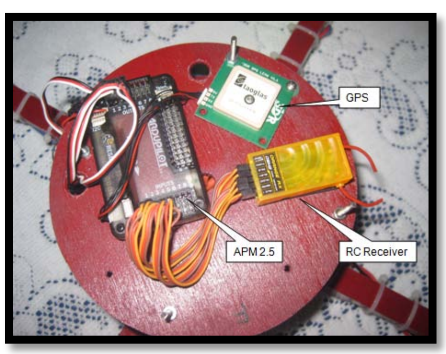
III. Payload Summary

Payload Mission

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

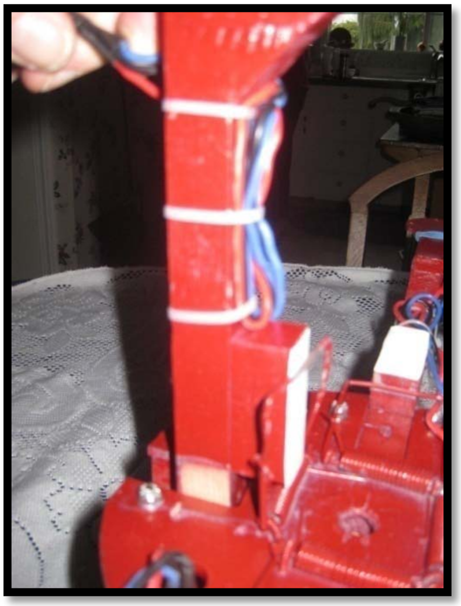
Multirotor Vehicle Construction

Our payload was a wooden quadcopter propelled by four 880 Kv brushless outrunner motors with 11 x 4.7 inch propellers. The Electronic Speed Controllers (ESC) were 20 amp supplied by 3D Robotics, and the battery was a Turnigy 2200 mAh. This battery would power the MV for 12 minutes under full throttle. The flight controller board and auto pilot was an Ardupilot with a 3DR GPS uBlox LEA-6 module. Telemetry was supplied by a 3DR radio transmitter and receiver. Manual control was with a Spketrum DX6i 2.8 gHz radio control (RC) transmitter and a dual Spketrum AR6210 6-Channel DSMX Receiver system.

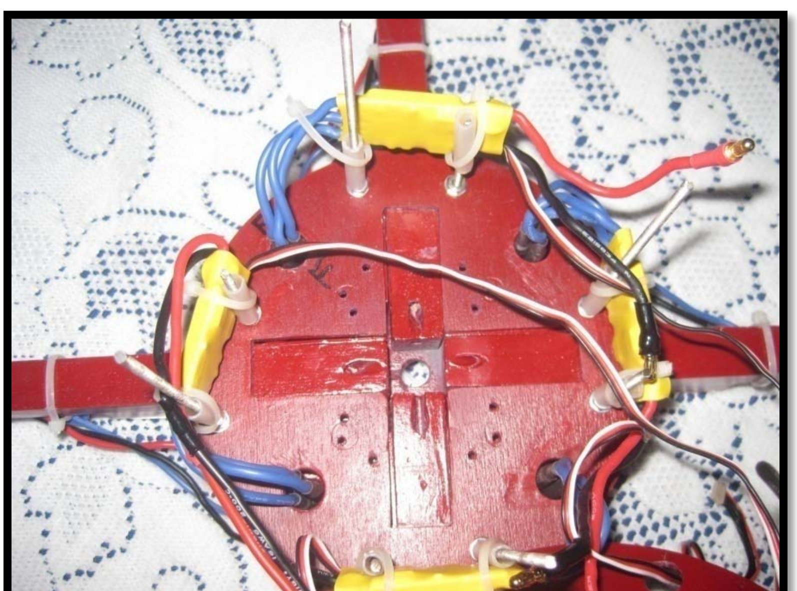


Deck 4 with Flight Avionics

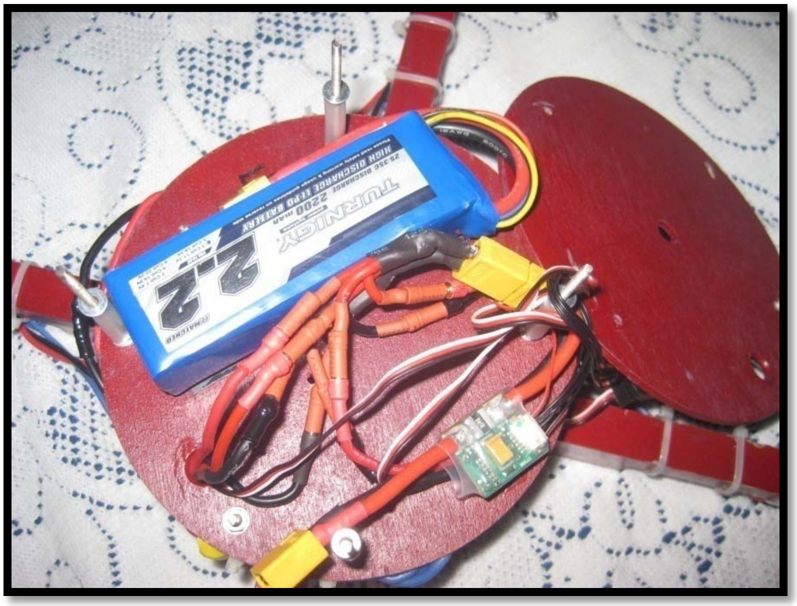
The MV was built with four 6 inch x 1/8 inch aircraft grade birch plywood disks. Each disk/deck was numbered from 1 to 4 with deck 1 being the bottom deck. Decks 1 and two held the arm pivots and the mouse trap springs the extended the arms from a downward folded position to their flight positions. The battery, 3DR radio and the four ESC were located between decks 2 and 3. The two receivers, GPS module and the Ardupilot/flight controller board were fastened on the top disk, deck 4. The disks were fastened together with 1/8 inch stainless steel threaded rods and plastic spacers.



Folded Arm with Mouse Trap Spring and Locking Block

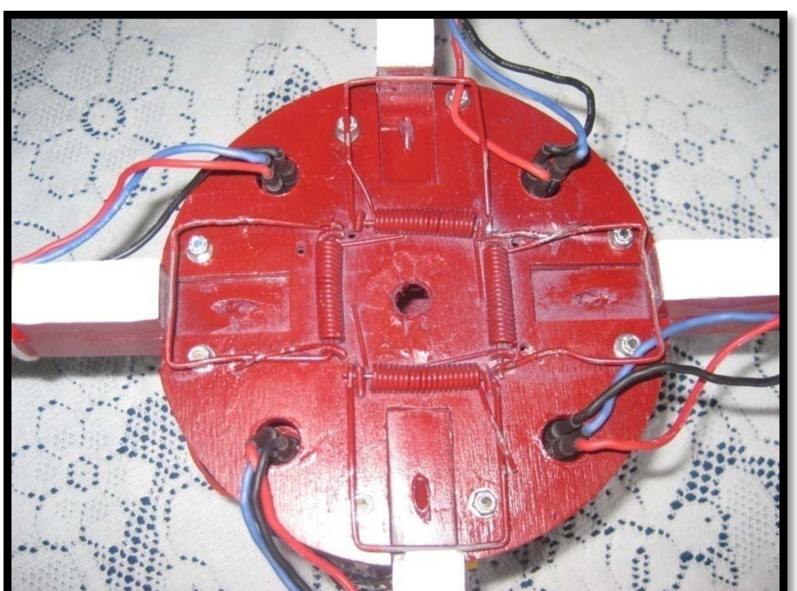


Deck 2 with ESC



Deck 3 with Battery and Power Distribution Unit

Each of the four arms was built from ¾ inch square fir and was 16 inches long. Each arm was pivoted two inches from its inboard end so that in its extended position decks one and two would prohibit the arms from rising beyond a horizontal position. Mouse trap springs were fastened to the underside of the bottom deck and provided enough lifting power to extend its respective arm to a horizontal position and then lock the arm into position.



Underside of Deck 4 with Arms Extended and Locked

MV Mini-Mincer in Flight Position

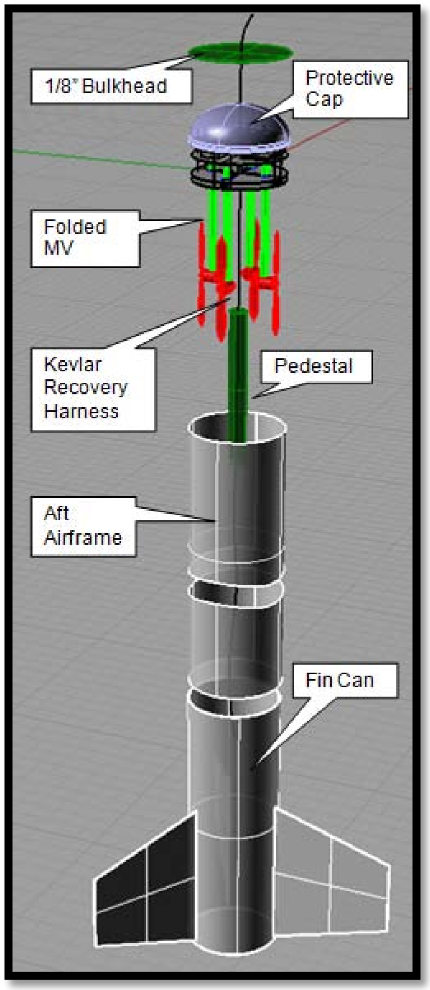
MV with Arms Folded, Harness and Pedestal in Position

The ½ inch tubular Kevlar tow harness consisted of the recovery harness that was attached to the bottom interior of the fin can that then passed through a 20 x ½ inch PVC tube that was a pedestal, then through an aluminum tube that ran through the middle of the MV. Next the Kevlar went through a 1/8 inch bulkhead and then finally it attached to the bottom of the ebay. In descent mode the MV was 3 feet above the fin can, 2 feet below the 1/8 inch bulkhead, and eighteen feet below the main parachute. The drogue parachute and nose cone, while on a separate recovery harness, was ten feet above the MV.

Mini-Mincer Test Flight

Salish Star Descending

The folded MV was packed into the fin can. The MV rested on the 20 x ½ inch PVC tube pedestal that supported the propellers above the bulkhead ”floor”. The folded arms were incased in a plastic sheath that both helped confine the arms as well as provided a reduced drag environment upon deployment. The 1/8 inch bulkhead rested upon the electronics protective plastic cap and provided an additional barrier from the ejection detonation gases.



MV Loading Schematic

Tow Harness, Aluminum Pass Through, Pedestal
and Protective Cap on MV Mini-Mincer

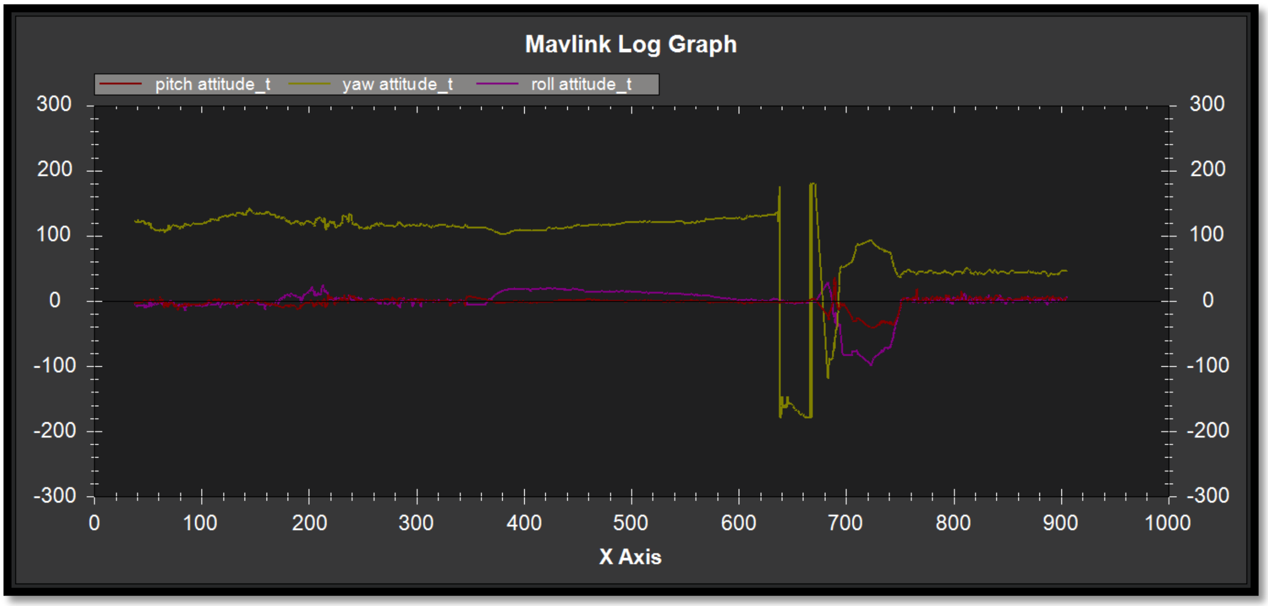
IV. Data Analysis and Payload Results

Telemetry

Telemetry data from the 3DR radio showed that the GPS unit made a lock with the GPS satellites required for navigation. The motors did not arm after deployment which left the autopilot waiting for motor verification to commence the programmed flight back to the launch area. The rocket and the MV all landed safely with no damage as indicated by the photos of the landed system and a frame from the video showing the MV flying after landing.

We have examined the autopilot program and have not discovered any logic or other programming errors. We are leaning towards the theory that the lengthened distance between the 3DR transmitter and receiver due to the main parachute's early deployment may have interfered with the transmission signal to arm the motors.

A portion of the MV logging system shows that the GPS was connected and the attitude changes were logged.



MV Onboard Logging of Pitch, Yaw, and Roll.

The above graph shows the data while waiting on the launch rail, during *Salish Star's* flight (large data variations), and finally, while resting on the ground waiting for the recovery crew.

Parachute Recovery System

The drogue deployed at apogee as planned as did the secondary ejection charge. However, the main also deployed at or near apogee, which was not planned. This resulted in the rocket drifting far further than estimated. The MV also deployed unplanned at or near apogee successfully and remained in position ready to perform its function throughout *Salish Star*'s descent.

We have yet to determine why the main parachute deployed at apogee. The primary causes of early deployment are:

1. Altimeter malfunction
2. Drag separation
3. Pressure leak into ebay causing a false altimeter reading.
4. Other

Data from the StratoLoggers eliminate causes 1 and 3. The previous two test flights with Mini-Mincer on board and launching under competition conditions did not result in drag separation. Nothing was changed between the last two test flights and the competition launch. We are still researching other possibilities.

MV Deployment

MV Deployment, Arms Starting to Extend

Protective Shield Off & Pedestal Sliding into Fin Can

Fully Deployed with All Subsystems Visible

V. Scientific Value

The objective of the payload is to learn engineering and aerodynamic skills. By building a MV and having it successfully bring the rocket back to the launch area without human interaction would prove to be a useful way for us to launch and retrieve our rockets in our often water-covered recovery area. Since the Huntsville trip, we have been contacted by the Salish Sea Research Institution to use our UAV expertise to help develop, build, and fly a research multirotor vehicle. The planning for this commences mid-May 2013. This is immediate feedback from our USLI experience.

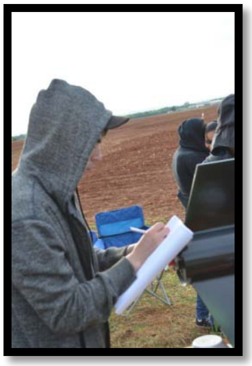
Our major reason for doing this is to enhance the learning and knowledge of our team members. All of the team members want to be challenged and to build upon last year's team successes.

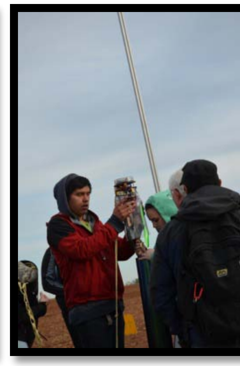
VI. Visual Data Observed


George C. Marshall
Space Flight Center

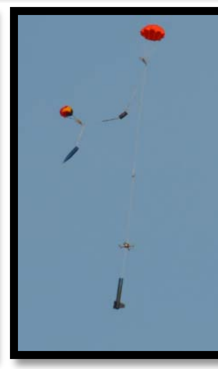

EMPTY


SKYLAB








VII. Lessons Learned

Salish Star flew extraordinarily well and we were delighted in its design and performance. Mini-Mincer was a very stable, yet responsive, MV. The majority of our lessons learned are focused on better communications between the ground and our MV.

1. Allow for weight creep while designing. Minor changes can have a major impact on weight.
2. Use some other material than carbon fiber where RF transparency is necessary. We thought that we had a work-around for this; however, the work-around did not function at the distances *Salish Star* traveled.
3. More powerful transmitters and better antennas. We were not able to engage Mini-Mincer due to the separation between it and our 3DR radio.

VIII. Overall Experience Summary

The Advisor/Mentor's Comments

This is a long and arduous task that each year I find myself surprised that a new bunch of students are willing to take it on and do an excellent job at it. As in years past, we have attempted to do something that none of us were able to bring any previous knowledge to. The students are tenacious in accomplishing the tasks set before them.

As mentioned previously, we have been invited by Northwest Indian College's Environmental Research Department to become part of a large research grant to study the Salish Sea. The request is because of our many successes with multirotor vehicles during this year's USLI event. This will afford, yet another opportunity, for students to become more involved with STEM activities.

Written Comments from Team Members

- The most exciting part of my USLI experience was the rocket fair. I was able to see the capabilities of schools across the country. I learned that there are so many other students who are learning about the same thing as us.
- I learned a lot about how to work with others to succeed. The most exciting thing for me was watching all the rockets launch at the competition.
- I learned quite a bit about other universities and colleges and their rocket experiences. The most fun was touring NASA and, of course, launch day.
- Watching all the other teams' rockets and interacting with them all week was very rewarding for me. I learned everything about the rocket and quadcopter. I didn't know about any of this before we started.
- I had a lot of fun at the museum and at the tours of the NASA Labs. I really like watching the "Mighty Eagle" fly. I learned that we need to have a better way of connecting to our rocket such as a stronger transmitter and nothing blocking our signal.
- I learned a lot of NASA stuff! Launching the rockets was the most exciting.

IX. Educational Engagement Summary

Team RPGs has participated in the following educational engagement activities:

- Washington Space Grant Annual Poster Session
- SACNAS Conference Presentation
- Eagle Ridge/Skyline School
- Lummi Nation Tribal School
- Bellingham Middle School
- 5/3/13 Presentation at Museum of Flight, Seattle, for Space Night

Many of our presentations were at national or regional events even though our emphasis was on middle school students. Our successes over the years have brought the NWIC Space Center to the attention of several organizations that want to improve their outreach to minorities, particularly Native Americans. USLI has given us the opportunity, the confidence, and the knowledge to participate in an exemplary manner, much to the pride of the various year's team members.

X. Budget Summary

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

Travel & Lodging	$9,676.00

Project Income	
	$19,000.00

We were within budget. Because of budgetary restraints, we had to leave four team members at home this year and not bring them to Huntsville. This is an issue that needs to be addressed. As you can see, the travel and lodging was almost double that of the rocket.

XI. Conclusions

The several of team members are intent on submitting a proposal for 2013-14 USLI project. They are convinced that the MV towing the rocket is a viable endeavor. They want to take the lessons learned and make adjustments so that they are 100% successful.

This year's team consisted of a younger set of students than we had in the past. While not quite as steady as the older students, they make up for it in enthusiasm, inquisitiveness and inventiveness.

I/we are looking forward to having our proposal accepted for the next event.