University of Hawaii

Windward Community College Campus

University Student Launch Initiative
2012-2013

Post-Launch Assessment Review
(PLAR)

Contents

1.0 PLAR Summary

1.1 Team

1.1.1 Team Name

Ke kime kao lele keu loa

1.1.2 Location

University of Hawai'i – Windward Campus
45-720 Kea'ahala Rd.
Kane'ohe HI, 96744

Team Name:	Ke kime kao lele keu loa (The Great Rocket Team)
Project Name:	Green Machine (Rocket) Wilfred (Payload)

1.1.3 Team Summary

Dr. Joseph Ciotti (Principle Investigator)
Dr. Jacob Hudson (Team Official, TRA/NAR L3 Certified)
Dr. Greg Witteman (Software Resource)
Helen Rapozo (IT Specialist)
Kristi Ross (TRA L3 Certified)
Joleen Iwaniec (TRA L2 Certified)
Kristin Barsoumian (TRA L1 Certified)
Lyra Hancock
Warren Mamizuka
Ada Garcia

1.1.4 Team Official

Dr. Jacob Hudson (Team Official) is the Coordinator for the NASA Aerospace Education "Flight Lab" facility, and a lecturer of Physics and Astronomy at the Windward campus of the University of Hawaii. Dr. Hudson has been developing the curriculum for an introduction to Rocket Sciences, which will be integrated into the recently developed Space Flight College within the College of Engineering. He is also an avid rocket enthusiast being L3 certified. He is a member of the National Association of Rocketry (NAR #82342 SR), and the Tripoli High Powered Rocketry Association (TRA #05343). Dr. Hudson is a member of the Reaction Research Collaboration, and has been an active member with the Aerospace Rocketry Association of the Pacific (AeroPac), where he has made over 15 flights of his Ho'ola rocket (using an M1419 motor) as part of the ARLISS (A Rocket Launch for International Student Satellites) program.

1.2 Launch Vehicle Summary

The team rocket is 124 inches in length with a 6 inch diameter. The rocket had an estimated loaded weight of just over 45lbs. The rocket was designed to accept an Aerotech L1500T 98-mm diameter motor which was fitted into an AeroPac 98 mm motor retainer. We estimate that this motor yielded a thrust to weight ratio of 7.4. The rocket was designed to have a dual deployment recovery system incorporating a 42-inch drogue deployed at apogee. This would have resulted in a descent rate of ~70 feet per second. A 144-inch main chute was to be deployed at a pre-determined altitude, causing the final descent rate to decrease to ~18 feet per second. It was observed that the vertical descent rate was less than this value: ~10 ft/s. The rocket was designed for an 8-foot launch rail, but we were able to use a longer 10-foot rail. According to our simulation results, our rocket reached the minimum safe speed at a height of 68 inches along the rail. We planned on using 10-10 standard rail buttons for our rail guidance, a separation distance of 22 inches between the two buttons, and an offset distance between the bottom of the rocket and the lower button of 4 inches. It was these values that yielded a launch rail length of 94 inches (~8 ft). That being said, there is a significant difference between what a simulation predicts and the actual launch itself - a longer rail gave a better safety margin. Use of the UAH 10-foot rail significantly eased the mind of the team mentor.

1.2 Payload Summary

For the payload we choose to do the scientific mission directorate with a magnetometer. Our payload takes pictures and atmospheric data every 4 seconds upon decent and after landing, it is also designed to transmit the stored data ten minutes after it has landed. The Magnetometer works off Faraday's Law of Inductance.

Our payload was designed to fulfill the Scientific Mission Directorate and test our fabricated magnetometer. We predicted the induced voltages caused by magnetometer's interaction with the Earth's magnetic field could determine the orientation of the rocket. Using the Arduino Mega 2560 and various sensors to read and store atmospheric data along with the induced voltages.

2.0 Flight

2.1 Data Analysis

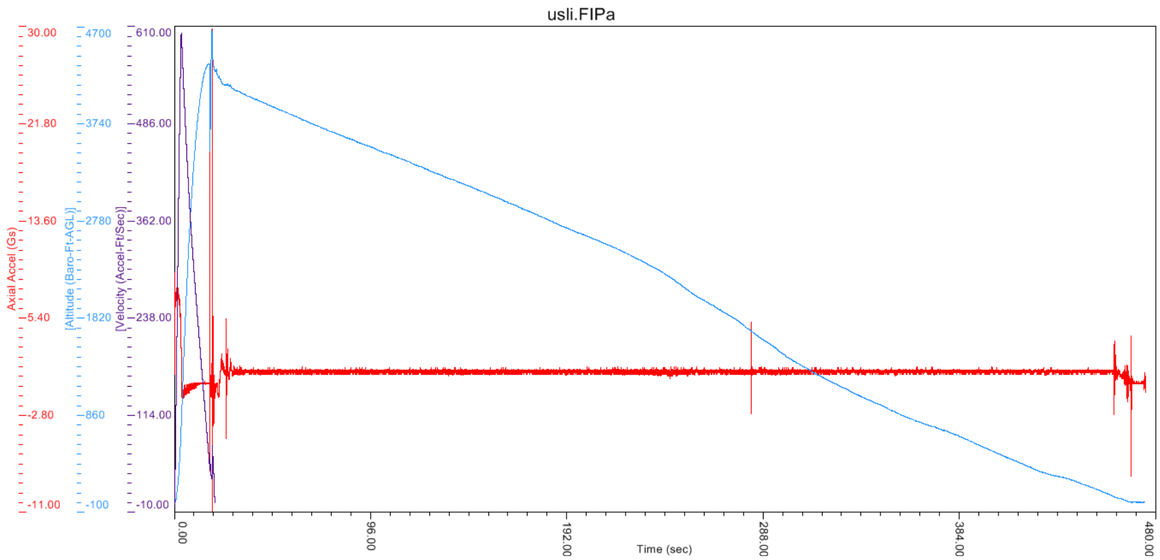
2.1.1 Vehicle Summary and Results

Attached is the flight data file obtained from the Featherweight Raven avionics unit. At ignition, the L1500T motor lit and very quickly came up to pressure. The motor burn-time was about 3.5 seconds, and the rocket reached a max velocity of around 598 feet per second, just before burnout. It continued to coast to apogee, which turned out to be 4671 feet when it was approximately 19 seconds into flight. Looking at the plot of acceleration vs. time (red curve), there is a large spike in the graph (showing the drogue chute deployment) followed by a smaller, yet discernible spike soon after. This spike shows where the premature separation occurred. Separated into its two descending parts, the rocket began its long slow descent that resulted in a total flight time of around 466 seconds (~8 minutes).

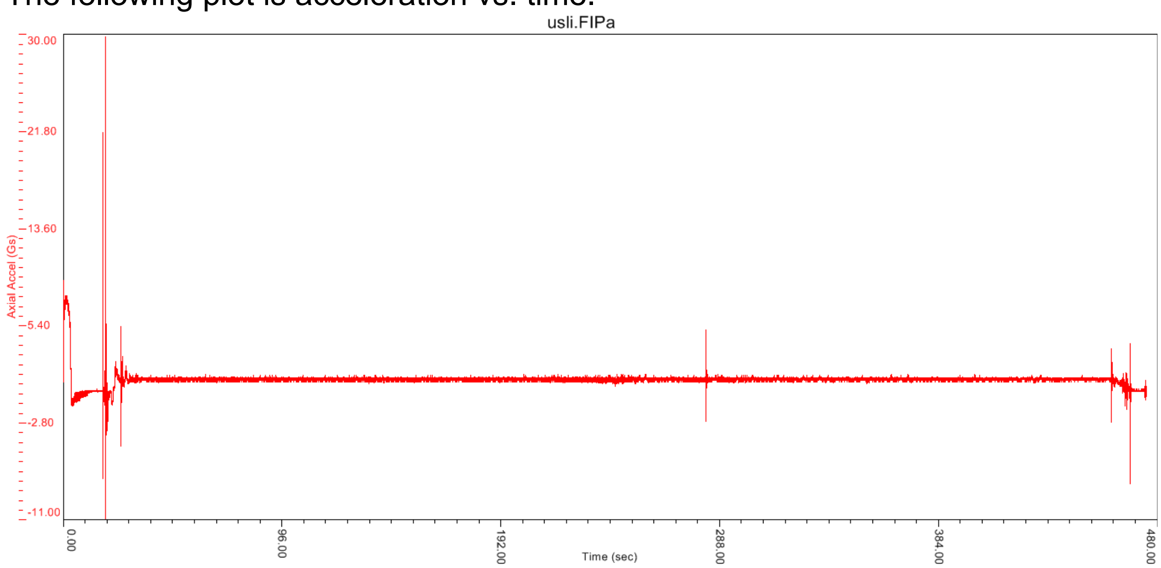
What were the possible causes for a premature separation? Initially it was thought that we were short in the number of shear pins; 4 as opposed to a higher number. Whereas the number of shear pins could always be increased, it is a fact that an increased number of shear pins (>4) was never tested, either in our Full-Scale Low-Powered (FSLP) test nor any of the deployment tests. Indeed, there was not any indication in any of our tests that would have led us to believe that the number of shear pins was insufficient for the job to be done. After FSLP, a discussion did arise as to weather the number of shear pins should be increased (4 to 6), but since the FSLP was a success, timing was an issue (there was not enough time to do another deployment test and get the rocket to Huntsville), and our safety protocol dictated that the main chute be deployed, no changes in the number of pins was made. So, what did lead to an early separation? Three possible causes: (1) an increased payload mass, (2) a higher then tested horizontal velocity at apogee, and (3) a failure to include a vent hole in the main chute stowage volume. As to an increased payload mass: at the time of FSLP, the payload prototype flown was a bread-board lacking a mounting board and the GPSFlight tracking unit. Although we tried to estimate the mass difference, and compensate for it at FSLP, we were off by about ½ a kilogram at the time of launch at Huntsville. In, and of itself, this was not a large issue but combined with the other two causes, it didn’t help. As to the second point: at the time of launch, the rail the rocket was on was adjusted to compensate for the horizontal wind – it was hoped that this would result in a closer touch-down after descent. Due to this ‘pointing into the wind’, at apogee the rocket did have a higher than anticipated horizontal velocity. A simple derivative of the drag force with respect to velocity shows that the drag force due to the deployment of the drogue scales linearly with the rocket speed. Therefore, a 10% increase in speed will yield a 10% increase in drag force – or deployment yank. This increased speed, along with its associated drag force at drogue deployment and the increased payload mass, has been attributed for half the blame. The other half of the blame lies in the omission of the vent hole in the main chute stowage. A very simple estimate of the pressure difference between ground level and apogee shows that there would have been ~45 lbs of force acting on the forward section of the rocket at the time of the drogue chute deployment. These three things are what we believe led to an early deployment of the main chute. So, how many shear pins would have prevented this? Following the methods outlined in the CDR report, and our early deployment tests, we would have had to have a minimum of 8 shear pins, not 6. And the question of weather or not our pyro charges would have been big enough to deploy would then have to be addressed again.

2.1.2 Raven

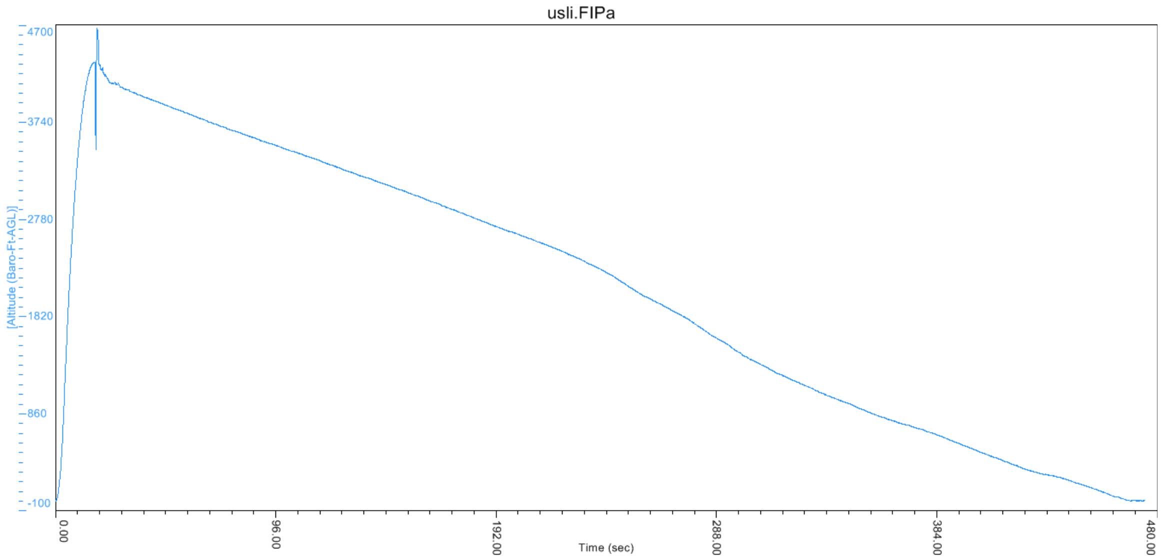
The following plot is acceleration, velocity, and altitude vs. time from the Featherweight Raven Flight controller.



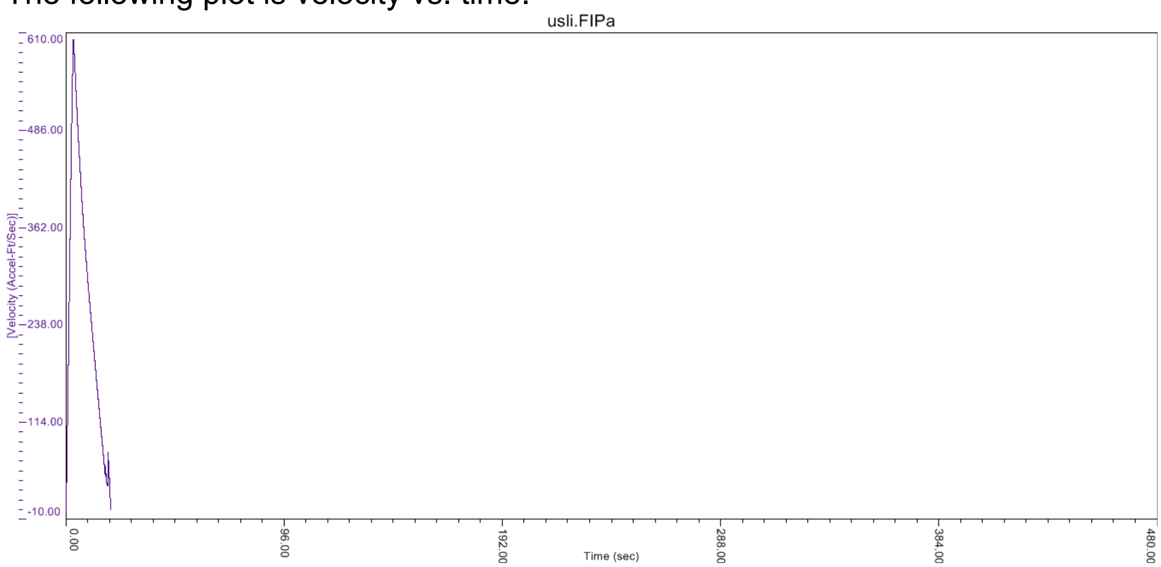
The following plot is acceleration vs. time.



The following plot is altitude vs. time.



The following plot is velocity vs. time.



2.1.3 Payload Summary and Results

Unfortunately, this year we were cursed with full failure with our payload. At launch day, Wilfred seemed ready for flight. All batteries and computers were charged. Everything was in place. The payload team was confident everything would go well with Wilfred. From our analysis of the data, we know that the code started. We had headers for each atmospheric data. It was the initialization of data collection that did not occur.

Our code was programmed to start collecting data after the rocket hit apogee. Through simulations and calculations, the payload team estimated the time of apogee to be a little over a minute. The team designed Wilfred to start a clock once it sensed a significant pressure change. The clock would run for about 70 seconds then the data collection of atmospheric data would start.

It was heart breaking to see our rocket launch the way it did. We thought it was going to float back home to Hawaii. The only thing that kept our spirits up was the thought that Wilfred was collecting copious amounts of data since it was in the sky for so long. Imagine our disappointment when we realized Wilfred collected no data.

After further analysis of the payload section, we realized that the nosecone section, where we housed Wilfred, was a bit suspicious. There were no holes in this part of the rocket to account for the collection of atmospheric data. Our team believes that the reason the Wilfred was unable to collect data was because there was not a significant enough change in pressure for the code to begin.

2.2 Scientific Value

The objectives of our payload are to obtain clear and visible pictures and also take data including temperature, acceleration, humidity, ultra violet light, real time, pressure, and visible light every 4 seconds upon decent and after landing. The Camera takes pictures through a hole in a bulkhead and a prism that is on a weighted swivel, so we can obtain oriented photos throughout the flight.

The Magnetometer tests Faraday's Law of Inductance. By Interaction with the Earth's magnetic field and three mutually perpendicular coils we were able to induce a voltage, which we then amplify to check against the field readings to see if we can tell the orientation of the rocket throughout the flight.

The code for the payload is set to initiate with a change in pressure, and works through each phase on a timer. The data is stored on board a SD card and transmitted to the team's ground station 10 minutes after the surface missions are complete. We choose to use an Arduino Mega as our micro controller along with two shields to integrate our sensors.

2.3 Visual Data Observed

Visually we were able to see the rocket ignite and continue through boost phase and the coast phase of our flight profile. At apogee we saw an event and then all of the parachutes were deployed. At this point there are a few possibilities; avionics not wired correctly, which is immediately discarded, not enough shear pins, which we had tested. It wasn't until further examination of the rocket that we were able to determine the answer. As for the payload due to full failure, we were unable to obtain any visual data.

3.0 Overall Experience and Lessons Learned

Kristin Barsoumian

Overall, the experience was remarkable, and although we did not achieve a full success we were able to diagnose and determine what we could have done to make it one. As part of the Payload team we decided to initiate our payloads code by a change in pressure. However, we did not provide the correct ventilation in the rocket to account for the pressure change, there was no change in pressure and the code continued to check for a change throughout the entire flight. Therefore, the next phase of code was never initiated and we were unable to obtain data from the flight.

I can speak for myself as well as the rest of the team in saying the whole experience was very rewarding. There were a lot of goals achieved during testing, integration, and the building process, which have better prepared me for the future. Working with a team and following the demands that of which a contracted company meets was a beneficial experience to my engineering education.

Lyra Hancock

This year I continued to work on the payload portion of our project. We attempted to fulfill the Scientific Mission Directorate and test our version of a magnetometer. The purpose of this magnetometer was to test Faraday's Law of Induction. We wrapped three coils perpendicularly to represent the three axes in a 3D plane. We hypothesized that, through the magnetometer's interaction with the Earth's magnetic field, a voltage would be induced in the coils. With these voltages, we hoped to determine the rocket's orientation through flight.

Though we had an interesting payload, we were not able to collect any feasible data. Our code was programmed to start when there was a significant change in pressure. After analyzing the flight and rocket, we were able to conclude that data collection did not start because there was not a substantial pressure change. We realized this through analyzing the nosecone, where Wilfred was stored, and noticed there were no holes for the pressure in the nosecone to equalize with the surrounding pressure. This caused us a full failure for our payload.

Despite having a full failure, I believe we succeeded. The cause of our failure was not based on a payload error, but rather an error in communication. Fortunately errors and mistakes are things that we can improve on, and we will be sure not to make them again. Kristin & I, as sophomores, were able to complete this year's payload with only the two of us. We were able to complete a project that usually takes many people. I was able to grow as a leader, student engineer, and person. Given this opportunity, I was able exercise my role as a leader and guide the payload development. I used my engineering skills to overcome the obstacle of coding by debugging and thinking out of the box. This whole experience along with launch week allowed me to gain a further appreciation of the words teammate and peer.

Warren Mamizuka

In our rocket's flight profile, the plan was to incorporate dual-deployment of the chutes. We set our avionics to deploy our drogue at apogee, and our main (holding the avionics and booster sections) and payload (holding the payload and SMD) chutes were set to deploy at 1150 ft. during descent. On launch day, however, only one event was discernible. At apogee, not only did the drogue chute deploy, but the rocket separated prematurely with the main and payload chutes popping out. We have attributed this failure to our payload having more mass than we had flown with at our full-scale test. Since we hadn't taken into account that additional mass, the 4 shear pins we used was not sufficient enough to keep the mass from separating the rocket. When we had gotten down to realizing that we needed more shear pins, there definitely was frustration felt throughout the team, for we had discussed implementing 6 shear pins before flying to Huntsville. That being said, I was happy that we were able to recover all the components of our rocket though it had drifted across the street from the launch site (thankfully before the tree line). I was also pretty happy with our altitude (4672 ft.) because it was only off by about 600 ft.

This experience really was one of the most rewarding ones I have ever had. I learned so much through this project about the engineering design process and what engineering entails as far as the importance of being able to work well in a group with others. The tours were probably my favorite; we got to see so many interesting projects and sites that really impressed me. Thank you so much for this experience, and I look forward to going back next year!

Ada Garcia

The experience I've gained by participating at USLI as a member of the Hawai'i team is invaluable, and rated above my expectations. This project allowed me to fully use my hands-on, technical, and creative abilities. It encompassed several fields, and an extensive process that, beyond any doubt, prepared me as an engineering student to succeed in my future senior design project. It consisted of a variety of components that allowed me to diversify my knowledge and skills, and become more versatile. Moreover, it allowed me to get a feel for what it will be like to be a part of the engineering workforce. Above all the requirements and steps, I learned to comply to a timeline and budget, work in a team, plan and communicate more effectively, apply concepts learned in class to a real life application, such as the rocket, and overcome some limitations that the Hawai'i team encounters each year. These limitations include the lack of resources to bring about the fabrication of the rocket, for the reason of being a community college, and the fact that we can only test the rocket once, unlike other universities, and cannot go over a ceiling of 2,500 feet, by law, as a result of being located in Hawai'i. Due to these limitations, I consider our rocket to have achieved very close to a successful flight. Working in the design and construction of the rocket, I was primarily interested in reaching the targeted one mile height, and the safe recovery of the rocket. Our rocket's apogee did not occur too far of the desired altitude. Although the main parachute ejected prematurely, the rocket did not drift too far off the area and was retrieved free of any damage. I got the opportunity to travel to Huntsville, Alabama, where the project culminated. This trip has been so far one of the best, if not the best, experiences throughout my education and professional development. Here I got the chance to expand my network, as well as meet several notable individuals, such as former astronaut Charles Precourt. In conclusion, this experience reinforced my passion for engineering, and helped me develop a new interest in NASA and rocketry.

Kristi Ross

I don't have very much to say because the other team members have already said everything. I am very grateful for the opportunity I have had to participate in this endeavor. I was able to learn more about myself and also expand my knowledge and love of scientific fields. All I can really say is thank you a million times over to the people who helped me in this journey. This year's team was amazing and I see great things ahead for them.

4.0 Educational Engagement Summary

The Hawai'i team got the opportunity to give back to the community by participating at various events throughout the year. These events consisted of the following: Windward Ho'olaule'a 2012, Windward Explore Gifted and Talented, Kaneohe Christmas Parade, American Cancer Society Family Camp, Windward Community College Annual Physics Olympiad, and WOW! That's Engineering. Every member of the team collaborated to provide education outreach about aerospace, NASA, and rocketry to middle school students, as well as to share our knowledge on the aerospace resources available in Hawai'i, and lead hands-on activities, including the assembling and launch of scimitars, with the ultimate purpose of nurturing in them our enthusiasm for STEM fields. Taking every opportunity offered to us participate in these events, we were able to have indirect contact with thousands of individuals.

5.0 Budget

USLI PARTS LIST
(rocket/tare cost)
Rocket

Part:	Price	Qty.	Total
Body Tube (FTEX 2 3.91"X4.00")	$18.96/ft	8 ft	$151.68
Nosecone (FNC 4.0-4-1 Ft 3.91 17" ogive)	$55.00	1	$55.00
Coupler (CT-3.91" 10" Long)	$13.61	3	$54.44
Rouse-Tech Fins	$15.00	4	$60.00
Rouse-Tech Aluminum Fin Can	$90.00	1	$90.00
Rouse-Tech Aluminum AV Can	$70.00	1	$70.00
Basuda Clear Tube	$20.00/2ft	5in	$4.17
Centering Rings (CR 3.91")	$4.20	2	$8.40

Bulkheads (BP 3.9FT-3.91 ½” ply.)	$2.10	5	$10.50
Motor Tube (PML 98-mm 36”)	$24.50	1	$24.50
Drogue Chute (60”)	$130.00	1	$130.00
Main Chute (96”)	$360.00	1	$360.00
Shock Cord (1” thick)	$0.80/ft	24ft/3	$57.60
Kevlar Patch (9”)	$14.00	1	$14.00
Kevlar Patch (16”)	$19.00	1	$19.00
Aeropack Motor Retainer (RA98)	$64.00	1	$64.00
		TOTAL:	$1,173.29

Avionics/Electronics

Part:	Price	Qty.	Total
PerfectFlight MiniAlt/WD	$99.95	1	$99.95
Featherweight Raven	$140.00	1	$140.00
GPSFlight (ST900e)	$695.00	1	$695.00
GPS-P25 (Patch antenna)	$30.00	1	$30.00
RPSMA900 (trans. antenna)	$18.00	1	$18.00
BeeLine GPS	$160.00	1	$160.00
Li-Po Battery Pack	$150.00	1	$150.00
9V Dry Cell	$2.99	4	$11.96
		TOTAL:	$1,304.91

Miscellaneous

Part:	Price	Qty.	Total
U-bolts	$1.29	4	$5.16
Epoxy Slow Cure	$14.49	1	$14.49
Epoxy 5 Min	$16.99	1	$16.99
JB Weld	$6.79	1	$6.79
1/8” Barrel Hex Bolts X 1”	$0.65	2	$1.30
1/8” Barrel Hex Bolts X ½”	$0.23	4	$0.92
3/16” X ¾” Machine Screws	$0.40	16	$6.40
BH 8-32 X 1/2” Bolts	$0.18	24	$4.32
Washers	$0.17	12	$2.04
Wing-nuts	$0.85	2	$1.70
Stop Nuts	$0.35	8	$2.80
Hex Nuts	$0.15	9	$1.35
3/16” X ½” FH Machine Bolts	$0.23	8	$1.84

3/16” X ½” Hex Head Bolts	$0.16	8	$1.28
Split Lock Washers	$0.23	8	$1.84
Pan Head Bolts	$0.23	3	$0.69
¾” Threaded Round Rod 3ft	$2.89	1	$2.89
Batteries 9V 2pk	$6.97	3	$20.91
Sandpaper various grit	$1.29	5	$6.45
Sandpaper various grit	$0.89	5	$4.45
Tape Blue Mask 1.87” x 60yds	$8.99	1	$8.99
Tape Blue Mask 1.00” x 60yds	$4.99	1	$4.99
Tape Mask .94” x 60yds	$1.49	1	$1.49
Dust Mask 2pk	$6.99	1	$6.99
		TOTAL:	$127.07

Payload

Part:	Price	Qty.	Total
Wilfred Phase I (SMD)			
Arduino MEGA 2560 R3	$58.95	1	$58.95
Micro SD Breakout Board	$17.95	1	$17.95
Humidity DHT11	$5.00	1	$5.00
Light TSL2561	$12.50	2	$25.00
Pressure BMP085	$19.95	1	$19.95
Camera TTL Serial JPEG	$42.00	1	$42.00
Mega Shield	$14.95	2	$29.90
Wilfred Phase II (Magnetometer)			
Op Amps	$2.95	3	$8.85
Wiffle Ball	$4.50	1	$4.50
Wire	$10.00/roll	1	$10.00
Real Time Clock DS1307	$9.00	1	$9.00
3DR Radio Tele. Kit (915MHz)	$74.99	1	$74.99
Lithium Ion Polymer Batteries	$12.00	2	$24.00
45-45-90 Prism	$8.00	1	$8.00
Swivel Mount	$3.40	1	$3.40
9V Battery	$2.99	3	$8.97
Mounting Board (3/4” bass.)	$3.00	1	$3.00
		TOTAL:	$353.46

Rocket Total (w/o Engine and pyrotechnicals)**:** **$2,958.73**

Travel

Item:	Price	Qty.	Total

Airfare	$890.00	5	$4,450.00
Airfare	$1,300.00	1	$1,300.00
Hotel	$484	4	$1,936.00
Food	$125.00	6	$750.00
		TOTAL:	$8,436.00
	Grand Total:		**$11,394.73**

Ke kime kao lele keu loa team members: Front row (left to right); Kristin Barsoumian, Warren Mamizuka, Kristi Ross. Back row; Ada Garcia, Lyra Hancock