University of Hawai'i
Windward Community College

University Student Launch Initiative
2010-2011

Flight Readiness Review

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I) Summary of FRR report

Team Summary

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Launch Vehicle Summary

- Rocket Name: Leo Hano
- The team rocket is to be 121 inches in length, with a 6" diameter
- The rocket is designed to accept an L1300R 98-mm motor
- The rocket is designed to have a dual deployment recovery system incorporating a 42" drogue deployed at apogee, and a 144" main to be deployed at 1100' altitude.
- 10/10 rail with a length of 12' (Per Jacob Hudson, arrangements have been through Dan Cavendar to use UAH's launch rail)

Payload Summary

In order to continue its efforts at promulgating interests in science, technology, engineering, and mathematics, Windward Community College's (WCC) Center for Aerospace Education (CAE) wanted to acquire a re-usable rocket to perform diagnostic testing for several of our education outreach projects: A Rocket Launch for International Student Satellites (ARLISS), testing for the National CanSat competition, various High School Science Fair experiments, and as the hands-on component for a course on Rocketry that is to be integrated into the University of Hawai'i curriculum. The rocket would be designed to carry a non-specific payload, of limited weight and size, to an altitude of 1 mile (5280'), and then return safely to its launchers. The targeted altitude can change with the incorporation of our Variable Drag Configuration (VDC) rocket and different engine selection. It will also have the ability to contain the payload through entire flight or to eject its payload at apogee. These options depend on the needs of the outreach program that it is being used for. The payload carrier would have an on-board data acquisition system capable of determining where the payload compartment is, how fast it is going, how high above ground level it is, and what angle the payload section is above the horizon.

In addition, the payload carrier electronics will also include the ability to perform a 'voice–over' to a ground PA system to inform all observers of the information being collected and the status of the rocket. This last will not be used in for the USLI launch in Huntsville.

The Payload is named Hula-hoop. Its purpose is to determine the rocket's orientation throughout the flight. It will have three perpendicular coils, each with its own parallel resistor. These coils will be wrapped around a sphere. This sphere will be of a material that does not produce or interfere with magnetic fields. As the rocket goes through its flight the payload will travel with the rocket through the Earth's magnetic field. In doing so, an induced voltage will be produced, due to the interaction of the coils as they travel through the Earth's magnetic field. Data will be collected concerning the voltage fluctuations for the three coils. Since the coils will be perpendicular to each other we will have data of voltage fluctuations in three dimensions (X, Y, and Z). This data can be used to determine the rocket's orientation throughout the flight. A more detailed description of the payload is given in later sections.

II) Changes made since CDR (w/ reason for change)

Changes made to Vehicle Criteria

Since CDR, we have added a motor mount-retention cap that has been integrated with the forward centering ring for the motor mount. A more detailed write up of this and corresponding drawings can be found in the section III. Vehicle Criteria, in the booster subsection.

Also, the deployment altitude for the main parachute has been changed from 1000ft to 1100 ft.

Changes made to Payload Criteria

Each coil will be connected to a network of 4 resistors such that when connected to it would generate a reading of .5 to .6 volts. If the coil is not connected to this network, this will generate a reading of 1 volt.

We will be using 2 ADCs. Our 24 bit ADC has been changed to a 12 bit ADC. One to handle data from the temperature sensor, the other from the coils. At this stage we are delaying the use of a barometric sensor in the project.

Changes made to Activity Plan

A second full-scale low power (FSLP) test was made on Sunday March 20th. This was in addition to our FSLP test a week earlier on Sunday March 13th. The additional launch day was needed because our first test was not successful. More information on these tests can be found in the Full-Scale Low Power section.

The plans for our TV show have slightly changed as well. Originally we were going to be broadcasting on a public access channel called O'lelo. If we were to go through O'lelo we would have had to rent equipment and do the filming and editing ourselves. We have instead put this effort into being on an episode of "Sports People Hawaii" which was shot and will be edited by a professional crew. More details in the Activity Plan section

III) Vehicle Criteria

With outreach being the main focus of WCC's USLI rocket, our vehicle must be able to successfully carry different payloads for various outreach projects. These payloads must meet all of our dimensional and weight limitations, to guarantee the safety of the rocket, payload, and observers.

The WCC USLI rocket is designed with Education Outreach in mind. Several design constraints are considered with this thought paramount. Since projects are to be canvassed from interested high school students or participating colleges, the payloads are somewhat unspecific. It was thought that a payload weight limit of 2 Kg would allow some latitude for the high school students, was four times the weight limit allowed by the National CanSat competition, and more than enough for the past electronic payload testing that has previously been performed for the ARLISS program. Along with this was the understanding that volume constraints must also be outlined; whereas we will be pushing the National CanSat competition, we did not want this to be the only option for interested students. A cylindrical volume, having a diameter of 5.25 inches, and length of 11.5 inches with a volume of 974 cubic inches was optimal for our purposes. If the payload weighs less than 0.5 Kg, to reach the desired altitude, extra mass can be added, a different motor can be selected, or Variable Drag Configuration (VDC) system can be used. Any changes made will be thoroughly tested using our simulation software (RockSim), as well as our scale prototype, to ensure that all safety requirements are still maintained throughout the rocket's flight.

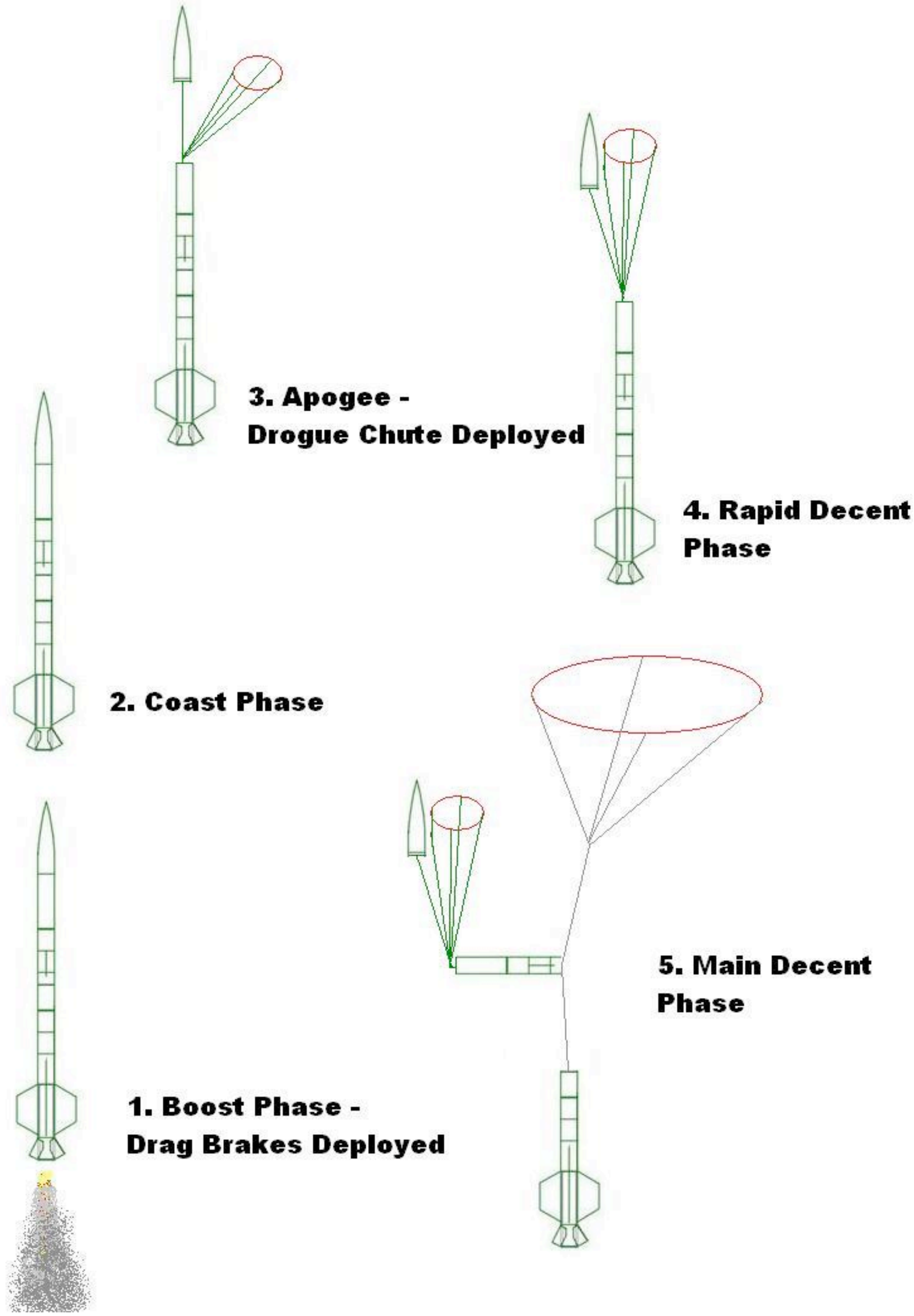
Determination of the motor that is going to be used in USLI was more problematic. It was thought that we should initially over-power the rocket to carry a heavy payload to a height greater than 1 mile. By suitably deploying the brakes shoes of our VDC, open to a set angle throughout the flight, and extra mass, it was thought that we could attain the right height. It was this in mind, as well as some simple kinematics, that led us to our initial choice of the L339 motor. After further consideration, it was thought that the thrust to weight ratio 1:4.49 was too low and a better choice should be made. Later flight simulations showed that the L777 motor was more in line with what we should be using. The problem with this motor was attainability – we could not find a vendor that had one. Shortly thereafter, we found that the estimated weights of the component parts (as given by RocSim) were too low. By actually measuring the component masses, and using a mass over-ride on the RocSim, a much more realistic estimate of the rocket flight profile was obtained, and a motor choice of an Aerotech L1300R was made, this was our choice from CDR and through continued testing remains the final choice that we will fly with if we go Huntsville. A 98/5120 casing length implies that the motor tube length should be ~26 long. A 30-inch length was chosen for convenience, and offers some latitude in future choice of motor, should the need arise.

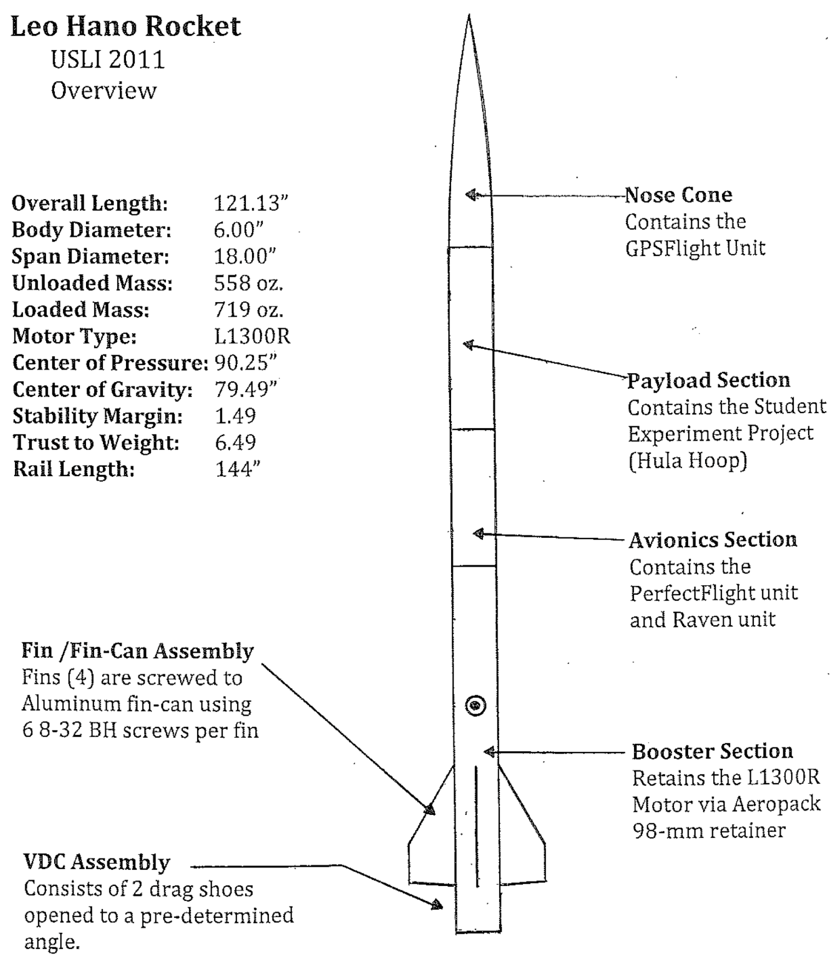
The overall length of the rocket was determined not so much by the payload, as by the dual deployment recovery that is planned. Rocket design started with the nose cone, standard ogive 1:5.16, yields a nose cone length of 30 inches. The choice of this type of nose cone was dictated by the fact that this shape is commercially available. This is where the GPSFlight unit, monitoring the rocket flight profile and status, will be located. The payload section of the rocket is 24 inches in length; 6 inches as the nose cone shoulder, 11.5 inches as the payload section, and 5 inches is the coupler length. Below the payload section of the rocket is the avionics section, chosen to be 18 inches in length; 6 inches to accommodate the forward coupler and stowage of the drogue chute, 7.5 inches for the avionics electronics, and 4.5 inches to accommodate the Aft coupler. The avionics electronics will consist of a Featherweight Raven flight-controller, and an PerfectFlight MAWDs as a redundant back-up system. The Booster section is 48 inches in length, of which the motor mount will take up the lower 30 inches. The upper 18 inches will accommodate the avionics coupler, and act as the main chute stowage area. It goes without saying that this section will hold the four fins, and the VDC assembly. This yields an overall length of 121 inches (10 feet, 1 inch).

We plan to use G-10 fiberglass as the main tube material, with two couplers, three ½ -inch thick plywood bulkheads, two ½-inch thick Birch wood centering rings, four aluminum trapezoidal fins bolted through the booster body into an aluminum fin can via six 8-32 BH stainless steel screws. We estimate the un-loaded weight of our rocket to be 35 lbs, and a pad weight of just under 44.9 lbs.

The flight profile that our rocket will follow is the standard dual deployment routine, and has been simulated (under various launch conditions) on RockSim. The flight will begin with the boost phase. The L1300 motor will produce an average thrust of ~290 lbs (giving us a thrust to weight ratio of ~6.4), with a burn time of 3.5 seconds. The maximum estimated acceleration is ~ 12.7 g's (407 ft/s/s) for about a 1/10 of a second, with an average of ~6 g's with an estimated maximum speed of 427 mile/hr (626 ft/s). At motor burnout, the rocket then enters its coast phase. We expect the rocket to reach apogee ~20 seconds after launch. At apogee, a 42-inch drogue chute will be deployed, yielding an initial descent speed of ~ 82 ft/s. At an altitude of 1100 ft (changed from 1000ft mentioned in the CDR), a 144-inch main chute will be deployed, slowing the rocket descent rate of 22 ft/s, which we believe to be a safe descent rate.

3.1 Flight Profile Diagram




Leo Hano Rocket
USLI 2011
Overview
Overall Length: 121.13"
Body Diameter: 6.00"
Span Diameter: 18.00"
Unloaded Mass: 558 oz.
Loaded Mass: 719 oz.
Motor Type: L1300R
Center of Pressure: 90.25"
Center of Gravity: 79.49"
Stability Margin: 1.49
Trust to Weight: 6.49
Rail Length: 144"
Nose Cone
Contains the GPSFlight Unit
Payload Section
Contains the Student Experiment Project (Hula Hoop)
Avionics Section
Contains the PerfectFlight unit and Raven unit
Fin /Fin-Can Assembly
Fins (4) are screwed to Aluminum fin-can using 6 8-32 BH screws per fin
Booster Section
Retains the L1300R Motor via Aeropack 98-mm retainer
VDC Assembly
Consists of 2 drag shoes opened to a pre-determined angle.

Testing and Design of Launch Vehicle

Mission Statement

It is the mission of the WCC Leo Hano rocket to promote interest in science, technology, engineering, and mathematics, for high school and college students, by providing a safe, reusable lifting body with safety being the primary concern.

This means that the safety of our prelaunch, flight, and recovery are of the highest priority. To have a successful mission the team must ensure that all safety requirements are maintained throughout the mission. The team must also meet all the following criteria below. A perfect mission with absolute success will meet all of the following criteria.

Mission Criteria:

- Payload functions properly
- Successful recovery of the rocket and all its components
- Both parachutes deployed
- The rocket is completely intact
- The data is downloadable via EEPROM
- The payload performed as it was planned to
- The appropriate levels of safety are maintained throughout the entire process of preparation, launch, flight, and recovery of the rocket

To achieve any type of success in the mission, the rocket must have deployed a parachute and must be intact upon recovery, meaning it has the ability to be considered flight ready and meets all safety requirements without any repairs done it. If the team does not have a parachute deployment and the rocket is not intact upon recovery, the mission will be considered a failure. A partially successful mission will be defined as meeting 6 of the 7 criteria, and has also deployed a parachute and remains intact upon recovery.

Motor Selection

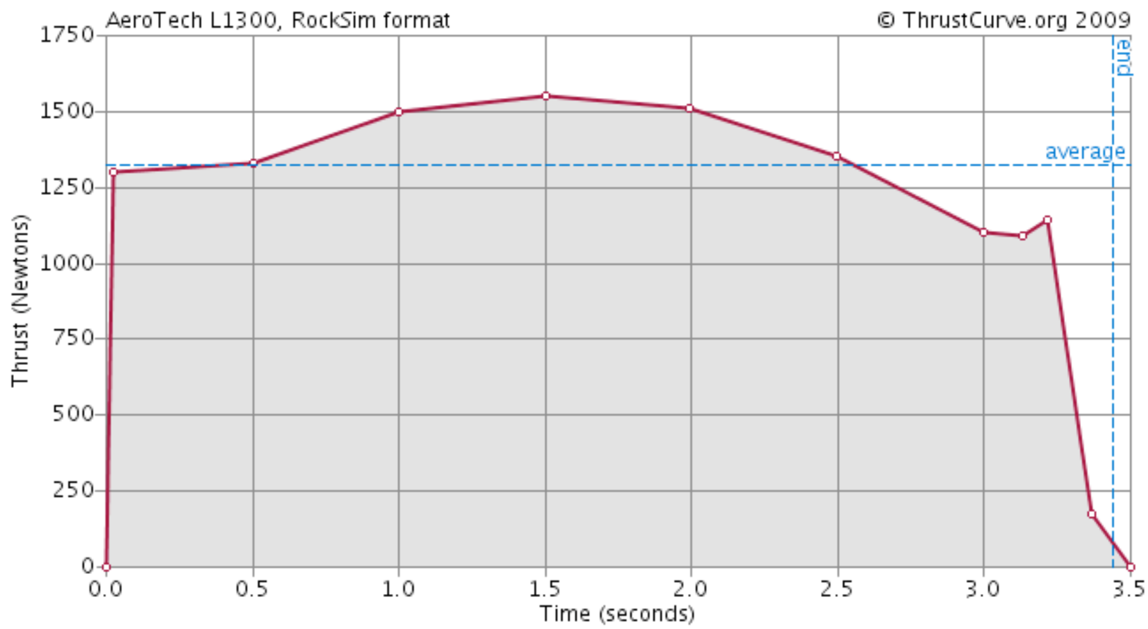
Proper motor selection requires several considerations, a suitable thrust to weight ratio, a predicted maximum altitude that is close to the desired altitude, and the physical constraints of the designed motor retention. As has been mentioned previously, it is hoped that with a proper choice in motor, one yielding an altitude less then 30% over the target height, and a judicious adjustment in deployment angle of the drag shoes, the desired altitude of 5280 feet can be obtained.

Originally we were considering using an L339 or an L777. We have since changed our motor selection to an L1300 because our RocSim predicted component weights were not consistent with the actual weights of the materials used. Because the rocket turned out to be much heavier, the L1300 motor allows us to reach an altitude of 5648. This overshoots the 5280-foot target by 6.97%. Assuming a reduction in altitude of about 2% per degree of deployment of our variable drag configuration (VDC), we expected a deployment angle of the VDC of ~3.5 degrees, to achieve the 5280 target. This was all determined through RockSim, however comparing actual data obtained from our Full-Scale Low-Power tests to these simulation have slightly altered our predictions of the actual altitude which have corresponded to a change in the deployment angle of the VDC. This will be covered in the VDC subsection later in the report.

Motor Information (provided by Thrustcurve.org)

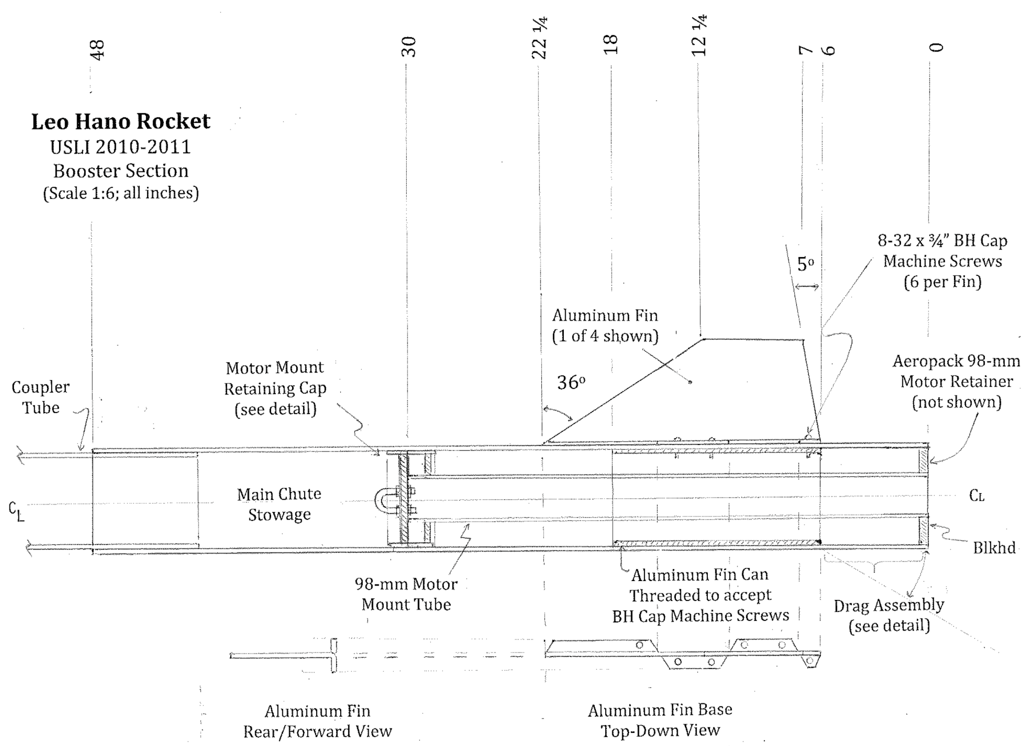
AeroTech L1300

Manufacturer:	AeroTech
Entered:	May 25, 2006
Last Updated:	May 4, 2009
Mfr. Designation:	L1300R
Brand Name:	L1300R
Common Name:	L1300
Motor Type:	reload
Diameter:	98.0mm
Length:	44.3cm
Total Weight:	
Prop. Weight:	2632g
Cert. Org.:	Tripoli Rocketry Association, Inc.
Cert. Date:	
Average Thrust:	1300.0N
Maximum Thrust:	
Total impulse:	4567.0Ns
Burn Time:	
Case Info:	RMS 98/5120
Propellant Info:	Redline

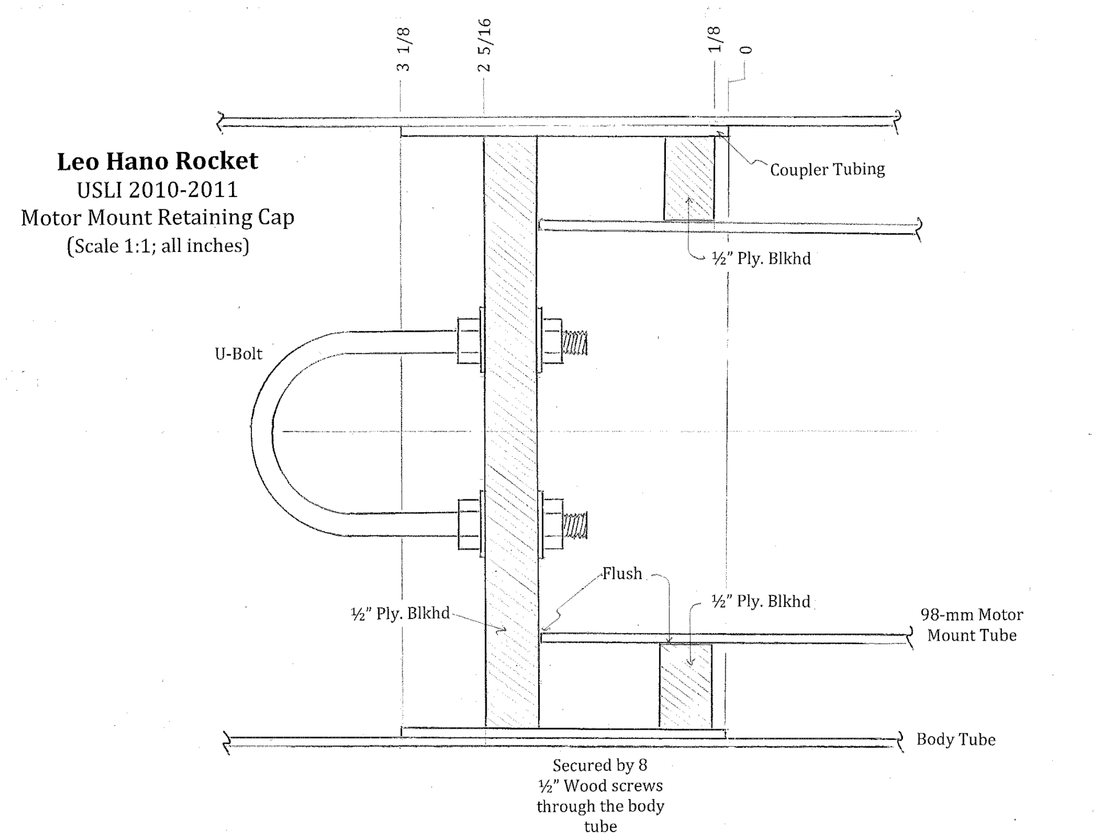

AeroTech L1300, RockSim format
© ThrustCurve.org 2009
Thrust (Newtons)
Time (seconds)
average
end
1750
1500
1250
1000
750
500
250
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Booster Section

The booster section is where the motor is located, and where most of the transitive stress of the rocket originates. As such, care was taken in its construction. Failure to construct an integrated body can lead to sudden (and detrimental) fragmentation on ascension. The body tube was constructed using a double filament wound (40^o wind angle) epoxy fiberglass available from Hawk Mountain Industries. Due to weight concerns, the motor mount tube that was used was from Public Missiles Limited and consisted of phenolic tubing (resin impregnated, spiral wrapped, and heat cured), which is much lighter then the originally planned fiberglass. The aft center-ring was constructed using ½-inch thick plywood, epoxied to the body, and further secured using two ¾-inch wood screws threaded through the body tube. Here, as in all other places that call for epoxy, we used two-part, 3 ton, slow cure epoxy. An Aeropack 98-mm motor retainer was attached to the aft center-ring by means of 8 nut and bolt assemblies.



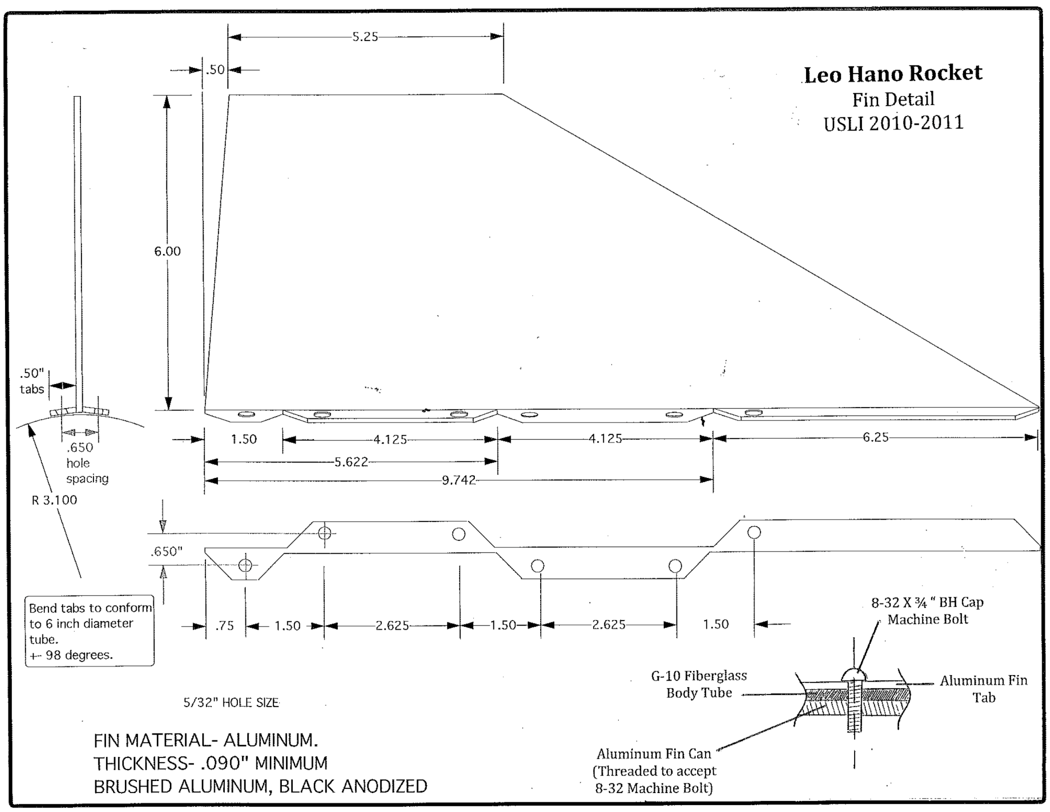
The major change to the booster construction was the removal of the fore centering ring, and replacing it with a Motor Mount Retention Cap. Of concern to the team was the realization that once the two center-rings were in place, access to the variable drag hardware was no longer possible. Furthermore, should the case arise where damage to the motor mount required a change of the motor mount, there was no way to do this short of re-building the entire booster section. After consultation with the local high powered rocketry section (AeroPAC), it was decided that this was the best method by which the motor mount tube could be secured, easily replaced, as well as affording future access to the variable drag hardware.



The motor mount retaining cap assembly consists of a 3 and 1/8-inch high slice of coupler tube, which has a solid ½-inch thick bulkhead and a ½-inch thick centering ring epoxied into it. The solid bulkhead is flush to the top of the motor mount tube with the center-ring acting as an alignment guide for the motor mount tube. The entire assembly is secured into place at the top of the motor mount tube, via eight ¾-inch wood screws threaded through the body tube and into the solid ½-inch thick bulkhead. Also attached to this bulkhead is a 2-inch U-bolt. This is where the shock cord joining the avionics section, and associated with the main chute, is attached.

Fin and Fin-can assembly

As was mentioned previously, WCC has a unique problem in transporting the completed rocket to Huntsville. Despite building to withstand the stresses of launch and recovery, shipping agents tend to find unforeseen ways to damage our completed rocket. The idea of removing the fins for ease of transport has appeal. This year's rocket incorporates a fin, and fin-can design produced by Tom Rouse of Rouse-Tech. Not only does this assembly conform to the ARLISS criteria, it has the added benefit of over ten years of flight-testing. Each fin was screwed (via 6 BH 8-32 X ½ " stainless steel screws), via holes that are drilled through a tab in the fin, through the body tube, and then into a threaded section of the aluminum fin-can. The fin-can not only acts as a nut to the aforementioned screw, it also is fixed to the overall booster body tube via two nut and bolt assemblies.

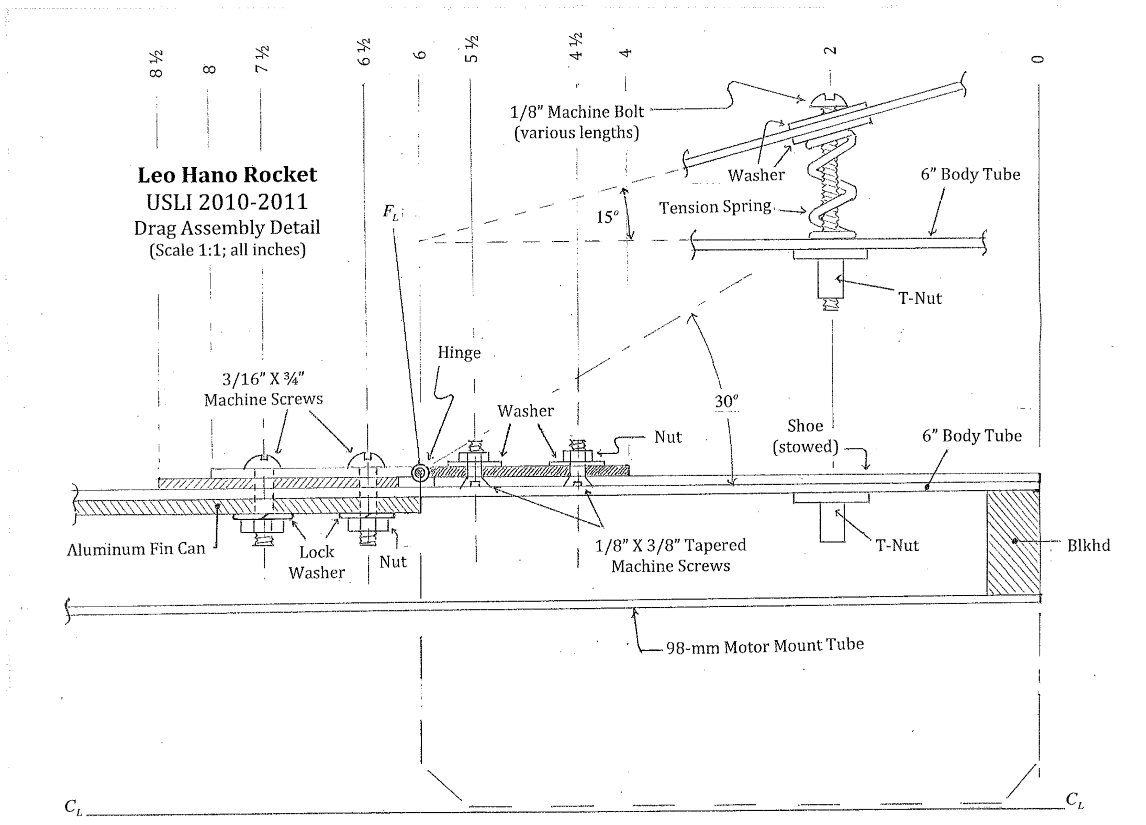


Variable Drag Configuration (VDC) / Drag shoes

Whereas there were no changes made to the construction of the Variable Drag Configuration assembly, there has been more information obtained, and a better estimate of deployment angle has been made since our FSLP (Full-Scale Low-Power) test. As has been mentioned previously, a simple approach to estimating the enhancement of drag force, acting on the rocket by the deployment of the drag-shoes, can be made. Take the geometry of a deployed drag-shoe to be that of a half cylinder (of radius *r*, just slightly larger then that of the rocket, and having a length *l*) canted at an angle of *q* to that of the rocket body. The canted drag shoe is hinged at the leading edge, and held open, to a specified degree, at the trailing edge by a spring-screw assembly. By comparing the drag force utilizing the deployed drag shoes and the drag force for the situation where the drag shoes are not deployed, we find that the drag force is enhanced by a factor of…

$$\frac{F_{D-Open}}{F_{D-Closed}} = (1 + \frac{2l}{r}\sin\theta) = \left(1 + b\sin\theta\right)$$

…where $b = 4$ for our design. A concern about the spring constant used to keep the drag shoes deployed was raised. Subsequent testing, using the spring to balance masses of various values, measuring stretch distances, lead us to determine the spring constant to be 14.7 N/cm. Since this was the same type of spring, in the same configuration, that has been tested previously, we believe this to be adequate. For low deployment angles, 5 degrees or less, where it will be difficult to physically compress the spring, it is planned to use washers to hold the shoes deployed.

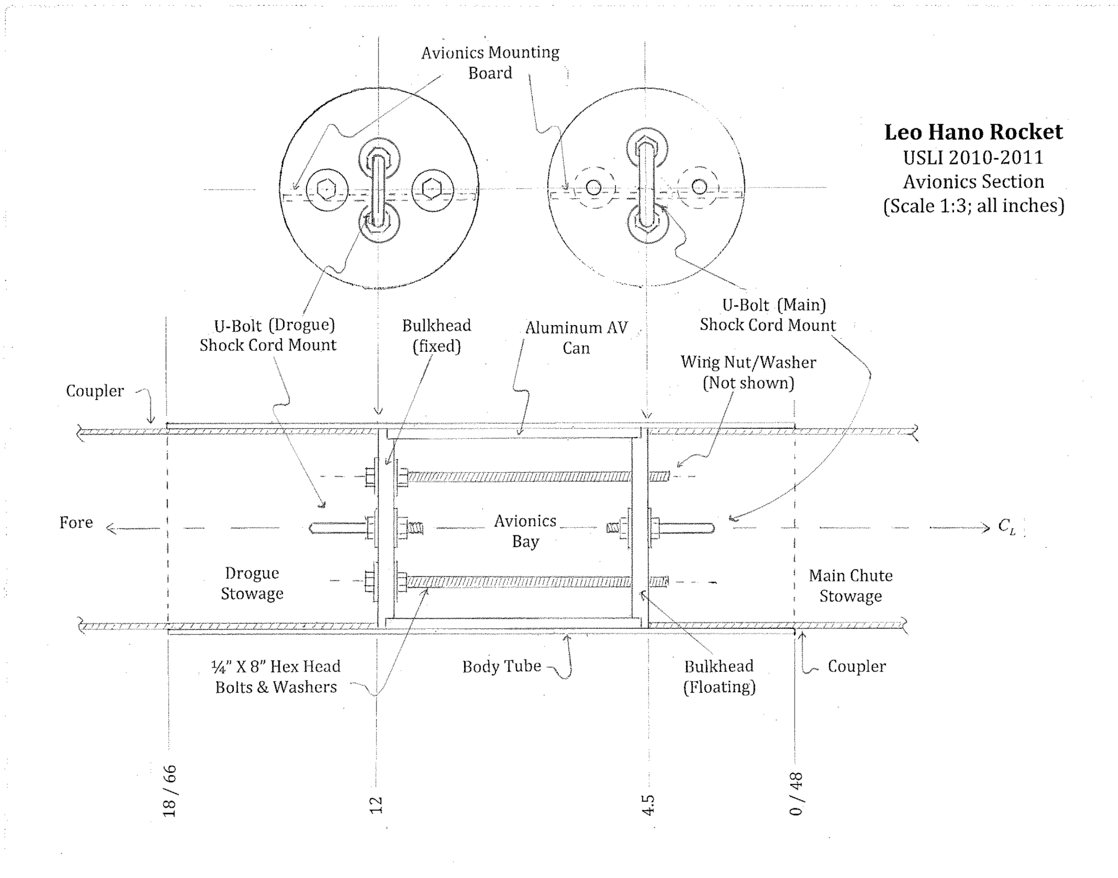


We constructed the Variable Drag Configuration (VDC) assembly as shown above. One observation that should be mentioned is that when the drag shoes are deployed, the CP of the rocket is lowered (~3% at full deployment, using center of area estimates), and enhances the stability of the rocket. Previous testing, using last year's *leo hano* rocket (full-scale, full-power using Aerotech K560W motors) showed a loss in altitude corresponding to ~1.2% for every degree of deployment in its deployment range. The drag-shoe geometry for this year's rocket is very similar to last year's, and we are expecting similar results. This expectation has been met with our 1:3.7 scale model testing, which showed that for angles less then 15 degrees the loss in altitude was ~1.2% for every degree of deployment.

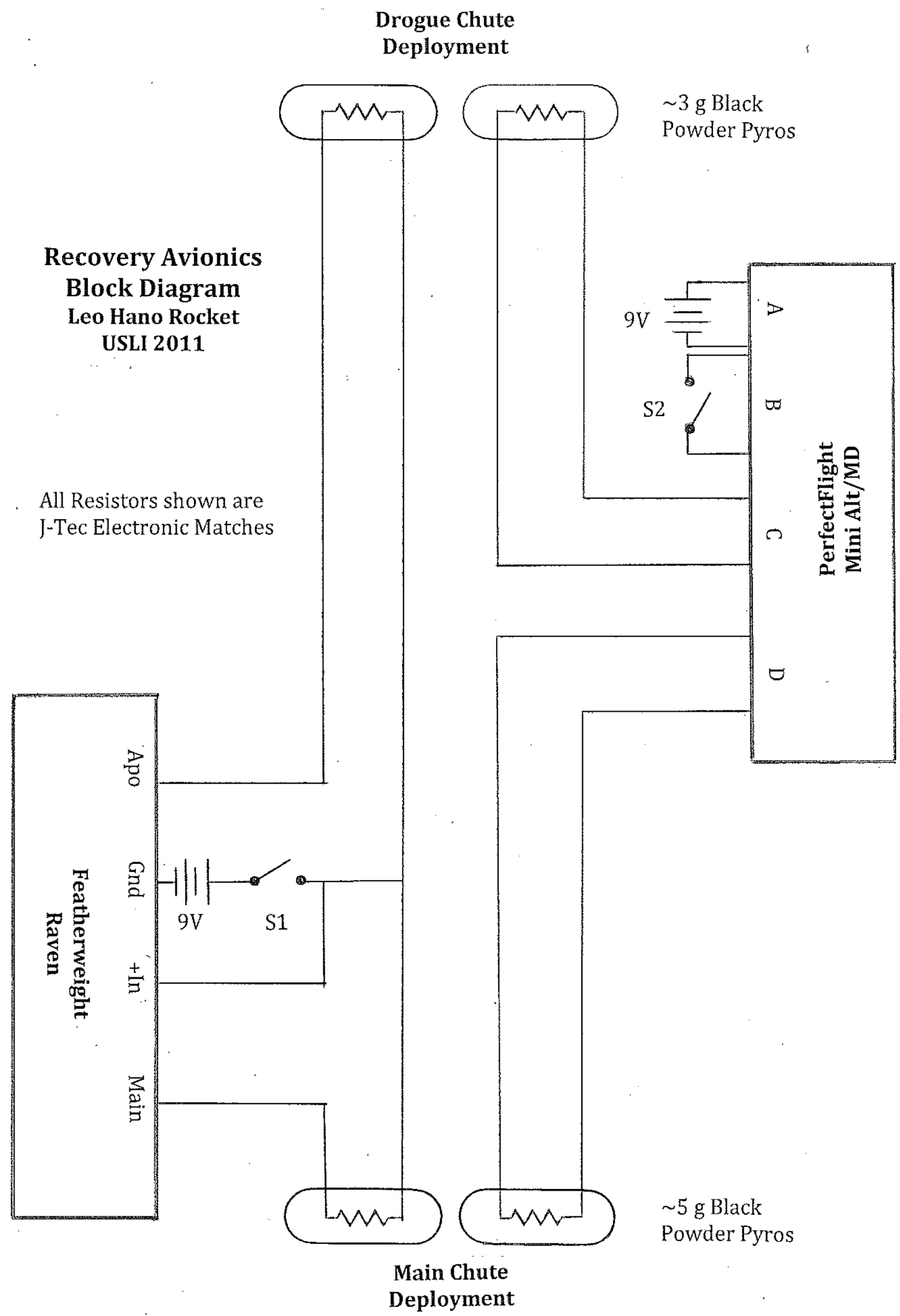
It is hoped that with a proper choice in motor, one yielding an altitude less then 30% over the target height, and a judicious adjustment in deployment angle, the desired altitude of 5280 feet can be obtained. We do not plan on a deployment angle of greater then 30^o. Our current RocSim projections, using an Aerotech L1300 motor, without the drag shoes being deployed, shows a maximum altitude of 6603 feet, which corresponds to a 25% over-shoot. Our FSLP test launched our rocket to an altitude of 1591 feet (with no deployment of the drag shoes). RocSim had estimated that the maximum altitude would be 1960 feet, which is about a 19% loss of altitude between expected and actual. Factoring this loss into the 25% over-shoot yields an estimated 'true' over-shoot of 6%, or a 'true' altitude of 5596 feet. To counter this over-shoot, the variable drag assembly will be used, corresponding to a deployment angle of ~5 degrees.

Avionics Section

The main purpose of this section is to carry the on-board recovery electronics (Avionics). In essence, our rocket was built around this section, and there were no major changes to what was designed. The body tube was constructed of the same tubing that the Booster section is made of. The avionics bay consists of a 7.5" long milled aluminum tube, epoxied into place within the body tube of the rocket. The milled aluminum tube has been "ribbed" so as to reduce its over-all mass, and is also commercially available from Rouse-Tech. This provides a rigid structure to support (and shroud) the avionics electronics should the rocket fail. It is unfortunate to mention this, but as our first FSLP test showed, this works. Affixed to the forward avionics bay, as well as to the body tube, is a circular plywood bulkhead having a two-inch high U-bolt similar to that shown in the diagram for the Motor Mount Retaining Cap. Original plans called for a center-mounted eyebolt, but it was decided that two anchor points, with the bulkhead, was more advantageous then a single anchor point. The shock cord, associated with the main chute and connecting this part of the rocket to the booster section, is attached at this U-bolt. Another circular plywood bulkhead, also with a center mounted U-bolt, is attached to the other end of the avionics bay by means of two ¼" X 8.5" long bolts and associated wing-nuts. This bulkhead is removable for access to the avionics section, and is where the shock cord to payload section is attached. Both plywood bulkheads will have ¼-inch holes placed for the pyro charge wires to pass through (not shown). Also not shown are the two ½" diameter holes drilled thru the body tube into the avionics bay. These holes are for access to the two 'on/off' power buttons for the avionics. A third 3/8-inch bore through the body tube is for the pressure sensor to equalize with ambient and to allow visual inspection of the indicator lights of the Featherweight Raven flight controller. The booster section is mated to the aft of the avionics section using two 4-40 X ½ inch nylon screws, which act as shear pins for our rocket.


Avionics Mounting Board
Leo Hano Rocket
USLI 2010-2011
Avionics Section
(Scale 1:3; all inches)
U-Bolt (Main) Shock Cord Mount
U-Bolt (Drogue) Shock Cord Mount
Bulkhead (fixed)
Aluminum AV Can
Wing Nut/Washer (Not shown)
Coupler
Fore
Avionics Bay
C_L
Drogue Stowage
Main Chute Stowage
¼" X 8" Hex Head Bolts & Washers
Body Tube
Bulkhead (Floating)
Coupler
18 / 66
12
4.5
0 / 48

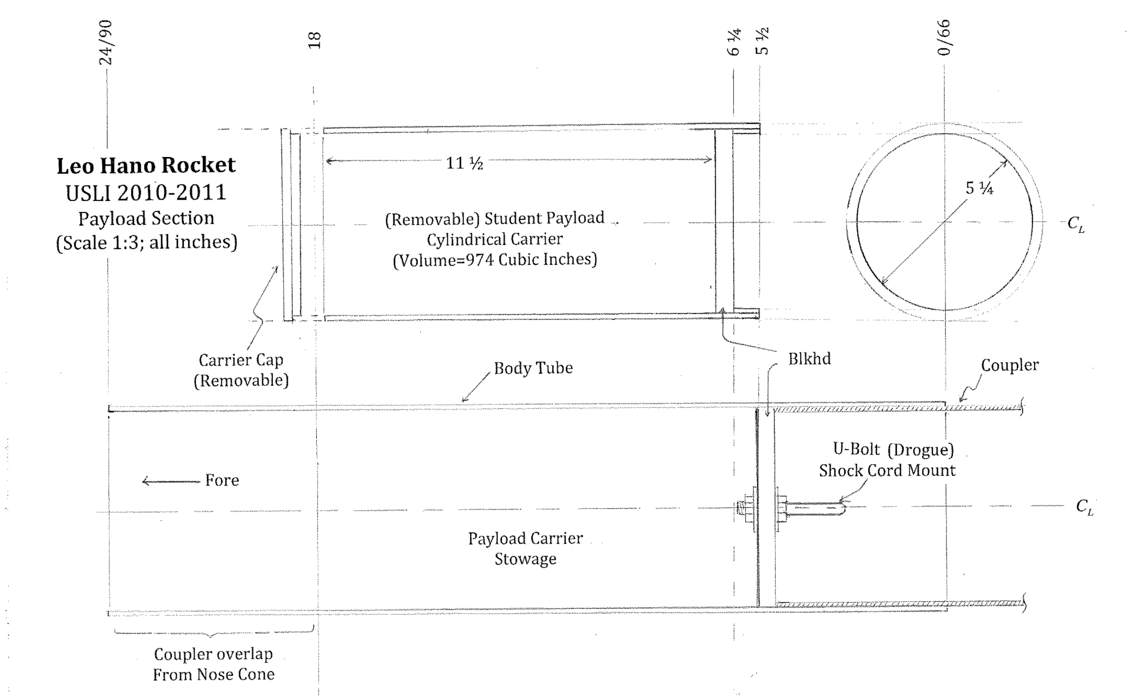
The wiring of the avionics electronic flight controllers was straight forward, and a block diagram follows:



Our deployment tests have shown that the drogue deployment pyro should consist of 4 g of black powder, and the main chute deployment pyro should consist of 5.5 g of black powder.

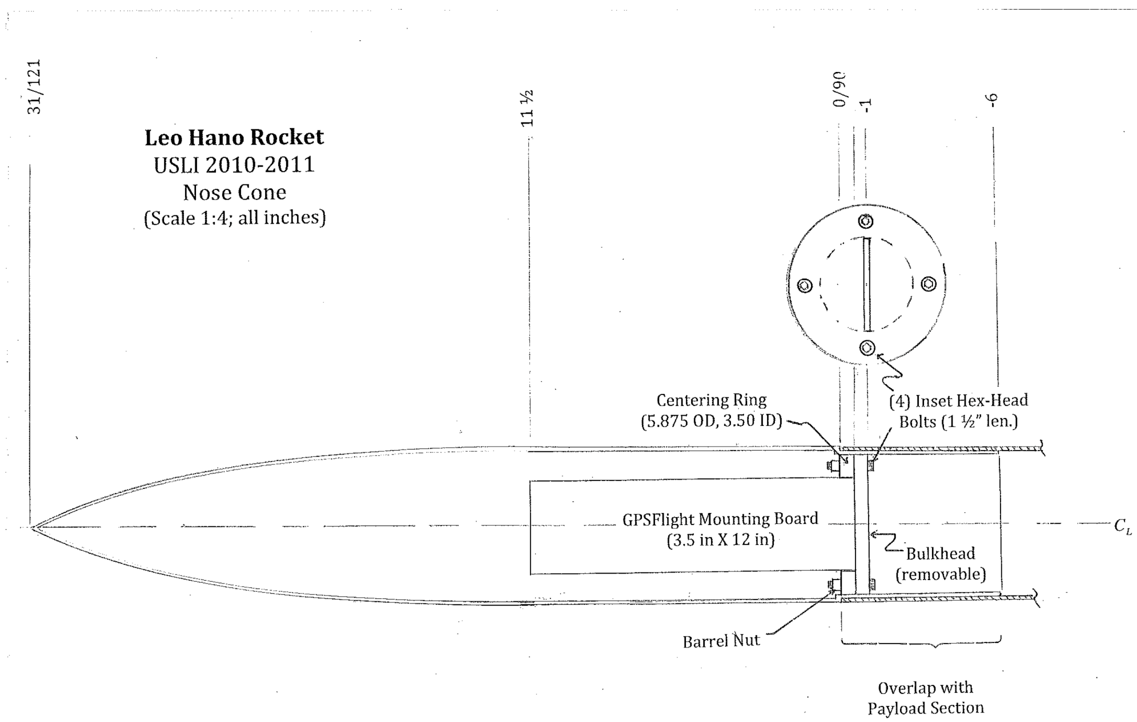
Payload section

The primary purpose of this section (and indeed for the entire rocket) is to carry the student payload carrier. The carrier, with its lid, would be given to the students prior to the launch date. On the launch date, the students would return the carrier (with their experiment in it) to the rocket preparation crew, who would then integrate it into the rocket. Once the student payload carrier is inserted into this section, the nose section would then be duct tape (which are not shown). For the USLI launch, the Hula Hoop project will be contained within the carrier. This section consists of a 24" long tube, of the same material as the booster section, with a circular ½ " thick plywood bulkhead epoxied into it. This section is attached to the rest of the rocket by a shock cord, which is mounted to the bulkhead via a U-Bolt, which is the only change made to the design. The shock cord is also attached to the avionics section, and is where the drogue chute would be attached. The payload section is then mated to the top of the avionics section, and held there using two 4-40 X ½ inch nylon screws, which act as shear pins for our rocket.



Nosecone

The nosecone is a standard 1:4.25 ratio ogive, having an outer diameter of 6", a shoulder length of 6", and made of fiberglass. A plywood centering ring, having a 3.5" inner diameter hole, was made to fit just inside the shoulder of the nose cone, and permanently epoxied in place. A circular plywood bulkhead, having a 3.5" X 12" electronic mounting board epoxied perpendicular to its surface, is attached to the fixed centering ring via 4 hex-head bolts and accompanying barrel nuts (the barrel nuts are epoxied in place on the inside of the centering ring). This allows the removal, preparation, and installation of the GPSFlight transceiver assembly required for the tracking of our rocket.



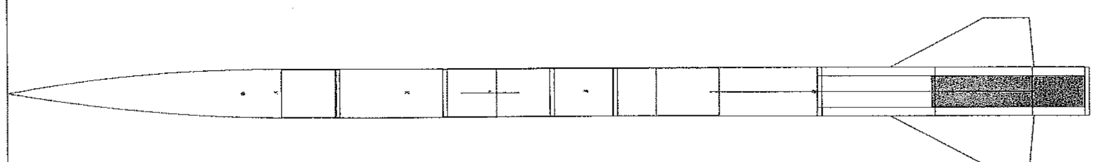
Recovery Subsystem

Our rocket will be using a duel deployment recovery system. At apogee, a 42-inch drogue chute will be deployed, yielding an initial descent speed of ~ 80ft/s. At an altitude of 1100 ft, a 144-inch main chute will be deployed, slowing the rocket descent rate to 22 ft/s, which we believe to be a safe descent rate.

Our main parachutes will be attached via quick links to a shock cord, which is attached to a U-bolt on the bottom of the avionics section. Our drogue parachute will be attached via quick link to the U-bolt to the base of the payload section.

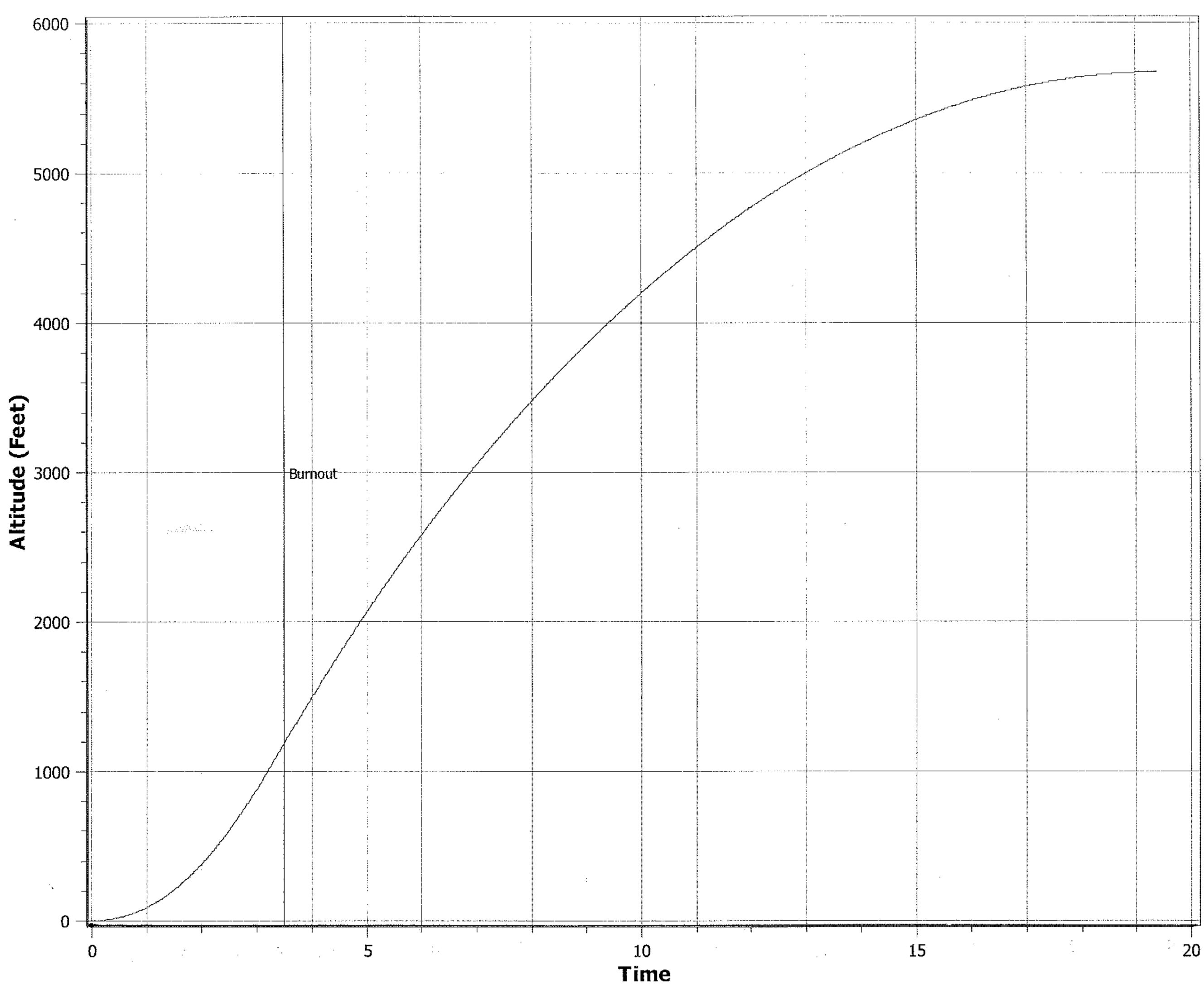
Mission Performance Predictions

USLIROC2011
Length: 121.1250 In. , Diameter: 6.0000 In. , Span diameter: 18.1250 In.
Mass 732.2769 Oz. , Selected stage mass 732.2769 Oz. (User specified)
CG: 26.3317 In., CP: 90.2507 In., Margin: 10.65 Overstable
Engines: [L1300R-None,]

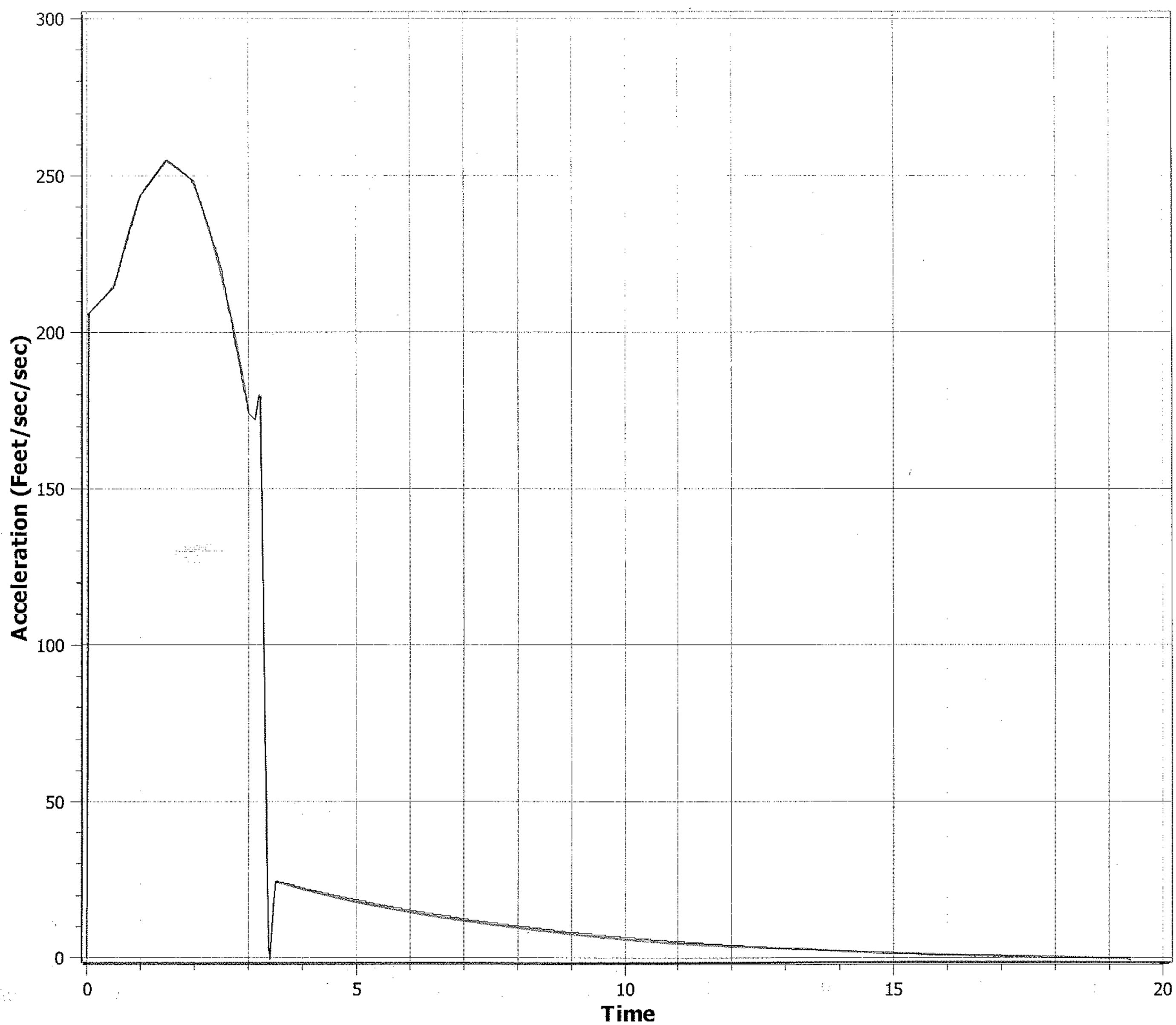


Mission Performance Predictions (Flight Simulations)

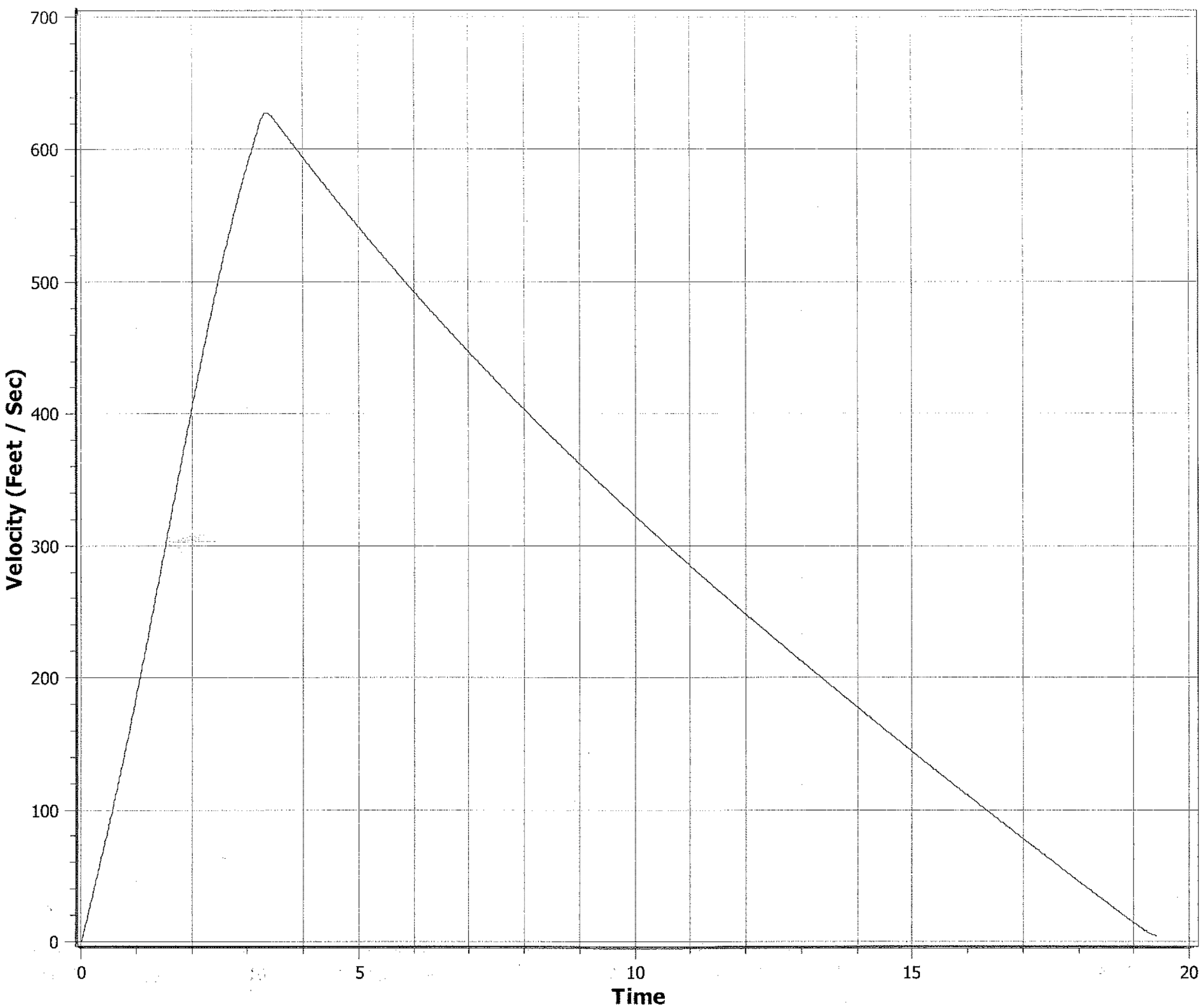
Altitude Vs Time (Till Apogee)



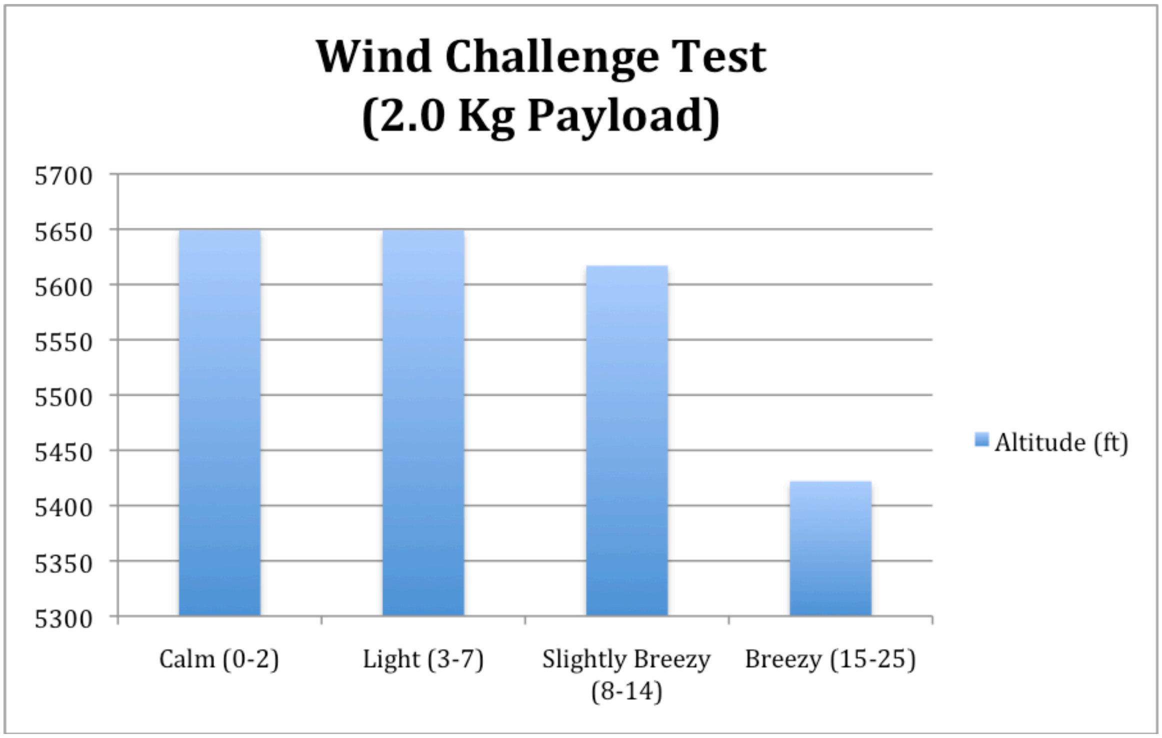
Acceleration Vs Time

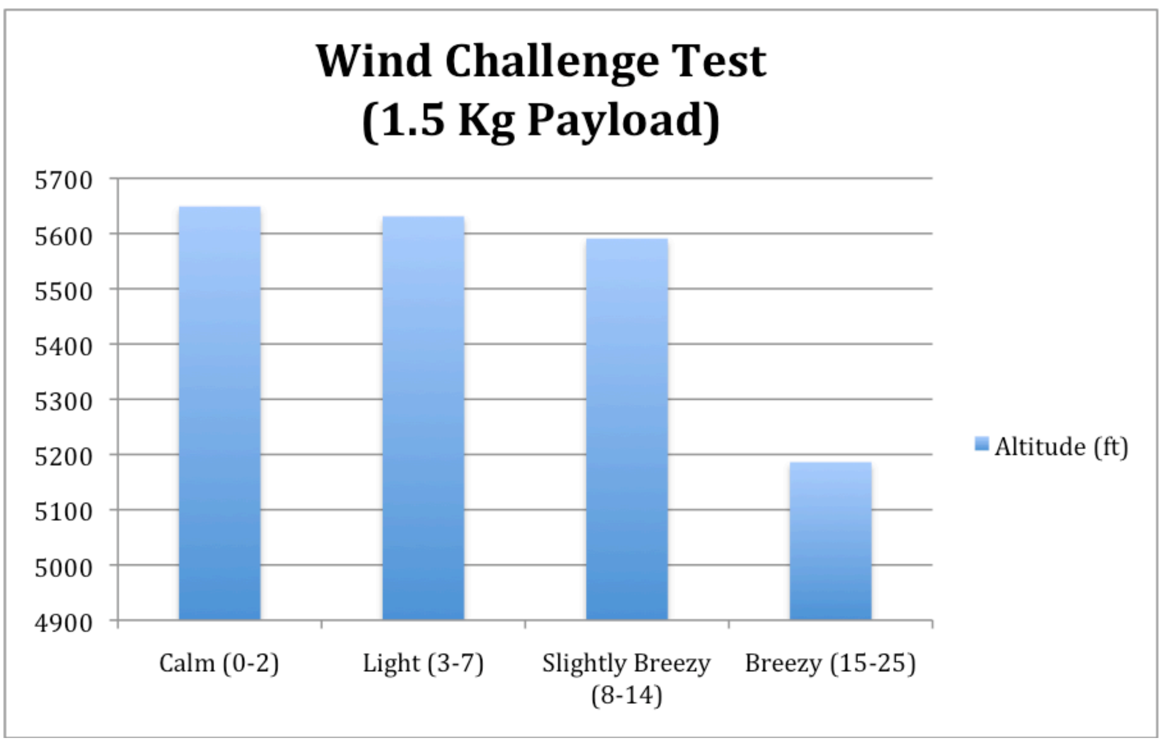


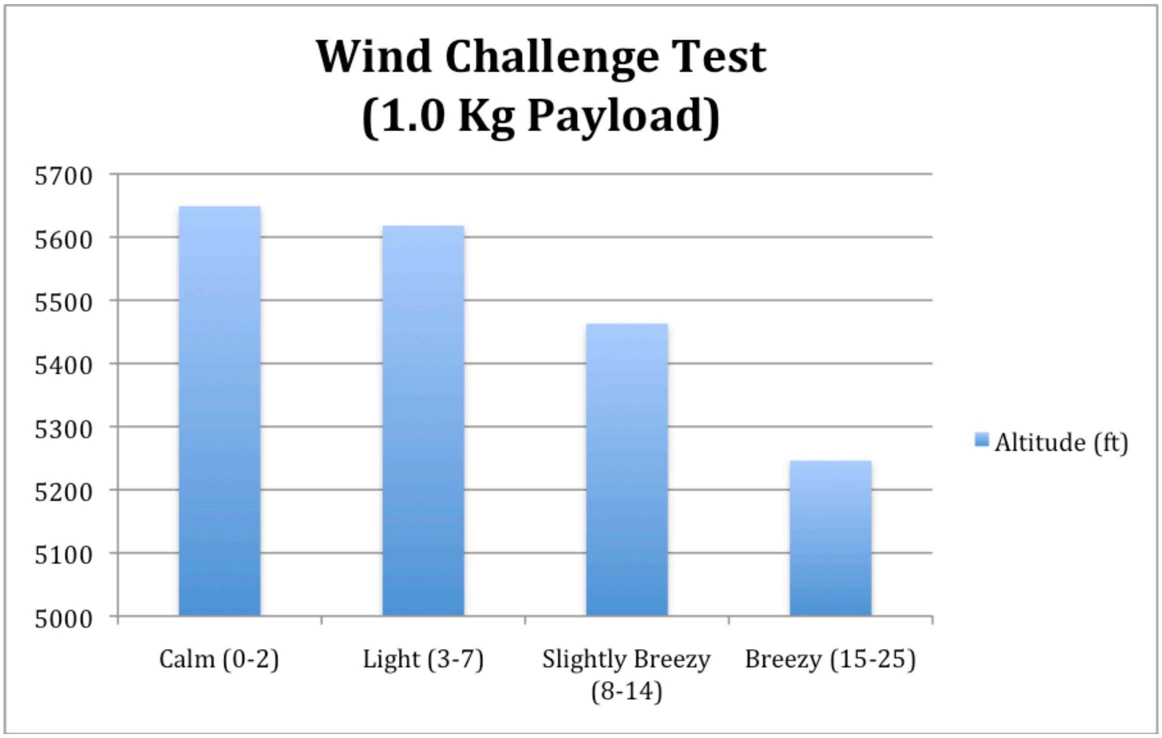
Velocity Vs Time



Wind and Mass Challenge Tests






Wind Challenge Test
(1.0 Kg Payload)
5700
5600
5500
5400
5300
5200
5100
5000
Calm (0-2)
Light (3-7)
Slightly Breezy (8-14)
Breezy (15-25)
Altitude (ft)

Estimate of the Center of Gravity and Stability Margin
Since the RocSim component weights became suspect, it was necessary to make an estimate of the Center of Gravity, as well as the Stability Margin. That calculation is straight forward and follows…

Component	Wt (oz)	Est. CG (in)	$(Wt.)r$
Nose Cone	38	24	912
GPSFlight	50	24	1200
Payload Tube	40	43	1720
Bulkhead	5	37	185
Experiment	50 (var.)	43	2150
Drogue	8	51	408
Bulkhead	5	49	245
Coupler	20	55	1100
Avionics Tube	30	64	1920
Bulkhead	5	61	305
AV Al Can	16	65	1040
Avionics	35	65	2275
Bulkhead	5	68	340
Coupler	20	74	1480
Booster Tube	80	97	7760
Motor Mount	50	106	5300
Cen. Ring	3	91	273
Main	20	83	1660
Fin/Fin-can	60	109	6540
VDC Assembly	10	119	1190
Cen. Ring	3	120	360
Motor Retainer	5	120	600
L1300R Motor	161	113	18193
	$\sum(Wt.) = 719$ oz.		$\sum(Wt.)r$ = 57,156 oz-in

Therefore: $CG = \dfrac{\sum(Wt.)r}{\sum(Wt.)} = \dfrac{57{,}156}{719}$ = 79.49 inches from the nose cone tip.

Since the Center of Pressure has been calculated to be 90.25 inches, our stability margin is…

$$\text{Margin } = \frac{|90.25 - 79.49|}{6.00} = \frac{10.76}{6.00} = 1.79$$

This indicates that our rocket will be stable, with a thrust to weight ratio of <u>6.49</u>.

Full-Scale Low-Power (FSLP) Attempts

Successful completion of the USLI project requires that a Full-Scale Low-Powered fight test (i.e. a Prototype test) be performed. Timing for the test is contingent upon Kaneohe Marine Corps Air Station (KMCAS). The main reason for this is because KMCAS is the only facility with a large enough infrastructure for us to perform a test of this magnitude. This means that the safety of our prelaunch, flight, and recovery are of the highest priority. To have a successful mission the team must ensure that all safety requirements are maintained throughout the mission. The team must also meet all the following criteria below.

FSLP Mission Criteria:

- Motor functions properly
- Avionics functions properly
- Successful recovery of the rocket and all its components
- Both parachutes deployed
- The rocket is completely intact
- The appropriate levels of safety are maintained throughout the entire process of preparation, launch, flight, and recovery of the rocket

To achieve any type of success in the mission, the rocket must have deployed a parachute and must be intact upon recovery, meaning it has the ability to be considered flight ready and meets all safety requirements without any repairs done it. If the team does not have a parachute deployment and the rocket is not intact upon recovery, the mission will be considered a failure. For FSLP, there is no partial success.

Proper motor selection requires several considerations, a suitable thrust to weight ratio, and a predicted maximum altitude that is above 1200 feet in order for the dual deployment test to work. Our limited recovery field directs that we cannot go too far over this height. Furthermore, the military cedes control of its air space over to the FAA on the days they open it up to civilian operations. As such, we must keep our flight to below 2500 feet.

In general, the FSLP flight profile that our rocket would follow is the standard dual deployment routine, and has been simulated (under various launch conditions) on RockSim. The flight would begin with the boost phase. The motor would have a burn time of 2 to 4 seconds depending on motor selection. The maximum estimated acceleration is ~ 10 g's, with an average of ~4 g's. At motor burnout, the rocket then enters its coast phase. We expected the rocket to reach apogee ~12 to 13 seconds after launch. At apogee, a 42-inch drogue chute would be deployed, yielding an initial descent speed of ~ 82 ft/s. At an altitude of 1000 ft, a 144-inch main chute would then be deployed, slowing the rocket descent rate of 22 ft/s, which we believe is a safe descent rate. The total flight duration was expected to be ~60 to 100 seconds depending on wind and drift.

Our first attempt was made on March 13 using an Aerotech K780R which was to give us a maximum height of 1960 feet, well within our flight constraints. Our only concern was that the thrust to weight ratio was only about 5.2 at maximum, and 4.2 on average, which is marginal. The flight was stable to apogee, whereupon the drogue chute was deployed. The rocket then descended at ~80 ft/s, and a main event was observed, but the main chute was never deployed. Impact with the ground was at sufficient speed to disconnect the Featherweight Raven flight controller. However, data from the PerfectFlight MAWD indicated that the rocket reached a maximum altitude of 1591 feet. Since we are flying on an abandoned airfield, which is adjacent to the main airfield, the rocket lands on a solid surface and damage could be considerable. That being said, the rocket did suffered some damage to the booster section but no where near as bad as it could have been; the aft centering ring, as well as the motor mount tube, had to be replaced.

Subsequent analysis of the rocket showed that several things could be blamed on the main chute failing to deploy. During preparation for the flight, it was found that the leads for the main chute pyros had been cut too short. As such, placement of the main chute pyros was not against the Motor Mount Retaining Cap as planned, but instead against the side of the booster body tube. We believe that when the main chute was then packed, the e-match heads were pulled out of the main pyro containers holding the black-powder charges. We believe that the avionics worked as expected, deployment altitudes were set for 900 feet and 700 feet, roughly a second apart in descent. It was observed that the main did separate, which shows that there was an event consistent with a partial burning of the pyro-charge, but not enough to toss the chute. This is supported by two facts; (1) the e-matches had both been burned, and (2) the unburned pyro-charges were later recovered and showed a majority of the black-powder remaining. Because of this, the pyrotechnic charge construction was re-designed to prevent future ‘pull-throughs’. Originally, Pyrex test tubes were used to hold the main charges; the e-match was inserted into the test tube, pre-measured black powder was then poured into the tube, chute wadding was then used to tamp the powder down, and the open end of the tube was then covered in masking tape. With sufficient force the e-match head could be pulled through the masking tape (and taking with it some of the chute wadding and black powder). The redesign involved drilling a small hole in the bottom of the tube, the e-match lead was then inserted into the tube, and then pulled through the hole. A layer of tape around the base of the match head insures that the e-match cannot be pulled through the hole. Pre-measured black powder was then poured into the tube, wadding is then used to insure that the powder does not separate from the match head, and the whole thing is then taped.

Another possible problem may have been with the timing for the chute deployment. It was thought that maybe with sufficient time the chute would have deployed. With a descent speed of ~80 ft/s, and a deployment altitude of 900 ft, this gives ~11 seconds for the chute to get out, unfurl, and fully deploy. It was thought that this was not enough time. As such, the avionics were re-configured to deploy at 1100 ft and 1000 ft, which then gives us ~14 seconds of descent time. We did not want to go any longer then this because, if we were given a second chance, we needed to have a clear separation between apogee events and main events so that our avionics (as well as those on the ground) would not get 'confused'.

Following this un-successful attempt, efforts to get a second attempt were initiated. Contact was made with KMCAS, and our request for a second attempt for March 20th was made. Initially it was doubtful because the airfield was planning to launch humanitarian missions to Japan, and as such would not be closed. However, due to re-scheduling, they were able to accommodate us for the morning of our requested date. Obtaining a motor was much more problematic! Our friends at AeroPAC were able to get an Aerotech K1000T motor out to us in (an unheard of) three days.

Our second attempt was made one week later. Concern was about the wind, which was 12 to 19 mph from the southeast. The rocket rose vertically for ~40 feet and then slightly weather-cocked into the wind. Thereafter the rocket rose to an altitude of ~1200 feet (based on RocSim estimates for this wind interval), deployed its drogue, and a short time later deployed its main chute. This is what was expected. The wind, however, played havoc with our recovery. The rocket was carried out over the ocean, and came down in the middle of Kaneohe bay. With the chute deployed and the high wind, it immediately began kite surfing away from shore! We had to have the Navy rescue our rocket. The problem is that the salt water got into the avionics bay and corroded all the electronics. We were not able to recover flight data, and the avionics will have to be replaced.

In both FSLP tests, the rocket was shown to be stable at lift-off, through out its flight, and the avionics worked. We believe that we have constructed a safe rocket.

Video of the 1st FSLP can be found on Helen Rapozo's Youtube page. Other video's concerning USLI can be found there as well.

FSLP Test #1
http://www.youtube.com/user/hrapozo#p/u/4/SYUycPKp41A

FSLP Test #2
http://www.youtube.com/user/hrapozo#p/u/2/rvUXiK0EMnw

FSLP Simulation results for 3/13/2011

Engine selection
[K780R-None]

Simulation control parameters
- Flight resolution: 800.000000 samples/second
- Descent resolution: 1.000000 samples/second
- Method: Explicit Euler
- End the simulation when the rocket reaches the ground.

Launch conditions
- Altitude: 0.00000 Ft.
- Relative humidity: 50.000 %
- Temperature: 80.000 Deg. F
- Pressure: 29.9139 In.
  Wind speed model: Light (3-7 MPH)
  - Low wind speed: 3.0000 MPH
  - High wind speed: 7.9000 MPH

  Wind turbulence: Fairly constant speed (0.01)
  - Frequency: 0.01000 rad/second
- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.000 Deg.
- Latitude: 22.000 Degrees

Launch guide data:
- Launch guide length: 144.00000 In.
- Velocity at launch guide departure: 53.5867 ft/s
- The launch guide was cleared at: 0.559 Seconds
- The user specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 100.4338 In.

Max data values:
- Maximum acceleration: Vertical (y): 344.468 Ft./s/s Horizontal (x): 0.508 Ft./s/s Magnitude: 344.468 Ft./s/s
- Maximum velocity: Vertical (y): 324.4643 ft/s, Horizontal (x): 6.2505 ft/s, Magnitude: 325.2313 ft/s
- Maximum range from launch site: 208.87743 Ft.
- Maximum altitude: 1960.39075 Ft.

Recovery system data

- P: Drogue Deployed at: 12.295 Seconds
- Velocity at deployment: 20.0897 ft/s
- Altitude at deployment: 1960.39071 Ft.
- Range at deployment: -208.87743 Ft.
- P: Main Parachute Deployed at: 25.906 Seconds
- Velocity at deployment: 81.3824 ft/s
- Altitude at deployment: 999.92078 Ft.
- Range at deployment: - 126.63283 Ft.

Time data

- Time to burnout: 3.064 Sec.
- Time to apogee: 12.295 Sec.
- Optimal ejection delay: 9.231 Sec.

Landing data

- Successful landing
- Time to landing: 61.296 Sec.
- Range at landing: 63.80652 Ft.
- Velocity at landing: Vertical: -28.1473 ft/s, Horizontal: 4.9767 ft/s, Magnitude: 28.5839 ft/s

Competition settings

Competition conditions are not in use for this simulation.

FSLP – Simulation results for 3/20/2011

Engine selection
[K1000T-P-None] - It must be noted that this motor is not on our standard data table for motors. Our friends at AeroPAC ran this simulation for us using their data file.

Simulation control parameters
- Flight resolution: 800.000000 samples/second
- Descent resolution: 1.000000 samples/second
- Method: Explicit Euler
- End the simulation when the rocket reaches the ground.

Launch conditions
- Altitude: 0.00000 Ft.
- Relative humidity: 50.000 %
- Temperature: 80.000 Deg. F
- Pressure: 29.9139 In.

  Wind speed model: slightly Breezy (15-25 MPH)
  - Low wind speed: 15.0000 MPH
  - High wind speed: 25.0000 MPH

  Wind turbulence: Fairly constant speed (0.01)
  - Frequency: 0.01000 rad/second
- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.000 Deg.
- Latitude: 22.000 Degrees

Launch guide data:
- Launch guide length: 144.00000 In.
- Velocity at launch guide departure: 70.0008 ft/s
- The launch guide was cleared at: 0.327 Seconds
- The user specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 55.8717 In.

Max data values:
- Maximum acceleration: Vertical (y): 335.993 Ft./s/s Horizontal (x): 5.666 Ft./s/s Magnitude: 336.041 Ft./s/s
- Maximum velocity: Vertical (y): 370.468 ft/s, Horizontal (x): 20.396 ft/s, Magnitude: 371.029 ft/s
- Maximum range from launch site: 1567.19636 Ft.
- Maximum altitude: 1155.89953 Ft.

Recovery system data

- P: Drogue Deployed at: 12.295 Seconds
- Velocity at deployment: 20.3961 ft/s
- Altitude at deployment: 1155.89953 Ft.
- Range at deployment: -208.87743 Ft.
- P: Main Parachute Deployed at: 15.906 Seconds
- Velocity at deployment: 81.3824 ft/s
- Altitude at deployment: 1099.92078 Ft.
- Range at deployment: - 126.63283 Ft.

Time data

- Time to burnout: 3.640 Sec.
- Time to apogee: 12.295 Sec.
- Optimal ejection delay: 9.231 Sec.

Landing data

- Successful landing
- Time to landing: 72.872 Sec.
- Range at landing: 1567.19636 Ft.
- Velocity at landing: Vertical: -22.6034 ft/s, Horizontal: 26.6759 ft/s, Magnitude: 34.9645 ft/s

Competition settings

Competition conditions are not in use for this simulation.

Safety and Environment (Vehicle)

Material Safety Data Sheets (MSDS)

Because of the large size of the MSDS Section a separate link on our download webpage has been devoted specifically to the MSDS section. Please refer to the MSDS link to view the MSDS.

Team Safety

The team's current mentor is Dr. Hudson, who is one of the peer mentors of the Center for Aerospace Education at Windward Community College. He is also a level (3) certified member for both National Association of Rocketry (NAR) and Tripoli Rocket Association (TRA). As the Team Official Dr. Hudson will oversee all launch operations and motor handling. His contact information is provided below: Contact Information: Name - Dr. Hudson Hudson Phone Number – (808) 347-8246 E-mail – jacobh@hawaii.edu

Safety information of all the materials that will be used in this project will be addressed in the Material Safety Data Sheets (MSDS) Section. The team will be following all the NAR/TRA safety protocols. Dr. Hudson, our peer mentor, has briefed students on hazard recognition, accident avoidance, and will be conducting pre-launch briefings.

The CAE WCC USLI team has a level three (3) certified member for both NAR and TRA. It also has three (3) level two (2) certified members of NAR/TRA (Todd, Joleen, and Patrick). These certifications ensure that the team is adequately acquainted with Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C, and also have sufficient knowledge on handling and using low- explosive (Ammonium Perchlorate Rocket Motors, APCP), fire prevention, Code of Federal Regulation Part 55, and NFPA 1127. All noncertified team members have been briefed, are aware, and will abide by all of these laws and regulations. In addition to these rules and regulations the entire team is knowledgeable and compliant of all federal, state, and local laws concerning the use of unmanned rockets and their components. A flight card will be used before each launch. The team's peer mentor, Dr. Hudson, is in charge of purchasing, storage, transport, and use of the rocket motors. Any flammable material will be stored in type 3/4 indoor magazine storage device. The only person with access to this storage device will be Dr. Hudson.

Rocket body Safety and Failure analysis

Failure Mode	Cause	Effects	Risk Mitigation
Loss of fin	Damage in shipping	Loss of stability (though still remaining stable) & aesthetics. Falling debris	Rigorous pre-flight inspection
Loss of Drag shoe	Damage in shipping	Loss of aesthetics, slow torque along z-axis. Falling debris	Rigorous pre-flight inspection
Airframe Failure	Damage to body during shipping or handling of the rocket	Catastrophic loss in stability and falling debris	Suitable packing for shipment of the rocket body, handling with care

Deployment Safety and Failure analysis

Failure Mode	Cause	Effects	Risk Mitigation
Drogue chute deployment failure	Main avionics failure	Rocket craters	Back-up Avionics
Main chute deployment failure	Main avionics failure	Rocket craters	Back-up Avionics
Drogue chute deployment failure	Main and back-up avionics failure	Rocket craters	Checklist for avionics
Main chute deployment failure	Main and back-up avionics failure	Rocket craters	Checklist for avionics
Drogue chute deployment failure	Main pyro failure	Rocket craters	Back-up pyro
Main chute deployment failure	Main and back-up pyro failure	Rocket craters	Checklist for avionics
Separation of sections	Shock cord severed	Falling debris, rocket damage	Checklist, preflight checks, and undamaged shoch cored
Separation of sections	Shock cord anchor points	Falling debris, rocket damage	Checklist, preflight checks

Hazard Mitigation List

In addition to all the mitigation tactics listed below the team will always maintain good hygiene and a clean work environment		
Materials	Risk	Mitigation
Phenolic Powder-Black	Ingestion Hazards, Skin Irritation, Eye Irritation, Respiratory Irritation from Dust	Team members will work in well-ventilated areas and wear face masks at all times to prevent inhalation and ingestion of the dust from the Phenolic Black Powder. Gloves will be worn at all times to prevent skin irritation. Goggles will be worn at all times to prevent eye irritation.
Phenolic Resin	Toxic Fumes, Skin Irritation, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
Copperhead igniter	Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin	Team members will work in well-ventilated areas and wear face masks at all times to prevent inhalation and ingestion of hazardous chemicals. Gloves will be worn at all times to prevent skin irritation and burns to skin. Goggles will be worn at all times to prevent eye irritation. Igniters will be kept away from ignition sources such as flames, matches, and heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition.

FirstFire Igniter	Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin	Team members will work in well-ventilated areas and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of hazardous chemicals. Gloves will be worn at all times to prevent skin irritation and burns to skin. Goggles will be worn at all times to prevent eye irritation. Igniters will be kept away from ignition sources such as flames, matches, and heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition.
FirstFire Jr Igniter	Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin	Team members will work in well-ventilated areas and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of hazardous chemicals. Gloves will be worn at all times to prevent skin irritation and burns to skin. Goggles will be worn at all times to prevent eye irritation. Igniters will be kept away from ignition sources such as flames, matches, and heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition.
Rocket Propellant	Skin Irritation, Inadvertent Ignition, Burns to skin	Gloves will be worn at all times to prevent skin irritation. Propellant will be kept away from ignition sources, such as flames, matches, igniters, heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition. After motor burn, the team will wait 15 minutes before disassembling the motor, while wearing insulated gloves to prevent burns to skin.

Epoxy Resin	Toxic Fumes, Skin Irritation, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
5-Minute Epoxy Resin	Toxic Fumes, Skin Irritation, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
Sinmast 4 Epoxy Mortar Mix - Normal Cure	Ingestion Hazards, Skin Irritation, Eye Irritation	Team Members will wear face masks at all times to prevent ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
Compressed Carbon Fiber Sheets	Inhalation Hazards, Eye Irritation, Skin Irritation	Team Members will wear face masks at all times to prevent inhalation of the material. Goggles will be worn at all times to prevent Eye Irritation. Gloves will be worn at all times to prevent skin irritation
Fiber Glass Cloth	Inhalation Hazards, Eye Irritation, Skin Irritation	Team Members will wear face masks at all times to prevent inhalation of the material. Goggles will be worn at all times to prevent Eye Irritation. Gloves will be worn at all times to prevent skin irritation

Polystyrene	Ingestion Hazards	Team Members will wear face masks at all times to prevent Ingestion of Material
Polystyrene Foam	Ingestion Hazards, Skin Irritation, Eye Irritation	Team Members will wear face masks at all times to prevent Ingestion of Material. Goggles will be worn at all times to prevent eye irritation
Duct Tape	Skin Irritation, Eye Irritation	Team members will avoid prolonged exposure of duct tape to bare skin to prevent skin irritation. Team members will not place duct tape on their eyes to prevent eye irritation
Masking Tape	No Risks Stated	
Super Glue	Toxic Fumes, Ingestion Hazards, Eye Irritation, Skin Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with. Goggles will be worn at all times to prevent eye irritation.
Acetone	Toxic Fumes, Ingestion Hazards, Eye Irritation, Skin Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with. Goggles will be worn at all times to prevent eye irritation.
Mineral Spirits	Severe Eye Irritation, Skin irritation, Ingestion hazards	Team Members will wear face masks at all times to prevent Ingestion of the material. Gloves will be worn at all times to prevent skin irritation. Goggle will be worn at all times to prevent eye irritation

Denatured Alcohol	Toxic Fumes, Ingestion Hazards, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Goggles will be worn at all times to prevent eye irritation
Carbon Dioxide	Inhalation Hazards	Team members will work in a well-ventilated area to prevent inhalation hazards
Silicone Lube	Ingestion Hazards, Skin Irritation, Eye Irritation, Toxic Fumes	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent eye irritation
White Lithium Grease	Ingestion Hazards, Skin Irritation, Eye Irritation, Toxic Fumes	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent eye irritation

Isopropyl Rubbing Alcohol	Toxic Fumes, Ingestionn Hazards, Eye Irritation, Inadvertent Ignition, Burns to Skin	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Goggles will be worn at all times to prevent contact with eyes leading to eye irritation. Material will be kept away from ignition sources, such as flames, matches, igniters, heat sources. Team members will wear gloves to protect from burns to skin in the event of an inadvertent ignition
Black Powder	Inhalation Hazards, Eye Irritation, Inadvertent Ignition, Burns to skin	Team Members will wear face masks at all times to prevent Inhalation of the Black Powder. The Black Powder will be kept away from ignition sources such as flames, matches, and heat source to prevent inadvertent ignition. Gloves will be worn to prevent burns to skin. Goggles will be worn at all times to protect eyes. Equipment used with or near the Black Powder will be nonstatic producing materials to prevent inadvertent ignition.

Environmental concerns (Vehicle)

If the rocket goes through its entire flight as planned, we believe that as long as the immediate launch area contains no objects that hold the potential of starting a fire (caused by the rocket motor ignition and takeoff phase) that the rocket contains no credible risks to the environment.

IV) Payload

Payload Integration

The Hula-hoop payload project will be placed in our payload carrier. The payload carrier will be sealed and placed in the payload section of the rocket. The nose cone will then be sealed to the payload section.

Payload Theory and Challenge

Is it possible to determine the rocket orientation, at any given instant in its flight path, by studying the induced voltage produced by the interaction of the Earth's magnetic field and three mutually perpendicular coils. The Faraday law of Electromagnetic Induction predicts that this should be so, and our experiment is to test this. If this is successful, there are several applications possible. By integrating this unit into a proper feedback network, a rocket stability system could be implemented.

The payload will consist of three mutually perpendicular coils wrapped around a nonmagnetic sphere – the hoops of Hula-hoop. Each coil will be in parallel to a resistor. Voltages read across the resistors will then be input into an Analog-to-Digital Converter (ADC) and those values will then be stored to an EEPROM unit. Additionally, there will be an on board accelerometer from which a comparative study can be made. Another two channels of the ADC will accept input from a temperature sensor (for in-situ temperature readings), and a barometric sensor (for altitude comparisons).

Theory

As was discussed in the Preliminary Design Review, the theory of the payload project begins with the Faraday law of induction: An induced electromotive force (E) is directly proportional to the product of the number of loops in a coil (N) and how quickly the magnetic field (Φ_B) is changing within the coil.

$$E = -N\frac{d\Phi_B}{dt} = -N\frac{d}{dt}\int_S \vec{B} \bullet d\vec{A}$$

Assuming that the Earth's ambient magnetic field is similar to that of a magnetic dipole, then the horizontal component (B_H), and the vertical component (B_V), of the field can be expressed as:

$$B_H = \frac{\mu\mu_o}{4\pi r^3}\cos\lambda_m$$

$$B_V = \frac{\mu\mu_o}{2\pi r^3}\sin\lambda_m$$

Where $\mu = 8\times 10^{22} J/T$ is the Earth's magnetic dipole moment, $\mu_o = 4\pi\times 10^{-7} Tm/A$ is the magnetic permeability constant, $\lambda_m = 22.56^o$ is the magnetic latitude of Huntsville (this is based on the latitude of Huntsville being given by $\lambda = 34.06^o$ combined with the 11.5^o offset between the rotational north pole and the magnetic north pole), and $r = R_E = 6.4\times 10^6 m$ is the radius of the Earth. These two expressions can be combined together…

$$B = \frac{\mu\mu_o}{4\pi r^3}\sqrt{1+3\sin^2\lambda_m} = \frac{\left(8\times 10^{22} J/T\right)\left(4\pi\times 10^{-7} Tm/A\right)}{4\pi\left(6.4\times 10^6 m\right)^3}\sqrt{1+3\sin^2 22.56^o} = 36.6\mu T$$

…to determine an approximate magnetic field intensity at Huntsville's latitude.

To determine a rough gauge estimate of the induced voltages involved, we shall assume a coil initially aligned with its area parallel to the Earth's surface. Our coil is to be placed within our rocket, and it is the motion of the rocket that will cause the magnetic field within the coil to change. If at some time during the rocket flight, the area normal vector has an angle ϕ with respect to the vertical, then the induced electromotive force at any instant of time is given by…

$$E = -N\frac{d}{dt}\left(BA\cos\phi\right) = -NA\left(\frac{dB}{dt}\cos\phi - B\sin\phi\frac{d\phi}{dt}\right)$$

Using the chain rule on the left hand term in the in the parenthesis…

$$\frac{dB}{dt} = \frac{dB}{dz}\frac{dz}{dt} = \frac{dB}{dt}v_z = v_z\frac{dB}{dz}$$

…where v_z is the ascent rate of the rocket. The above then reduces the equation for the induced electromotive force to:

$$E = -NA\left(v_z\frac{dB}{dz}\cos\phi - B\sin\phi\frac{d\phi}{dt}\right) = -NA\left(v_z\frac{dB_\perp}{dz} - B_{11}\frac{d\phi}{dt}\right)$$

Where $B_\perp$ is the component of the magnetic field perpendicular to the plane of the coil area, and B_{11} is the component of the magnetic field that is parallel to the plane of the coil area. From this result, we can see that the induce electromotive force will be determined by two terms; a kinetic term ($\sim v_z dB_\perp/dz$), and a pitch-over term ($\sim B_{11}d\phi/dt$). The kinetic term is greatest when the rocket attains its maximum velocity, and as such, is often referred to (by our group) as the ascension term. The pitch-over term corresponds to the rocket orientation going from essentially a vertical alignment to one that is parallel to the Earth's surface (as one would expect at apogee), as such it is often referred to as the apogee term.

Our rocket diameter is 6 inches, and assuming this to be the maximum diameter of our coil, the Area is given by $A = \pi r^2 = \pi(0.027m)^2 = 0.0163m^2$. Given an ascent speed of 600 m/s, the induced electromotive force for the ascent term is then approximated to be…

$$E_{Ascent} = -NAv_z \frac{dB_\perp}{dz} = -NAv_z \frac{d}{dz}\left(\frac{\mu\mu_o}{2\pi(R_E + z)^3}\sin\lambda_m\right)$$

$$\approx 6NAv_z\left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\frac{\sin\lambda_m}{R_E}$$

$$\approx 6N\left(0.027m^2\right)\left(600\frac{m}{s}\right)\left(3.06\times10^{-5}T\right)\frac{\sin 22.56^o}{\left(6.4\times10^6 m\right)}$$

$$\approx N\left(1.78\times10^{-10}V\right) \approx 17.8nV$$

…for a coil of 100 turns.

The apogee term can be simply approximated by assuming a constant change from a vertical arrangement to a parallel arrangement, over a time interval.

$$E_{Apogee} \approx -NA\frac{\Delta B}{t} = -NA\frac{|B_{11} - B_\perp|}{t}$$

Using the magnetic component results expressed at the beginning of this section…

$$B_{11} = B_H = \left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\cos\lambda_m = \left(3.05\times10^{-5}T\right)\cos 22.56^o = 28.2\mu T$$

$$B_\perp = B_V = \left(\frac{\mu\mu_o}{2\pi R_E^3}\right)\sin\lambda_m = 2\left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\sin\lambda_m = 2\left(3.05\times10^{-5}T\right)\sin 22.56^o \approx 23.4\mu T$$

…a coil of 100 turns, and an approximate pitch-over time of ~3s, yields our induced voltage estimation:

$$E_{Apogee} = N\left(0.0163m^2\right)\frac{|28.2\mu T - 23.4\mu T|}{3s}$$
$$= N\left(2.61\times 10^{-8}V\right) \approx 2.6\mu V$$

We estimate that the induced voltage at apogee and its corresponding pitch-over to be roughly 150 times the induced voltage due to ascent. These results can be compared to the estimated induced voltages calculated for Hawaii (~12.5nV on ascent, and ~3.9mV at apogee) to show that they are comparable, and that the induced voltage fluctuations from a reference voltage will be very tiny.

Challenge

The challenge for this experiment, as is clear from the previous section, is that due to the small value of the Earth's ambient magnetic field, the induced voltages are correspondingly even smaller. As such the choice of ADC must be such that its resolution can detect small changes. Another problem that arises is that Lenz's law was ignored throughout the entire theory discussion. Lenz's law states that the induced current, in our coil, will oppose the change that initiated its induction in the first place. As such, we should be getting positive and negative voltages, when the ADC will only acknowledge a positive voltage. To this end, it will be necessary to have a voltage offset (in addition to a standard reference voltage), and then to look for variation with respect to that offset voltage.

Answering the Challenge

Initially the Hula-hoop project was thought to consist of two separate electronic projects dubbed Hula-hoop 1 and Hula-hoop 2, but (as it turned out) a third project was needed which will be called Hula-hoop 3. All three projects will be 'measure and store' missions.

Hula-hoop 1 would be the simplest of the three projects; it will be designed to fit into an Estes-Cox Corporation BT-60 (inside diameter of 1.6 inches) type model rocket. This will allow *in-situ* testing of the prototype electronics on the limited size grounds of Windward Community College. This unit will be testing the bread-board of the electronics ADC infrastructure, the microcontroller, and data storage. Construction of this unit is on-going, with the first flight testing to coincide with our regularly scheduled launch on Feb. 15th.

Hula-hoop 2 will also be a slightly more project as well, in so far as it will be flown on a longer BT-60 model rocket, or on a wider BT-80 (inside diameter of 2.56 inches) model rocket. This unit consisting of a single axis magnetic coil assembly will test the sensitivity of our ADC, as well as accelerometer data. It is planned to have this unit available for testing at our scheduled Full-Scale Low-Powered (FSLP) prototype test on March 13th.

Hula-hoop 3 would have been the actual payload flown for the USLI 2011 event, having three magnetic axis, more storage and sensors. However the plan has changed to flying Hula-hoop 2 at Huntsville. There are more details on this in the following sections.

The key to this project is in the use of analog sensors and analog to digital converters (ADC) - which we, as a group, have very little experience with.

Analog to Digital Converters

In general, an Analog to Digital Converter's (ADC) sensitivity is a function of that device's Voltage Reference sometimes referred as V_{REF} and the number of bits it uses to report its detected voltage. This function can be represented as:

$$\text{Sensitivity} = \frac{V_{REF}}{2^{n_{Bits}}}$$

Hula-hoop 1

Major Parts List:

- Parallax Basic Stamp 2pe – controller and EEPROM storage
- Microchip Technology MCP3202 – ADC
- National Semiconductor LM34 – temperature sensor

The reason for choosing these parts is that we already have these parts on hand.

The Parallax Basic Stamp 2pe has 16 Kbytes of EEPROM storage, enough for a 5 to 10 minute flight window.

The MCP3202 is a 12-bit ADC, which will be able to detect a voltage change of 1.22 mV (or 1.22 x 10-3 volts), provided that the maximum voltage is at 5 volts (5 volts/2^{12}). While this is too big a step for the Hula-hoop coil (which is in the nV, or 10-9 volt range) the project has merit in gaining experience with using an ADC, analog sensors and building electronic circuits.

Hula-hoop 2

Major Parts List (original):

- Parallax Basic Stamp 2p – controller
- National Semiconductor LM34 – temperature sensor
- Microchip Technology MCP3202 – ADC
- Analog Devices AD7714YNZ - ADC
- Freescale Semiconductor/Parallax MMA7455 – accelerometer

- Hula-hoop coil

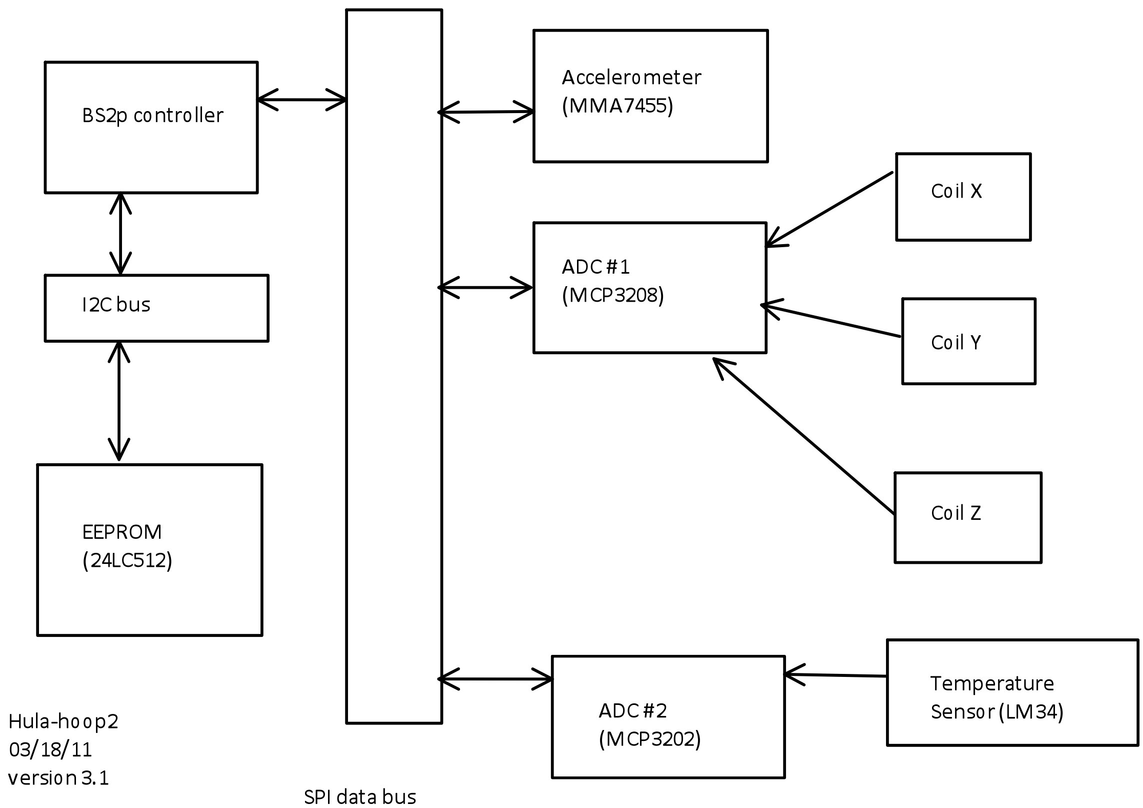
Major Parts List (as of Feb/March 2011):

- Parallax Basic Stamp 2p – controller
- Microchip Technology 24LC512 - EEPROM
- National Semiconductor LM34 – temperature sensor
- Microchip Technology MCP3202 – ADC
- Microchip Technology MCP3208 – ADC
- Freescale Semiconductor/Parallax MMA7455 – accelerometer
- Hula-hoop coil

Originally we had planned to use the Analog Devices Inc. AD7714YNZ which is a 24-bit ADC, we have since replaced that with the Microchip Technology MCP3208 ADC which is a 12 bit ADC. The reason we had to make this change is that our programmers found the AD7714YNZ very hard to use due to the device required understanding of analog electronics which the group had no prior knowledge of it.

The reason for the temperature sensor is to verify that the ADC is actually connected up properly.

The initial project was meant to measure the change in the magnetic field in one axis but the hardware and software were done to record changes in the magnetic field in two axis. There is enough support in terms of available ADC channels and EEPROM storage to record changes in the magnetic field in three axis, and this is what we will be doing during the mission in Huntsville.



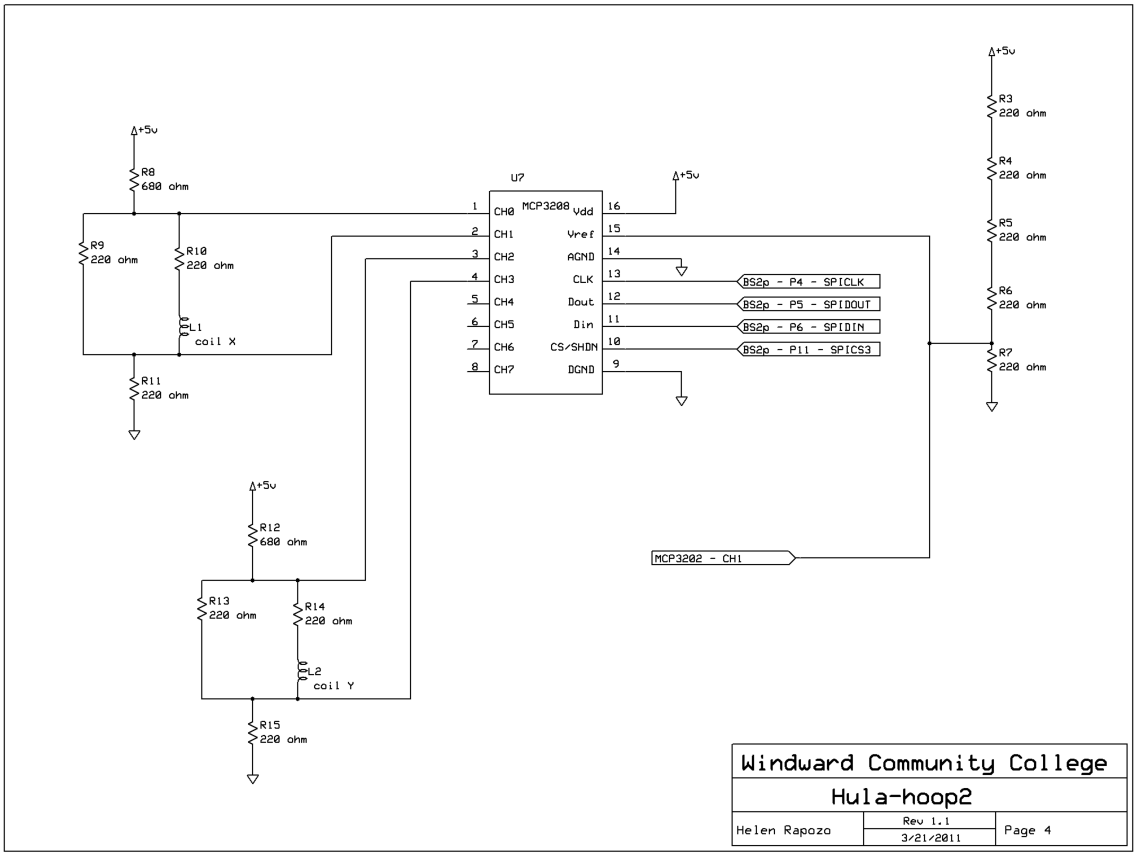
Hula-hoop 3

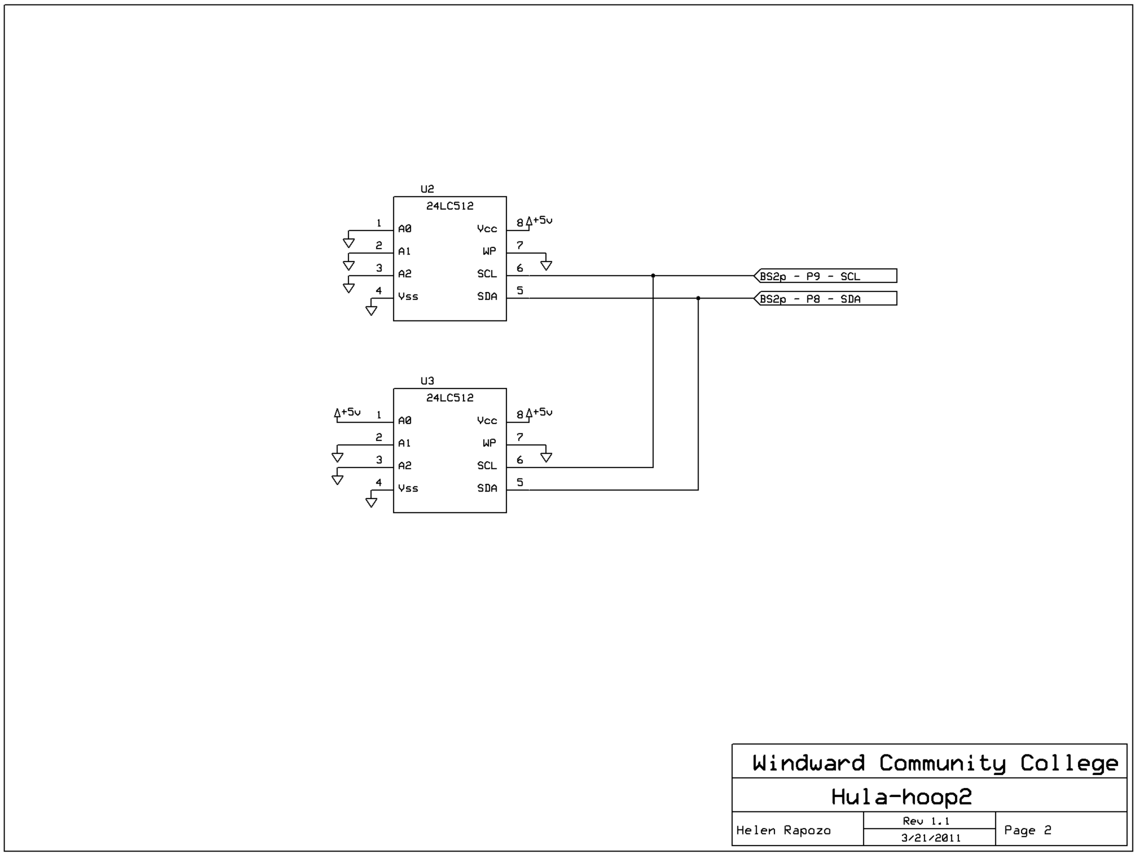
Major Parts List:

- Parallax Basic Stamp2p – controller
- Microchip Technology 24LC512 – EEPROM storage
- Analog Devices Inc AD7714YNZ – ADC
- National Semiconductor LM34 – temperature sensor
- Microchip Technology MCP3202 – ADC
- Freescale Semiconductor MMA7455 – accelerometer
- Hula-hoop coil/Flux-Ball

Originally this project was to be flown for the USLI 2011 but due to time limitations we will not doing this project for Huntsville.

Hula-Hoop 2 Schematic
Diagram




U2
24LC512
A0
A1
A2
Vss
Vcc
WP
SCL
SDA
+5v
BS2p - P9 - SCL
BS2p - P8 - SDA
U3
24LC512
A0
A1
A2
Vss
Vcc
WP
SCL
SDA
+5v
+5v
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Hula-hoop2
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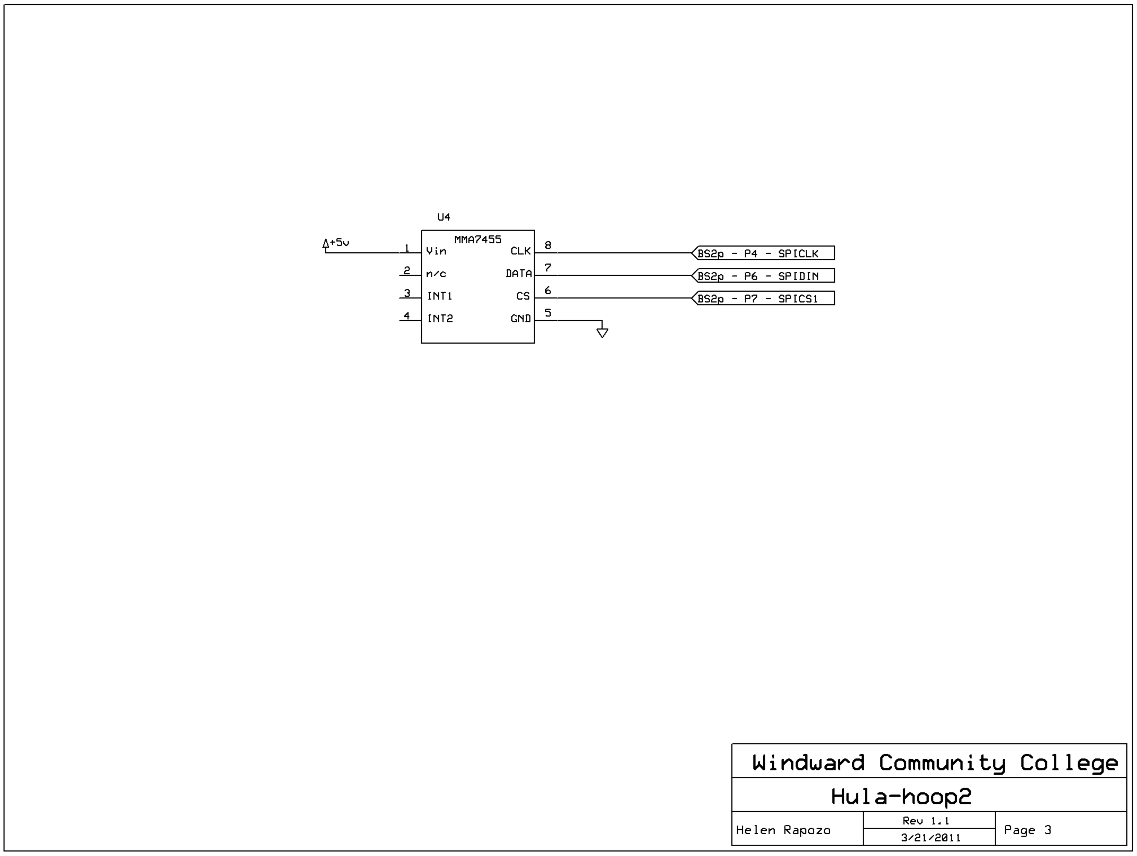
3/21/2011
Page 2


U4
MMA7455
+5v
1 Vin
2 n/c
3 INT1
4 INT2
8 CLK
7 DATA
6 CS
5 GND
BS2p - P4 - SPICLK
BS2p - P6 - SPIDIN
BS2p - P7 - SPICS1
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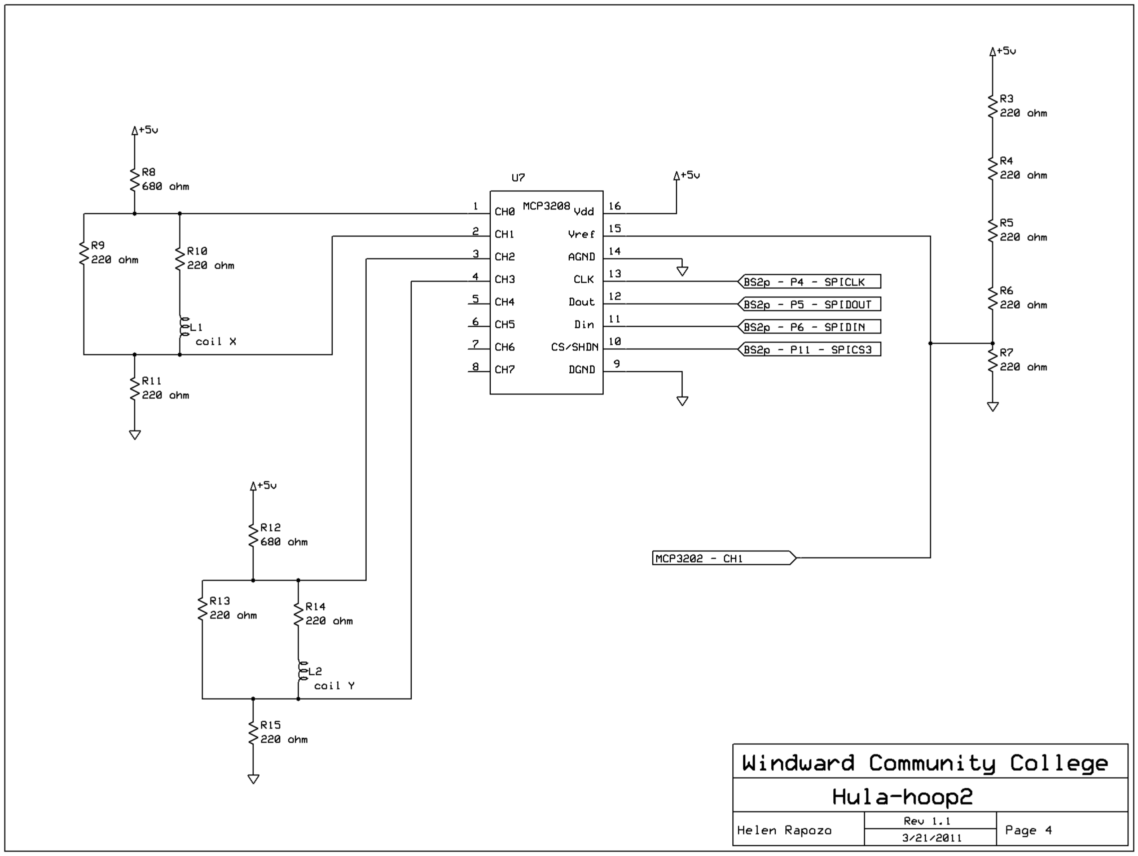
+5v
R8
680 ohm
R9
220 ohm
R10
220 ohm
L1
coil X
R11
220 ohm
U7
MCP3208
CH0
CH1
CH2
CH3
CH4
CH5
CH6
CH7
Vdd
Vref
AGND
CLK
Dout
Din
CS/SHDN
DGND
BS2p - P4 - SPICLK
BS2p - P5 - SPIDOUT
BS2p - P6 - SPIDIN
BS2p - P11 - SPICS3
R3
220 ohm
R4
220 ohm
R5
220 ohm
R6
220 ohm
R7
220 ohm
R12
680 ohm
R13
220 ohm
R14
220 ohm
L2
coil Y
R15
220 ohm
MCP3202 - CH1
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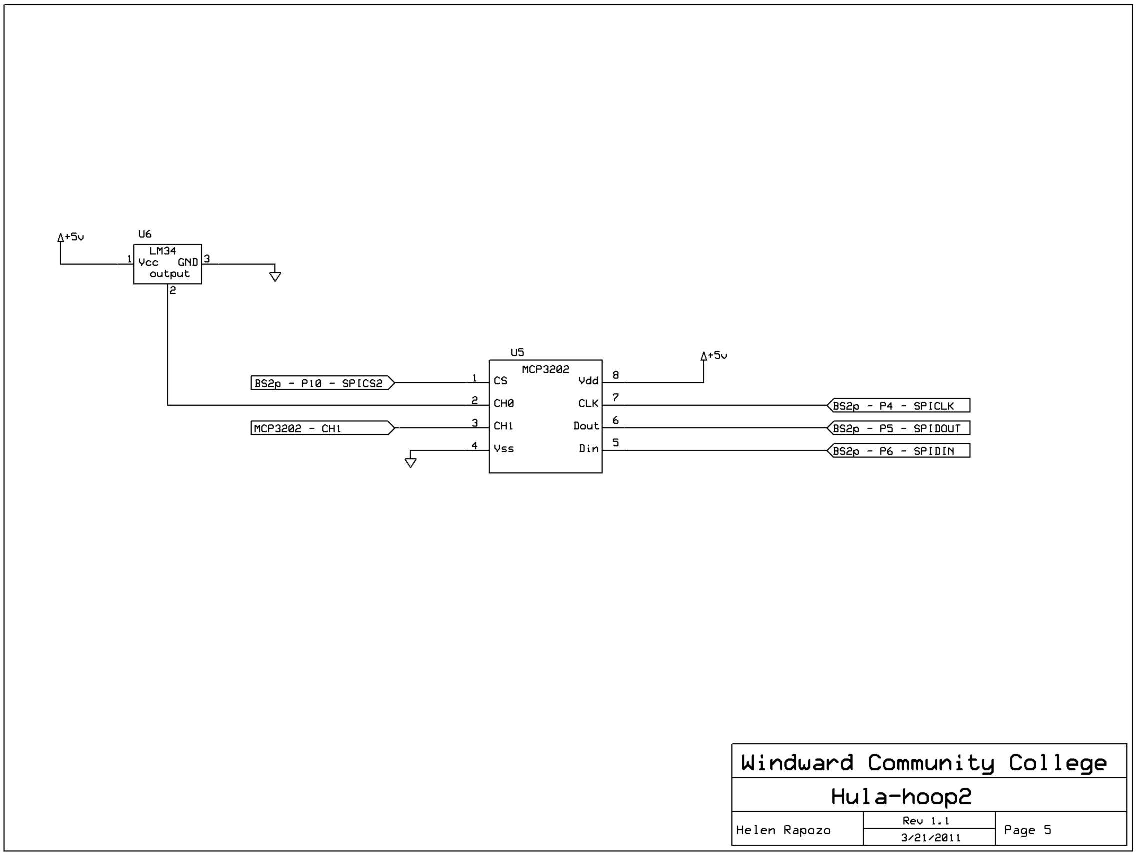
+5v
U6
LM34
Vcc
GND
output
1
2
3
U5
MCP3202
BS2p - P10 - SPICS2
MCP3202 - CH1
1 CS
2 CH0
3 CH1
4 Vss
8 Vdd
7 CLK
6 Dout
5 Din
+5v
BS2p - P4 - SPICLK
BS2p - P5 - SPIDOUT
BS2p - P6 - SPIDIN
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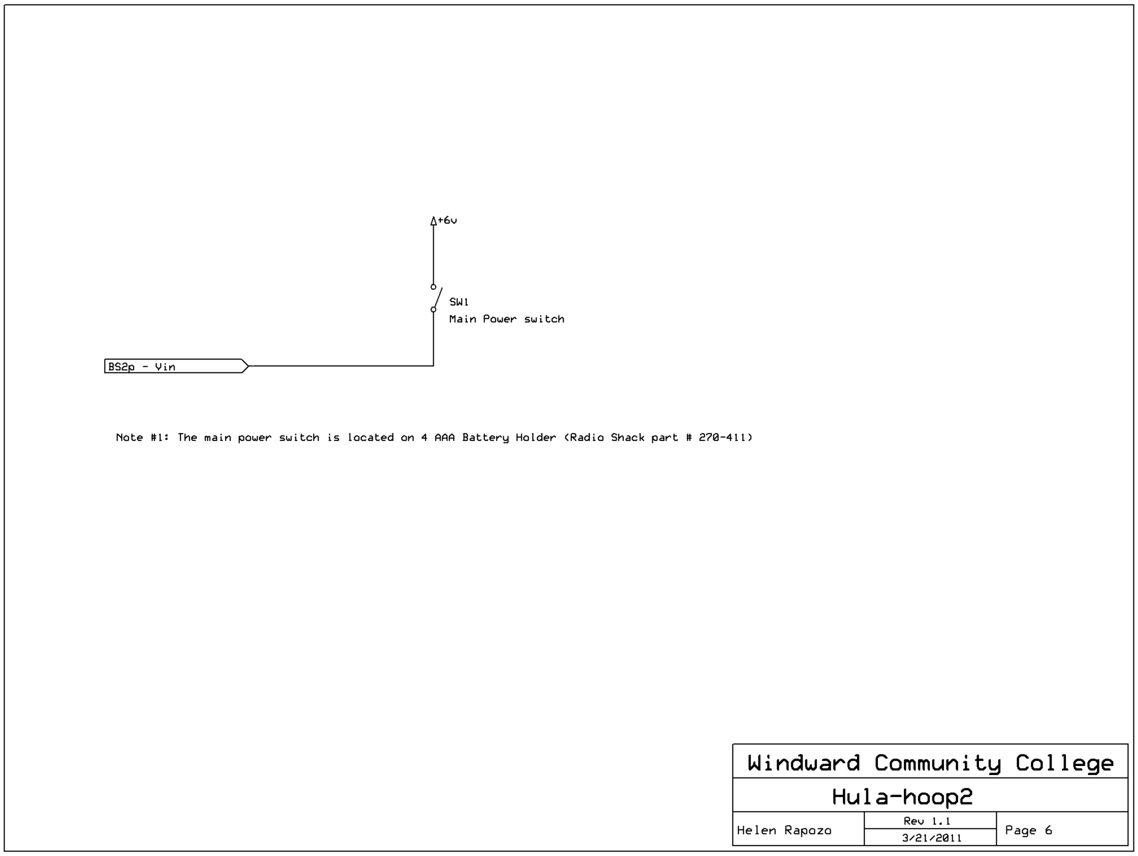
+6v
SW1
Main Power switch
BS2p - Vin
Note #1: The main power switch is located on 4 AAA Battery Holder (Radio Shack part # 270-411)
Windward Community College
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Hula-Hoop Layout

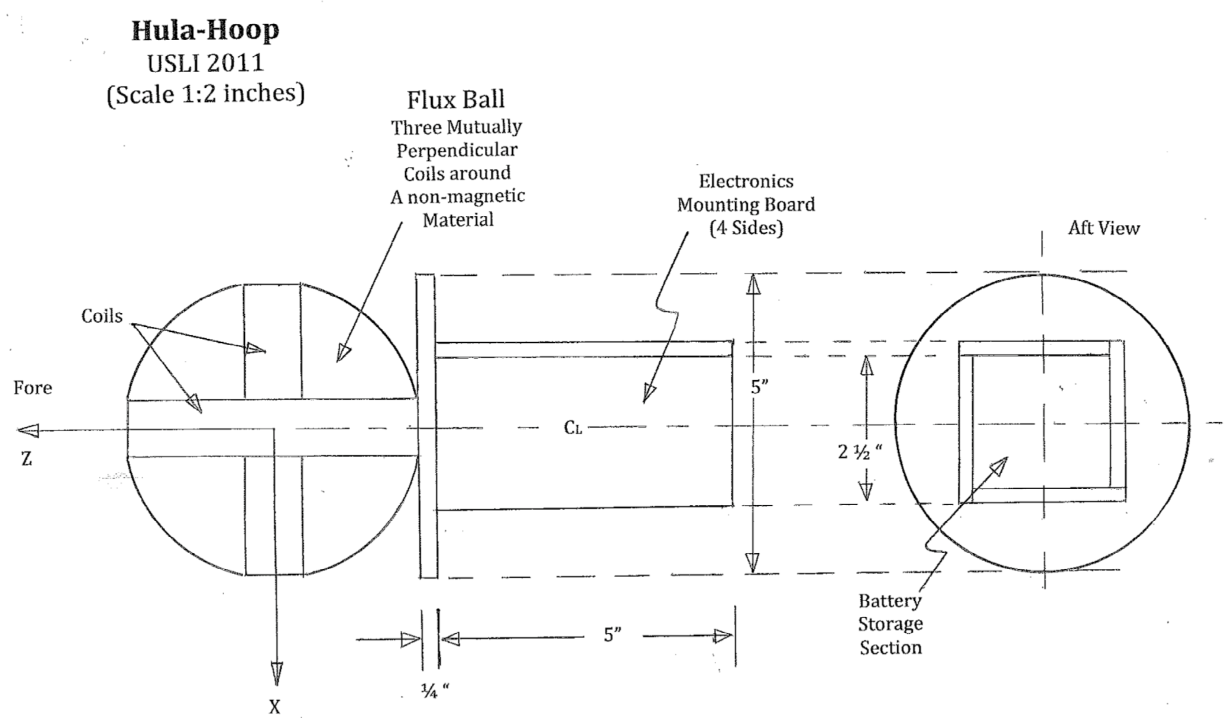
The experimental layout for the Hula-hoop 3 payload consists of three sections; the flux ball, the electronic mounting frame work, and the battery storage section. The payload must fit the volume constraints of the payload carrier (i.e. a cylinder having an inside diameter less then 5 1/2", and a length less then 11"), and a total mass less then 2.0 kg.

The main component of the experiment, the flux ball, consists of three mutually perpendicular coils that are wound around a non-magnetic material. At this time, the non-magnetic material is Styrofoam because of its low cost, easy shape-ability, and ready availability. The three coils will be adhered to the Styrofoam ball by an epoxy layer. The flux ball will be mounted to a circular, ¼" thick, 5" diameter plywood base that will have 3 holes, one for each of the pairs of wires from each of the coils, to act as a pass-through to the electronics section.

Below the disk the flux ball is mounted upon, are the electronic mounting boards. At this time there is some discussion as to how much area the electronics will require. The current bread-boarding has required 3 units of 2.5" X 6.0" electronic layout boards. It is hoped that the actual electronics will take up less area then the current bread-board, but this layout affords us ample room, and easy accessibility.

The electronics mounting surfaces form a rectangular middle section that will contain the batteries powering the Hula-hoop 3. Currently, the voltage and current needs for Hula-hoop 3 require 4 AA batteries – there is more then enough volume for this.

Hula-Hoop Layout



Environmental concerns (Payload)

The batteries that power the payload, if broken open, would cause some environmental concern. But because of the mounting of the payload in sealed payload section of the rocket, we do not foresee any environmental concerns if the rocket flight goes as planed.

V) Launch Operations Procedures

Preflight Checklist

Rocket Pre-Flight:

- ◊ Payload switched on
- ◊ Payload Carrier Integrated to Payload Section
- ◊ Nosecone/GPSFlight Powered and Secured
- ◊ Nosecone attached to Payload Section
- ◊ Payload secured to Shock Cord Tether
- ◊ Drogue Chute folded
- ◊ Drogue Chute Nomex wrapped
- ◊ Drogue Chute secured to Aft Blkhd Payload Section U-Bolt
- ◊ (2) Drogue Chute Pyros (4g, short leads) connected to Fore Avionics Blkhd terminal
- ◊ Shock Cord Tether secured to Fore Blkhd Avionics Section U-Bolt
- ◊ Drogue Chute Packed
- ◊ Payload/Avionics Sections integrated
- ◊ 2 nylon shear pins inserted securing Payload section to Avionics Section

[Payload A-Blkhd/Drog. Chute/Nomex/Pyros/Avionics F-Blkhd]

- ◊ Shock Cord Tether secured to Fore U-bolt of Motor Mount Retaing Cap U-Bolt
- ◊ Motor Inserted into Motor Mount and secured via Retaining Ring
- ◊ Drogue Pyros (2) connected to Avionics via jack-plug
- ◊ (2) Main Chute Pyros (5.5g, long leads) placed against Motor Retaining Cap and leads taped to inside of booster section
- ◊ Main Chute Pyros connected at aft Avionics Blkhd terminal
- ◊ Avionics tested for continuity
- ◊ Avionics off
- ◊ Avionics inserted into Avionics Bay
- ◊ Aft Avionics Bkhd secured to Avionics Bay via (2) Wing Nuts
- ◊ Shock Cord Tether attached to Aft Avionics Blkhd of Avionics Section
- ◊ Main Chute folded
- ◊ Main Chute Nomex wrapped
- ◊ Main Chute secured to Aft Blkhd of Avionics Section
- ◊ Main Chute Packed
- ◊ Avionics/Booster Sections integrated
- ◊ 3 nylon shear pins inserted securing Avionics section to Booster

[Avionics A-Blkhd/Main Chute/Nomex/Pyros/MMRC-Booster]

General/Overall:

- ◊ Fins Secured
- ◊ Air Pressure Sensors holes clear
- ◊ Rail Buttons Usable
- ◊ Brake shoes deployed
- ◊ Balance test for stability

Clearance to Pad

At the Pad:

- ◊ Rocket Slid onto Rail (no constraints)
- ◊ Avionic Armed/Consistent signals
- ◊ Igniter inserted into Motor
- ◊ Rocket/Rail Righted to vertical
- ◊ Igniter leads connected to Electronic Launch System
- ◊ Continuity Test

VI) Activity Plan

Educational Engagement

The USLI team at Windward Community College devoted many successful hours into building stronger community ties that have now enabled our outreach program to include outer-island advertising, more school projects and a competition that will advance a Hawaii team to SLI.

The state of Hawaii is unique not only because it has 2400 miles of ocean separating it from the Continental United States but also the state itself is divided into eight islands making events on one island difficult for the residents of another island to attend. Therefore, we are confident that once our plan to become televised on the local news and the locally produced and run show "Hawaii Sports People" on network OC16 we will close the inter-island communication gap. Our plan was to use the local public access station O'lelo. The plan was for a half an hour television program in which our CAE facilities, NASA resources, USLI program, SLI program and other educational endeavors that involve rocketry (such as the Hawaii Space Flight College, the Pacific Missile Range Facility, etc.) were described. We would have had to borrow equipment from the O'lelo station to film and edit the piece ourselves. With the team having very limited experience with filming and editing we determined that this would take up too much time, though we still plan to do this within the next year. Fortunately an opportunity arose to be in an episode of "Hawaii Sports People" on a more widely viewed TV channel called OC16. This gave us a chance for the team and our USLI project, including our FSLP tests, to be filmed and edited by a professional crew. We also had interviews with the show's host, Howard Dashefsky, who is a well-known local news anchor. Unfortunaltey, this episode will not air until the second half of April, though we have been able to attain some raw footage from them. This approach is the catalyst to get our message into households and businesses alike throughout the state. Furthermore, press releases to all local newspapers to include the military periodicals have been instrumental in the continuation of the development and growth of community involvement. This millennium has changed to, and is all about, social networking and as such, we need to be a part of this change. Targeting these venues are actively being investigated and pursued.

One outreach project that has been in effect, and will continue to be utilized, is a model rocket launch we hold every month. On the third Saturday of every month we launch model rockets for research purposes. This launch is open to the public and is also used for community engagement. These launches have been very successful in reaching people. We have a few regulars that show up consistently. We have afforded an opportunity for teams to utilize this time to launch in preparation for the Team America Rocket Challenge.

On December 13, 2010 we engaged middle school students, of the Boys and Girls Club of America, in a hands-on educational experience where the students built paper Scimitar rockets. We instructed them on simple principles of rocketry (Newton's Third Law, etc.). This was a way for us to share the world of rocketry and possibly strike an interest in science, technology, engineering, and math (STEM).

Detailed flyers and brochures to include what the WCC CAE (Windward Community College Center for Aerospace Education) has to offer students, and schools, and how they can get involved in TARC, SLI, USLI, and the numerous other NASA learning opportunities encompassing rocketry have also be distributed to schools and organizations throughout the state. It is hoped that this will lead to an open-line communication between WCC CAE and the rest of Hawaii. Students of today will be the leaders, discoverers, and inventors of tomorrow and are entitled to be introduced to the opportunities that exist by being a part of this organization.

Additionally, an inclusion to this year's outreach development plan is to host A Rocket Contest for Hawaiian Skies (ARCHeS) in the spring. The preliminary idea for this competition is to have a parachute payload duration experiment. After conversing with SPRCH (Sky Performance Rocketry Club of Hawaii), the local NAR chapter, we have tentatively decided that the competition that fulfills the conditions for suitable challenge, and our limited field size, is the payload parachute duration. We have obtained grant funding, and are planning to supply the motors for all participating teams. This ensures that all teams will have the same specific impulse, and should keep all rockets within our limited field size. In fact, the fact that the motor is pre-determined will be part of the design criteria. The plan is that the student-designed rockets will eject a payload section with a separate parachute and the time of descent will be measured. We are still contemplating on whether to use a kukui nut, or an egg, as a payload mass. This contest, open to all interested high schools, will enable (we hope) a Hawaii team to compete at SLI in the following year. We look forward to the participation, and the shared learning experiences, that will ensue with this year's outreach plans. Our mentor Jacob Hudson has had preliminary discussions with Julie Clift concerning the feasibility of ARCHeS.

With this multifaceted approach, it is expected that all educational outreach goals will be fulfilled. Windward Community College, a University of Hawaii satellite campus, and the Kaneohe Marine Corps Air Station, will be essential to all of the launches that take place on Oahu. The Pacific Missile Range Facility on Kauai has also been a host to community events in the past, and has expressed a willingness to continue this collaborative effort. They hosted one such event on December 18, 2010, at which we acted as a resource for the involved learning institutions. Support for our educational endeavors are being sought on the islands of Maui and Hawaii (The Big Island).

Community Support

The Marine Corps Base Hawaii has offered the use of its airfields for aerodynamics testing and community events. Since safety is our number one priority, there is always an on call fire truck for any incidentals. With their aid, we are able to launch with a 2500ft. ceiling, the highest available to date on the island of Oahu.

We are looking into several local sponsors, and some high-powered rocketry sponsors. Some sources approached are:

Fiberglass Hawaii
Parallax.com
Oceanit
Performance Kites
Aerotech
AeroPAC Model Rockets
Rocketmotion
Fruity Chutes
Olelo Community Television

Sponsorship solicitation will begin with an explanation of our education outreach goals to those targeted. Included with the solicitation for support will be offers for advertisement of said sponsor at outreach events, local launches, demonstration launches, and special events through various means, such as: "over the air thank you to said sponsor" at events where a public address system is available and in use, visual signage of banners and/or posters at launch tents, visual advertisement via clothing or patches of said sponsor on team clothing, visual advertisement on team public Web page, & arranged press coverage of events.

A new component to our outreach plan is to connect with audiences across the state via television broadcasting. The Olelo Community Television provides this opportunity with little to no cost for a thirty minute, commercial-free show. The goal is to encourage youth, parents, and educators to participate in mutual community events by displaying unique learning opportunities possible through this association.

Outreach Projects

Our entire project is based on educational outreach and the possibilities of students utilizing rockets for their own projects (a payload bay), along with learning about the different phases a rocket goes though in flight via hands on experiments. It is our goal to encourage interest in STEM programs. Using programs such as K.I.T.S. (Kids In Technology and Science) to reach out to young students everywhere and demonstrate the technology employed at NASA, and resources available for students at all learning levels. These student participants would be introduced to the plethora of varied career paths within NASA, including those in fields of aerospace engineering, electrical engineering, horticulture, nutrition, physics, astronomy, and even cosmology! Their potential roles within these applied fields would be examined and encouraged through hands-on tactile activities and guided study devised for just that purpose.

This program will develop a diverse portfolio of educational initiatives that target students at all levels, and through different venues, be it primary, secondary schools, YMCA, or the Boys and Girls Scouts of America. Most importantly, we want to reach out to America's traditionally under-served and under-represented communities because they deserve our greatest support. Additionly, our ambition is to expand the K.I.T.S. horizon to military installations in foreign parts of the world (Asia). This would provide transient American students with the same opportunities their peers would be receiving in CONUS (Continental United States). It is hoped that, possibly next year, these students would have the opportunity to create and construct a payload that would be integrated with our Leo Hano.

The NASA Aerospace Education Labs (AELs) are currently located in thirty-eight states nationwide, and one mobile unit that travels throughout the continental United States. In the state of Hawaii, we are fortunate to have one of these treasures located at Windward Community College as part of the Center for Aerospace Education. Along with the K.I.T.S. program, this facility would provide the tools, experience, and opportunities to enhance the participating student's knowledge of the aerospace industry. It is our goal to increase both the general public awareness, and the specific number of students involved in the Aerospace Education Lab. It is our hope that this will inspire, and motivate students to pursue higher levels of study in technology and science.

Educational Engagement Plan

14 Feb.	- Valentine's Day *kisses*
15 Feb.	- Distribute pamphlets
19 Feb.	- Community Launch
21 Feb.	- Begin preliminary work with OC16 TV show
	- Outreach with Iwakuni AFB, Japan project payload
13 March	- Full-Scale Low-Power (FSLP) launch at KMCAS
	- Filming of "Sports People Hawaii"
19 March	- Community Launch
20 March	- Second Full-Scale Low-Power launch at KMCAS
	- Filming of "Sports People Hawaii"
12 April	- Compete at USLI

USLI 2011 Timeline

Feb 5 - Booster Complete
Feb 19 - Model Rocket Launch
Feb 19 - Avionics Complete
Feb 26 - Duel Deployment Avionics Test
Feb 26 - Rocket Complete
March 13 – Full Scale Low Power (FSLP) Test
March 19 - Model Rocket Launch
March 20 - FSLP Rain Date
April 12-18 – USLI

Budget Plan:
Rocket Cost

Part:	Price Each	Quantity	Total Cost
Body Tube (FT-6.0)	$45.32/ft	10	$453.20
Nosecone (FNC-6.0 30.5" ogive)	$89.95	1	$89.95
Coupler (CT-6.0, 16" length)	$68.00	2	$136.00
Aluminum Fins/Can assembly	$80.00	1	$80.00
Centering Rings (FCR-6.0-3.9)	$16.00	2	$32.00
Bulkheads (CBP-6.0)	$5.93	2	$11.86
Motor Tube (FTEX2-3.91, 36")	$58.92	1	$58.92
Drogue Chute (42")	$75.00	1	$75.00
Main Chute (144")	$290.00	1	$290.00
Shock Cord (1" thick)	$0.70/ft	42	$29.60
Kevlar Patch (21")	$27.00	2	$54.00
Aero-Pack 98 mm Motor retainer	$19.00	1	$19.00
Aero-Pack 98-75 mm motor adapter	$64.00	1	$64.00
	$45.00	1	$45.00
Subtotal			$1,438.53

Avionics/Electronics Cost

Item	Price Each	Quantity	Total Cost
PerfectFlight MiniAlt/WD	$99.95	1	$99.95
Featherweight Raven-2	$155.00	1	$155.00
GPSFlight (ST900e)	$695.00	1	$695.00
GPS-P25 (Patch antenna)	$30.00	1	$30.00
RPSMA900 (trans. antenna)	$18.00	1	$18.00
Li-Po Battery Pack	$150.00	1	$150.00
9V Dry Cell	$2.99	4	$11.96
Subtotal			$1,159.91

Payload Cost

Item	Vendor	Part number	unit cost	qty	cost	notes
Basic Stamp 2p	Parallax	BS2P24	$79.00	1	$79.00	
MMA7455	Parallax	28528	$34.99	1	$34.99	accelerometer
24LC512	Digi-key	24LC512-I/P-ND	$1.96	2	$3.92	eeprom
MCP3202	Parallax	604-00060	$3.47	1	$3.47	ADC#2 - 12 bit
MCP3208	Parallax	604-00062	$5.22	1	$5.22	ADC#1 - 12 bit
LM34	Parallax	604-00011	$3.99	1	$3.99	temperature sensor
Green LED assembly	Radio Shack	276-271	$1.99	1	$1.99	Status LED
Red LED assembly	Radio Shack	276-270	$1.99	1	$1.99	Error LED
.1uF capcitor	Parallax	200-01040	$0.15	2	$0.30	debug port
220 ohm resistor	Radio Shack	271-1111	$0.24	12	$2.86	1-DIP,5-Vref,3-CoilX,3-CoilY
680 ohm resistor	Radio Shack	271-1117	$0.24	2	$0.48	1-CoilX,1-CoilY
4.7K ohm resistor	Radio Shack	271-1124	$0.24	2	$0.48	EEPROM interface
10K ohm resistor	Radio Shack	271-1126	$0.24	1	$0.24	DIP
DIP switch	Digi-key	SW897-ND	$2.87	1	$2.87	
40 pin single row header	Parallax	451-04001	$1.99	1	$1.99	4-debug,4-data,2-power
Solderless Breadbroad	Parallax	700-00012	$3.99	1	$3.99	mounting for Coil interface
Modular Breadbroad	Radio Shack	276-002	$14.99	1	$14.99	mounting for the main circuit boa
AAA battery holder	Radio Shack	270-411	$1.99	1	$1.99	Also contains power switch
total					$164.75	

Budget Total

Rocket Body/Construction		$1,438.53
Rocket Avionics/Electronics		$1,159.91
Payload		$164.75
	Total:	$2,763.19

VII) Conclusion

The 2010-2011 USLI experience has been a very fun and great learning experience for us. There is still some minor work that needs to be done before we get ready to ship everything out. If we are cleared to fly at Huntsville we look forward to heading there and flying Leo Hano. In any case we are grateful for the opportunity.

Appendix A: RocSim Results and Parts List

USLIROC2011 – Simulation results

Engine selection
[L1300R-None]

Simulation control parameters
- Flight resolution: 800.000000 samples/second
- Descent resolution: 1.000000 samples/second
- Method: Explicit Euler
- End the simulation when the rocket reaches the ground.

Launch conditions
- Altitude: 827.00131 Ft.
- Relative humidity: 50.000 %
- Temperature: 59.000 Deg. F
- Pressure: 29.9139 In.

  Wind speed model: Calm (0 - 2 MPH)
  - Low wind speed: 0.0000 MPH
  - High wind speed: 2.0000 MPH

  Wind turbulence: Fairly constant speed (0.01)
  - Frequency: 0.01000 rad/second
- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.000 Deg.
- Latitude: 34.060 Degrees

Launch guide data:
- Launch guide length: 144.00000 In.
- Velocity at launch guide departure: 65.2024 ft/s
- The launch guide was cleared at: 0.382 Seconds
- The user specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 66.3407 In.

Max data values:
- Maximum acceleration: Vertical (y): 407.392 Ft./s/s Horizontal (x): 0.389 Ft./s/s Magnitude: 407.392 Ft./s/s
- Maximum velocity: Vertical (y): 625.7592 ft/s, Horizontal (x): 2.9060 ft/s, Magnitude: 625.8372 ft/s
- Maximum range from launch site: 142.67690 Ft.
- Maximum altitude: 5648.02551 Ft.

Recovery system data
- P: Drogue Deployed at: 19.391 Seconds
- Velocity at deployment: 7.4360 ft/s
- Altitude at deployment: 5648.02548 Ft.
- Range at deployment: -142.67690 Ft.
- P: Main Parachute Deployed at: 75.070 Seconds
- Velocity at deployment: 83.5897 ft/s
- Altitude at deployment: 999.99622 Ft.
- Range at deployment: -11.63689 Ft.

Time data
- Time to burnout: 3.500 Sec.
- Time to apogee: 19.391 Sec.
- Optimal ejection delay: 15.891 Sec.

Landing data
- Successful landing
- Time to landing: 119.060 Sec.
- Range at landing: 111.49581 Ft.
- Velocity at landing: Vertical: -22.2654 ft/s, Horizontal: 2.9060 ft/s, Magnitude: 22.4542 ft/s

Competition settings

Competition conditions are not in use for this simulation.

Sustainer parts

Nose cone – Custom, material: Fiberglass
- Nose shape: Hollow Ogive, Len: 30.6250 In., Dia. 6.0000 In. Wall thickness: 0.1250 In. body insert: OD: 5.8750 In., Len. 6.1250 In.
- CG: 23.2050 In., Mass: 4.7265 Oz. Radius of gyration: 0.248459 (m), 24.8459 (cm) Moment of Inertia: 0.00827163 (kgm^2), 82716.3 (gcm^2), rockSim XN: 14.2470 In., CNa:2

GPSFlight Mass – Custom, Material: Custom
- CG: 0.0000 In.
- In., Mass: 52.9109 Oz. radius of gyration: 0 (m), 0 (cm) Moment of Inertia: 0 (kgm^2), 0 (gcm^2)

Payload section – Custom, material: Fiberglass
- OD: 6.0000 In., ID: 5.8750 In., Len: 24.0000 In.
- CG: 12.0000 In., Mass: 2.0726 Oz. Radius of gyration: 0.184085 (m), 18.4085 (cm) Moment of Inertia: 0.0019911 (kgm^2), 19911 (gcm^2), RockSim XN: 0.0000 In., CNa: 0

NC Bulkhead – custom, Material: Aircraft plywood (Birch)
- Bulkhead OD: 5.8750 In., Len: 0.50000 In., Location: 6.0000 In. From the front of Payload Section
- CG: 0.2500 In., Mass: 5.6802 Oz. Radius of gyration: 0.0375281 (m), 3.75281 (cm) Moment of Inertia: 0.000226791 (kgm^2), 2267.91 (gcm^2)

Payload Mass – Custom, Material:
- CG: 0.0000 In., Mass: 70.5479 Oz. Radius of gyration: 0 (m), 0 (cm) Moment of Inertia: 0 (kgm62), 0 (gcm^2)

Drogue/experiment Bulkhead – Custom, Material: Aircraft plywood (Birch)
- Bulkhead OD: 5.8750 In., Len: 0.5000 In. Location: 18.0000 In. From the front of Payload Section
- CG: 0.2500 In., Mass: 5.6802 Oz. Radius of gyration: 0.0375281 (m), 3.75281 (cm) Moment of Inertia: 0.000226791 (kgm^2), 2267.91 (gcm^2)

Drogue – Custom, Material: Rip stop nylon
- 1 parachute, Shape: 6 sided Dia: 32.0000 In., Spill hole: 0.0000 In.
- CG: 2.6667 In., Mass: 1.0631 Oz. Radius of gyration: 0.0492488 (m), 4.92488 (cm) Moment of Inertia: 7.30965e-05 (kgm^2), 730.965 (gcm^2)

Forward Tube coupler – Custom, Material: Fiberglass
- Tube coupler OD: 5.8750 In., Hole #1: : 146.0500 In., Len: 12.0000 In. Location: 18.0000 In. From the front of payload Section
- CG: 6.0000 In., Mass: 1.0145 Oz. Radius of gyration: 0.102423 (m), 10.2423 (cm) Moment of Inertia: 0.000301703 (kgm^2), 3017.03 (gcm^2)

Avionics section – Custom, Material: Fiberglass
- OD: 6.0000 In., ID: 5.8750 In., Len: 18.0000 In.
- CG: 9.0000 In., Mass: 1.5544 Oz. Radius of gyration: 0.142507 (m), 14.2507 (cm) Moment of Inertia: 0.000894938 (kgm^2), 8949.38 (gcm^2), RockSim XN: 0.0000 In., CNa: 0

For AV Bulkhead – Custom, Material: Aircraft Plywood (Birch)
- Bulkhead OD: 5.8750 In. Len: 0.50000 In. Location: 6.0000 In. From the front of Avionics section
- CG: 0.2500 In., Mass: 5.6802 Oz. Radius of gyration: 0.0375281 (m), 3.75281 (cm) Moment of Inertia: 0.000226791 (kgm^2), 2267.91 (gcm^2)

Aluminum AV Can – Custom, Material: Aluminum
- Tube coupler OD: 5.8750 In., Hole #1: : 146.0500 In. Len: 7.0625 In. Location: 6.0000 In. From the front of Avionics section
- CG: 3.5312 In., Mass: 0.5971 Oz. Radius of gyration: 0.0736121 (m), 7.36121 (cm) Moment of Inertia: 9.17194e-05 (kgm^2), 917.194 (gcm^2)

Avionics Mass – Custom, Material: Custom
- CG: 0.0000 In., Mass: 35.2740 Oz. Radius of gyration: 0 (m), 0 (cm) Moment of Inertia: 0 (kgm^2), 0 (gcm^2)

Aft AV Bulkhead – Custom, Material: Aircraft plywood (Birch)
- Bulkhead OD: 5.8750 In., Len: 0.5000 In., Location: 13.1250 In. From the front of Avionics section
- CG: 0.2500 In., Mass: 5.6802 Oz. Radius of gyration: 0.0375281 (m), 3.75281 (cm) Moment of Inertia: 0.000226791 (kgm^2), 2267.91 (gcm^2)

Aft Tube coupler – Custom, Material: Fiberglass
- Tube coupler OD: 5.8750 In., Hole#1: : 146.0500 In., Len: 12.0000 In. Location: 13.0650 In. From the front of Avionics section
- CG: 6.0000 In., Mass: 5.6802 Oz. Radius of gyration: 0.0375281 (m), 3.75281 (cm) Moment of Inertia: 0.000226791 (kgm^2), 2267.91 (gcm^2)

Booster Section – Custom, Material: Fiberglass

- OD: 6.0000 In., ID: 5.9375 In., Len: 48.0000 In.
- CG: 24.0000 In., Mass: 2.0841 Oz. Radius of gyration: 0.356412 (m), 35.6412 (cm) Moment of Inertia: 0.00750546 (kgm^2), 75054.6 (gcm^2), RockSim XN: 0 In., CNa: 0

Motor Mount – Custom, Material: G10 fiberglass

- OD: 3.8976 In., ID: 3.8583 In., Len: 30.0000 In. Location: 18.0000 In. From the front of Booster section
- CG: 15.0000 In., Mass: 7.9092 Oz. Radius of gyration: 0.222961 (m), 22.2961 (cm) Moment of Inertia: 0.0111464 (kgm^2), 111464 (gcm^2), RockSim XN: 0.0000 In., CNa: 0

Forward Centering ring – Custom, Material: Aircraft plywood (Birch)

- Centering ring OD: 5.9375 In., ID: 3.8976 In., Len: 0.5000 In. Location: 18.0000 In. From the front of Booster Section
- CG: 0.2500 In., Mass: 3.3017 Oz. Radius of gyration: 0.0453003 (m), 4.53003 (cm) Moment of Inertia: 0.00019208 (kgm^2), 1920.8 (gcm^2)

Aluminum Fin Can – Custom, Material: Aluminum

- OD: 5.9375 In., ID: 5.7500 In., Len: 11.0625 In. Location: 31.0000 In. From the front of Booster Section
- CG: 5.5313 In., Mass: 20.9665 Oz. Radius of gyration: 0.0967224 (m), 9.67224 (cm) Moment of Inertia: 0.00556065 (kgm^2), 55606.5 (gcm^2), RockSim XN: 0.0000 In., CNa: 0

Aft Centering ring – Custom: Material: Aircraft plywood (Birch)

- Centering ring OD: 5.9375 In., ID: 5.7500 In., Len: 0.5000 In. Location: 48.0000 In. From the front of Booster Section
- CG: 0.2500 In., Mass: 5.8017 Oz. Radius of gyration: 0.0526721 (m), 5.26721 (cm) Moment of Inertia: 0.000456313 (kgm^2), 4563.13 (gcm^2)

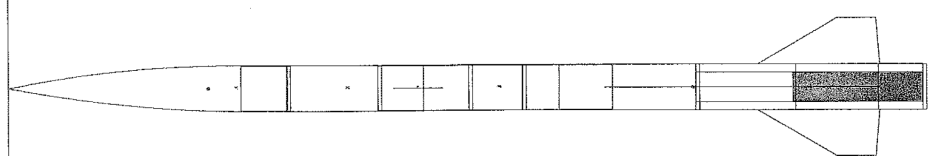
Fin set – Custom, Material: Aluminum

- Planform: trapezoidal, Root chord: 16.2500 In., Tip chord: 5.2500 In., Semi-span: 6.0625 In., Sweep: 10.5023 In., Mid-chord: 7.8598 In., Misc: Location: 26.0000 In. From the front of Booster Section Thickness: 0.0625 In. Profile: square
- CG: 10.1996 In., Mass: 0.0089 Oz. Radius of gyration: 0.104264 (m), 10.4264 (cm) Moment of Inertia: 2.73189e-06 (kgm^2), 27.3189 (gcm^2), RockSim XN: 105.9026 In., CNa: 13.2355

Main Parachute – Custom, Material: Rip stop nylon

- 1 parachute, Shape: 6 sided Dia: 108.0000 In., spill hole: 0.0000 In.
- CG: 9.000 In., Mass: 13.8431 Oz. Radius of gyration: 0.135537 (m), 13.5537 (cm) Moment of Inertia: 0.00720934 (kgm^2), 72093.4 (gcm^2)

USLIROC2011
Length: 121.1250 In. , Diameter: 6.0000 In. , Span diameter: 18.1250 In.
Mass 732.2769 Oz. , Selected stage mass 732.2769 Oz. (User specified)
CG: 26.3317 In., CP: 90.2507 In., Margin: 10.65 Overstable
Engines: [L1300R-None,]



Appendix B:

Additional Safety Regulations

Additional Safety Regulations may be found on the following Websites:

Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C:

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=14:2.0.1.3.10&idno=14#14:2.0.1.3.10.3

Code of Federal Regulation Part 55:

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=03c9459678c94e51c2fae38c3346cf93&rgn=div5&view=text&node=40:5.0 .1.1.3&idno=40

NFPA 1127:

http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=1127

Appendix C
Center for Aerospace Education

Established in 1986, the Center for Aerospace Education (CAE) supports WCC's credit and community outreach programs in aerospace science. The mission of the CAE is to inspire students to actively engage in science activities through formal education and informal experiences, to explore career options in aerospace science and industry, and to become informed, contributing citizens by becoming science-literate.

The following facilities and services are offered by the CAE:
• Aerospace Exploration Lab
• Hokulani Imaginarium
• NASA Flight Training Aerospace Education Laboratory
• Lanihuli Observatory
• Hawaiʻi Space Grant–Windward

The CAE serves over 12,000 visitors annually through these facilities. It also sponsors teacher workshops and offers consultation to students and teachers on aerospace education and science projects.

The goals of the CAE are to:

- generate greater interest in careers in science and help facilitate the successful transition of students from high school to post-secondary institutions; and,

- increase the number of underserved students entering college who choose to major in science, technology, engineering and mathematics (STEM) and have the skills necessary to successfully complete their higher education.

- increase enrollment and success of K-12 students in science, mathematics and technology courses in high schools;

- help students develop high-tech skills to succeed in a knowledge-based global economy;

For more information, http://aerospace.wcc.hawaii.edu

Appendix D

National Association of Rocketry High Power Rocket Safety Code

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Appendix E

Tripoli Rocketry Association Safety Code

The following is a condensed version of the TRIPOLI HIGH POWER SAFETY CODE. The complete code can be found in the TRIPOLI handbook. The Tripoli High Power Safety Code is based on NFPA 1127. You may view the current version of NFPA 1127 on the NFPA Website.

Only a person who is a certified flyer shall operate or fly a high power rocket.

Must comply with United States Code 1348, "Airspace Control and Facilities", Federal Aviation Act of 1958 and other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.

A person shall fly a high power rocket only if it has been inspected and approved for flight by a Safety Monitor for compliance with the applicable provisions of this code.

<u>Motors</u>

Use only certified commercially made rocket motors.

Do not dismantle, reload, or alter a disposable or expendable high power rocket motor, will not alter the components of a reloadable high power rocket motor or use the contents of a reloadable rocket motor reloading kit for a purpose other than that specified by the manufacture in the rocket motor or reloading kit instructions.

A high power rocket shall be constructed to withstand the operating stresses and retain structural integrity under conditions expected or known to be encountered in flight.

A high power rocket vehicle intended to be propelled by one or more high power solid propellant rocket motor(s) shall be constructed using lightweight materials such as paper, wood, plastic, fiberglass, or, when necessary, ductile metal so that the rocket conforms to the other requirements of this code.

A person intending to operate a high power rocket shall determine its stability before flight, providing documentation of the location of the center of pressure and center of gravity of the high power rocket to the Safety Monitor, if requested.

<u>Weight and Power Limits.</u>

Ensure that the rocket weighs less than the rocket motor manufacturer's recommended maximum liftoff weight for the rocket motor(s) used for the flight. During pre-flight inspection, The Safety Monitor may request documentary proof of compliance.

Do not install a rocket motor or combination of rocket motors that will produce more than 40,960 newton-seconds of total impulse (4.448 newtons equals 1.0 pound).

Recovery.

Fly a high power rocket only if it contains a recovery system that will return all parts of it safely to the ground so that it may be flown again.
Install only flame resistant recovery wadding if wadding is required by the design of the rocket.

Do not attempt to catch a high power rocket as it approaches the ground. Do not attempt to retrieve a high power rocket from a place that is hazardous to people.

Payloads

Do not install or incorporate in a high power rocket a payload that is intended to be flammable, explosive, or cause harm.

Do not fly a vertebrate animal in a high power rocker.

Launching Devices

Launch from a stable device that provides rigid guidance until the rocket has reached a speed adequate to ensure a safe flight path.

Incorporate a jet deflector device if necessary to prevent the rocket motor exhaust from impinging directly on flammable materials.

A launching device shall not be capable of launching a rocket at an angle more than 20 degrees from vertical.

Place the end of the launch rod or rail above eye level or cap it to prevent accidental eye injury. Store the launch rod or rail so it is capped, cased, or left in a condition where it cannot cause injury.

Ignition Systems

Use an ignition system that is remotely controlled, electrically operated, and contains a launching switch that will return to "off" when released.

The ignition system shall contain a removable safety interlock device in series with the launch switch.

The launch system and igniter combination shall be designed, installed, and operated so the liftoff of the rocket shall occur within three (3) seconds of actuation of the launch system. If the rocket is propelled by a cluster of rocket motors designed to be ignited simultaneously, install an ignition scheme that has either been previously tested or has a demonstrated capability of igniting all rocket motors intended for launch ignition within one second following ignition system activation. Install an ignition device in a high power rocket motor only at the launch site and at the last practical moment before the rocket is placed on the launcher.

<u>Launch Site.</u>

Launch a high power rocket only in an outdoor area where tall trees, power lines, and buildings will not present a hazard to the safe flight operation of a high power rocket in the opinion of the Safety Monitor.
Do not locate a launcher closer to the edge of the flying field (launch site) than one-half the radius of the minimum launch site dimension.

The flying field (launch site) shall be at least as large as the stated in Table 1. *or* Not less than one-half the maximum altitude expected, calculated, or simulated, or as granted by an FAA waiver or the authority having jurisdiction.

<u>Launcher Location</u>

Locate the launcher more than 1,500 feet from any occupied building.

Ensure that the ground for a radius of 10 feet around the launcher is clear of brown grass, dry weeds, or other easy-to-burn materials that could be ignited during launch by the exhaust of the rocket motor.

<u>Safe Distances</u>

No person shall be closer to the launch of a high power rocket than the person actually launching the rocket and those authorized by the Safety Monitor.

All spectators shall remain within an area determined by the Safety Monitor and behind the Safety Monitor and the person launching the rocket.

A person shall not be closer to the launch of a high power rocket than the applicable minimum safe distance set forth in Table 2.

Launch Operations.

Do not ignite and launch a high power rocket horizontally, at a target, or so the rocket's flight path goes into clouds or beyond the boundaries of the flying field (launch site).

Do not launch a high power rocket if the surface wind at the launcher is more than twenty (20) miles per hour.

Do not operate a high power rocket in a manner that is hazardous to aircraft.

Launch Control.

Launch a high power rocket only with the immediate knowledge, permission, and attention of the Safety Monitor.

All persons in the launching, spectator, and parking areas during a countdown and launch shall be standing and facing the launcher if requested to do so by the Safety Monitor.

Precede the launch with a five (5) second countdown audible throughout the launching, spectator, and parking areas. This countdown shall be given by the person launching the rocket, the Safety Monitor, or other flying site operating personnel.

Do not approach a high power rocket that has misfired until the safety inter-lock has been removed or the battery has been disconnected from the ignition system, one minute has passed, and the Safety Monitor has given permission for only a single person to approach the misfired rocket to inspect it.

TABLE 1: LAUNCH SITE DIMENSIONS

Installed Total Impulse (N-sec)	Equivalent Motor type	Minimum Site Distance (feet)	Equivalent Dist. (miles)
160.01 - 320.00	H	1,500	0.28
320.01 - 640.00	I	2,500	0.50
640.01 - 1280.00	J	5,280	1.00
1280.01 - 2560.00	K	5,280	1.00
2560.01 - 5120.00	L	10,560	2.00
5120.01 - 10240.00	M	15,480	3.00
10240.01 - 20480.00	N	21,120	4.00
20480.01 - 40960.00	O	26,400	5.00

TABLE 2: SAFE DISTANCE

Installed Total Impulse (N-sec)	Equivalent Motor type	Minimum Safe Distance (feet)	Complex Safe Dist.
160.01 - 320.00	H	50	100
320.01 - 640.00	I	100	200
640.01 - 1280.00	J	100	200
1280.01 - 2560.00	K	200	300
2560.01 - 5120.00	L	300	500
5120.01 - 10240.00	M	500	1,000
10240.01 - 20480.00	N	1,000	1,500
20480.01 - 40960.00	O	1,500	2,000