University of Hawai‘i
Windward Community College

University Student Launch Initiative
2010-2011

Critical Design Review
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I) Summary of CDR report

Team Summary

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  Kane‘ohe Hawai‘i 96744
- Dr. Joseph Ciotti (Principle Investigator)
- Dr. Jacob Hudson (Team Official)
- Helen Rapozo (IT Specialist)
- Kristi Ross
- Joleen Iwaniec
- Todd Esposito
- Patrick Lancaster
- Jasmine Maru

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 1000’ altitude.
- 10/10 rail with a length of 12’

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 PDR (w/ reason for change)

Changes made to Vehicle Criteria

We have since added detailed plans of the rocket. These diagrams cover the entire rocket, but focus on specific sections of the rocket. In doing so, greater detail of the particular area of the rocket can be reached, this will aid in the understanding of the physical components and layout of the rocket.

A comparison of the mass specifics given by the RocSim program and the actual weighed components caused us to re-evaluate our choice of motor selection. RocSim flight simulations, using mass over rides (more consistent with the actual component masses), using motors manufactured by Aerotech and Cesseroni (CTI) only, having diameters of 98-mm or 75-mm, taking the rocket to altitudes between 5280’ and 6864’ (target altitude + 30%) were performed, and an L1300R was the selected motor

Changes made to Payload Criteria

No changes to Windward Community College’s (WCC) payload have been made since the PDR. However, detailed information of the payload that will be carried in the rocket has been included.
Changes made to Activity Plan

There have been no changes in WCC’s team activity plan since the PDR.

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 final motor choice of an Aerotech L1300R was made. 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 1000 ft, 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

1. Boost Phase - Drag Brakes Deployed

2. Coast Phase

3. Apogee - Drogue Chute Deployed

4. Rapid Decent Phase

5. Main Decent Phase
**Major Milestone Schedule**  
(Project Initiation, Design, Manufacturing, Verification, Operations, and Major Reviews)

WCC’s major milestone schedule follows the USLI Timeline with the addition of our team’s specific events. The USLI Timeline we follow is out of the 2010-2011 University Student Launch Initiative Booklet. Our team specific events can be seen on the gantt plot. This gantt plot provides the team’s time line schedule for doing things, such as construction.
Design and Verification 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 expect a deployment angle of the VDC of ~3.5 degrees, to achieve the 5280 target.

**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
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 must be taken in its construction. Failure to construct an integrated body can lead to sudden (and detrimental) fragmentation on ascension. The motor mount and the body tube are constructed using a double filament wound (40° wind angle) epoxy fiberglass. The tubing is commercially available from Hawk Mountain Industries, and is extremely strong. All bulkheads will be constructed using \( \frac{1}{2} \) inch thick plywood, epoxied to the body. Here, as in all other places that call for epoxy, we are using two-part, 3 ton, slow cure epoxy.

An Aeropack 98-mm motor retainer will be attached to the aft bulkhead by means of 6 nut and bolt assemblies. What is not shown is the motor casing, with its threaded cap. It is at the cap where the final eyebolt is placed. 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 in the design proposal, 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. For this reason the idea of removing the fins for ease of transport has appeal. This year’s design 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. The fin is to be 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, but is fixed to the overall booster body tube.

Both the fin, and its associated fin-can, are made using annealed 6061 Aluminum (0.4-0.8% Si, <0.7% Fe, 0.15-0.40% Cu, < 0.15% Mn, 0.8-1.2% Mg, 0.04-0.35% Cr, <0.25% Zn, <0.15% Ti), having a density of 2.70 grams per cubic centimeter, a Young’s modulus of 10 Mega-psi, a maximum tensile strength of 18,000 psi, a maximum yield strength of 8,000 psi, and an elongation (stretch before ultimate failure) of 25-30%.
A concern about the obvious possible points of failure, the screws fastening the fin to the rocket, has been raised. An over estimate of the pulling force acting on a screw can be made. The net pulling force that would be acting on a screw is the sum of the drag force acting on a fin, and the inertial consideration of the fin itself. For our force estimate, we consider a fin of surface area \( A \) (i.e. area that is parallel to direction of travel)

\[
(1/2)(0.5\text{in})(6.0\text{in}) + (5.25\text{in})(6.0\text{in}) + (1/2)(10.25\text{in})(6.0\text{in}) = 63.5 \text{ square inches}
\]

(or \( 3.68 \times 10^{-2} \text{ m}^2 \)), a cross-sectional area \( A_{cs} \) (i.e. area that is perpendicular to direction of travel) of \( (0.1\text{in})(6.0\text{in}) = 0.6 \text{ square inches} \) (or \( 3.43 \times 10^{-4} \text{ m}^2 \)), and a mass of 238 grams. The drag force shall be considered first; a literature search shows that the coefficient \( C_D \), for objects impeding a fluid flow in a transverse manner, ranges in value from 1.0 to 2.0 depending on geometry; for our over estimate we shall take the extreme value of \( C_D = 2.0 \). This yields a drag force of...

\[
F_D = \frac{1}{2} C_D \rho A_{cs} v^2 = \frac{1}{2} (2.0)(1.29 \frac{k \text{g}}{m^2})(3.43 \times 10^{-4} \text{ m}^2)(223.52 \frac{m}{s})^2 = 22.11 \text{N}
\]

...where we have used our maximum RocSim speed of 223.52 m/s. This drag force translates to a torque on the fin. Taking the bottom-aft point of the fin as our point of rotation, and assuming that the drag force acts at the extreme span of the fin, we have a pulling force on the forward screw of...

\[
F = \left( \frac{S}{R} \right) F_D = \left( \frac{6.00''}{9.75''} \right)(16.4 \text{N}) = 10.1 \text{N}
\]

...where we have used \( S=6.00'' \) as our fin span, \( R=9.75'' \) as the distance, measured along the root edge, from the bottom aft of the fin to the location of the forward screw.
The inertial consideration of the fin requires use of the RocSim estimate for maximum acceleration, which is 125.4 m/s/s. This yields a force of...

\[ F_I = ma_{\text{max}} = (0.238 \text{kg})(125.4 \frac{m}{s^2}) = 29.8 \text{N} \]

Again, this force translates to a torque on the fin. Taking the force to act along a direction that is parallel to the fin root edge, and having a lever-arm distance equal to half the fin span distance, yields a pulling force on the forward screw of...

\[ F = \left( \frac{S/2}{R} \right) F_I = \left( \frac{3.00}{9.75} \right)(29.8 \text{N}) = 9.18 \text{N} \]

Using these results, we estimate a total pulling force on the forward screw of 10.1 N + 9.2 N = 19.3 N, or about 4.3 lbs. Whereas these results are for the forward screw, the force on the other screws should be lower than this result – at the very worst, it should not exceed this value.

**Extrusion Test**

A simple extrusion test was performed on the 8-32 BH (18/8 Stainless) screw threaded into an aluminum metal strip of the same composition and thickness of the aluminum fin-can. By varying the hanging masses, dependant from the screw, it was found that an extrusion force of 53 +/- 7.5 lbs was needed to strip
the screw from the aluminum. This is well above the estimated force that will be acting on the screw head. Additionally, the entire estimated force acting on the fin will be dispersed (though unevenly) over the six screws that attach the fin to the booster section. We believe this to be safe and acceptable.

**Variable Drag Configuration (VDC) / Drag shoes**

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 than 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...

\[
F_{D-Open} = \frac{1}{2} C_D \rho A_{Deployed} v^2 = \frac{1}{2} C_D \rho \pi r^2 \left[ 1 + \frac{2l}{r} \sin \theta \right] v^2
\]

...to the drag force for the situation where the drag shoes are not deployed...

\[
F_{D-Closed} = \frac{1}{2} C_D \rho A_o v^2 = \frac{1}{2} C_D \rho \pi r^2 v^2
\]

...for the same speed and assuming that the Drag Coefficients are roughly the same for both cases, we find that the drag force is enhanced by a factor of...

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

...where \( b = 4 \) for our design. A plot of this factor versus deployment angle results in concave down curve that is fairly linear for the first 30°. 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 this deployment range. The drag-shoe geometry for this year’s rocket is very similar to last year’s, and we are expecting similar results.
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. Subsequent testing of our expectations, using a 1:3.7 scale model has been performed. The scale model testing, using C11-3 motors over 16 flights, has shown that there is a pronounced loss in altitude for the first 15 degrees of deployment of our drag shoes. The altitude loss corresponds to ~2% +/- 0.5% loss for every degree deployed. For angles greater then 15 degrees, but less then 30 degrees, the loss in altitude was not as great. For this deployment range the altitude loss was ~1.2% +/- 0.5% loss for every degree deployed. For deployment angles greater then 30 degrees, the altitude loss corresponded to ~ 0.8% +/- 0.3% for every degree the shoes were deployed, and was pretty consistent out to a deployment angle of 45 degrees (the maximum angle tested). Our intention is to deploy out to an angle that is less then 30 degrees. Additional testing, consisting of one shoe in an unopened configuration, and the other deployed to various angles, showed the rocket to be stable throughout its flight profile. At large angles of the one shoe deployment tests, the rocket did develop a roll about its long axis, but was in all respects, safe.
**Avionics Section**

The main purpose of this section is to carry the on-board recovery electronics (Avionics). The center section consists of the avionics bay that will contain the necessary electronics. The body tube is to be constructed of the same tubing that the Booster section is made of. The avionics bay consists of a 7.5” long milled aluminum tube, bolted 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 will provide a rigid structure to support (and shroud) the avionics electronics should the rocket fail. Affixed to the forward avionics bay, as well as to the body tube, is a circular plywood bulkhead having a center-mounted eyebolt. The shock cord, associated with the main chute and connecting this part of the rocket to the booster section, is attached at this eyebolt. Another circular plywood bulkhead, also with a center mounted eyebolt, 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 will be removable for access to the avionics section, and is where the shock cord to payload section is attached. Both plywood bulkheads will have to have holes placed for the pyro charge wires to pass through (not shown). Also not shown is the ½” diameter hole that is to be drilled thru the body tube into the avionics bay, for the pressure sensor to equalize with ambient.

[Diagram Of Avionics On Next Page]
**Wiring Diagram of Avionics**

The wiring of the avionics electronic flight controllers is straight forward, and a block diagram follows:
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 inserted on top of the payload carrier lid, and held in place by means of 3 nylon screws (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 an eyebolt. The shock cord is also attached to the avionics section, and is where the drogue chute would be attached.
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, is to be fitted 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 to be attached to the fixed centering ring via 4 hex-head bolts and accompanying barrel nuts (the barrel nuts will be epoxied in place on the inside of the centering ring). This will allow the removal, preparation, and installation of the GPSFlight transceiver assembly required for the tracking of our rocket.
Mission Performance Predictions

USLROC2011
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

The graph shows a plot of acceleration (Feet/sec^2) against time. The acceleration starts at a high value, decreases rapidly, and then decreases gradually as time increases. The x-axis represents time, while the y-axis represents acceleration.
Velocity Vs Time
Wind and Mass Challenge Tests

Wind Challenge Test
(2.0 Kg Payload)

Wind Challenge Test
(1.5 Kg Payload)
Wind Challenge Test
(1.0 Kg Payload)
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 straightforward and follows...

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt (oz)</th>
<th>Est. CG (in)</th>
<th>(Wt.)r</th>
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<td>24</td>
<td>912</td>
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<td>GPS Flight</td>
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<td>24</td>
<td>1200</td>
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<td>185</td>
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<td>Experiment</td>
<td>50 (var.)</td>
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<tr>
<td>Main</td>
<td>20</td>
<td>83</td>
<td>1660</td>
</tr>
<tr>
<td>Fin/Fin-can</td>
<td>60</td>
<td>109</td>
<td>6540</td>
</tr>
<tr>
<td>VDC Assembly</td>
<td>10</td>
<td>119</td>
<td>1190</td>
</tr>
<tr>
<td>Cen. Ring</td>
<td>3</td>
<td>120</td>
<td>360</td>
</tr>
<tr>
<td>Motor Retainer</td>
<td>5</td>
<td>120</td>
<td>600</td>
</tr>
<tr>
<td>L1300R Motor</td>
<td>161</td>
<td>113</td>
<td>18193</td>
</tr>
</tbody>
</table>

\[
\sum (Wt.) = 719 \text{ oz.} \quad \sum (Wt.)r = 57,156 \text{ oz-in}
\]

Therefore:

\[
CG = \frac{\sum (Wt.)r}{\sum (Wt.)} = \frac{57,156}{719} = 79.49 \text{ inches from the nose cone tip.}
\]

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 6.49.
Preflight Checklist

Payload integrated to Leo Hano rocket

Rocket Pre-Flight:

- Payload Carrier Integrated to Payload Section
- Nosecone/GPS Flight 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
- (2) Drogue Chute Pyros (~3g, short leads) connected to Avionics Section
- Shock Cord Tether secured to Fore Blkhd Avionics Section
- 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 (via Motor Mount) secured to Fore Eye-bolt of Motor Casing
- Motor Inserted into Motor Mount and secured via Retaining Ring
- Drogue Pyros (2) connected to Avionics
- (2) Main Chute Pyros (4g, long leads) fed through Aft Avionics Blkhd
- Main Chute Pyros connected to Avionics
- Avionics inserted into Avionics Bay
- Aft Avionics Blkhd secured to Avionics Bay via (3) 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 Pyros placed against the Fore Blkhd of Booster Section
- Main Chute Packed
- Avionics/Booster Sections integrated
- 2 nylon shear pins inserted securing Avionics section to Booster

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

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
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 \( \sim 80 \text{ft/s} \). At an altitude of 1000 ft, a 144-inch main chute will be deployed, slowing the rocket descent rate to 22 \text{ft/s}, which we believe to be a safe descent rate.

Our main parachutes will be attached by quick links to shock an eyebolt on the bottom of the avionics section. Our drogue parachute will be attached via quick link to the eyebolt to the base of the payload section.

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 (\( \Phi_B \)) is changing within the coil.

\[
E = -N \frac{d\Phi_B}{dt} = -N \frac{d}{dt} \int B \cdot dA
\]
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 \( \mu = 8 \times 10^{22} \text{J/T} \) is the Earth’s magnetic dipole moment, \( \mu_o = 4\pi \times 10^{-7} \text{Tm/A} \) is the magnetic permeability constant, \( \lambda_m = 22.56^\circ \) is the magnetic latitude of Huntsville (this is based on the latitude of Huntsville being given by \( \lambda = 34.06^\circ \) combined with the \( 11.5^\circ \) offset between the rotational north pole and the magnetic north pole), and \( r = R_E = 6.4 \times 10^6 \text{m} \) is the radius of the Earth. These two expressions can be combined together...

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

...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 \( \phi \) with respect to the vertical, then the induced electromotive force at any instant of time is given by...

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

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

\[
\frac{dB}{dt} = \frac{dB}{dz} \frac{dz}{dt} = \frac{dB}{dz} v_z = v_z \frac{dB}{dz}
\]

...where \( v_z \) is the ascent rate of the rocket. The above then reduces the equation for the induced electromotive force to:
\[ E = -NA \left( v \frac{dB}{dz} \cos \phi - B \sin \phi \frac{d\phi}{dt} \right) = -NA \left( v \frac{dB_\perp}{dz} - B_{11} \frac{d\phi}{dt} \right) \]

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 (\( \sim v \frac{dB_\perp}{dz} \)), and a pitch-over term (\( \sim B_{11} \frac{d\phi}{dt} \)). 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...

\[
E_{\text{Ascent}} = -NAv \frac{dB}{dz} = -NAv \frac{d}{dz} v \left( \frac{\mu \mu_0}{4\pi R_E^3} \sin \lambda_m \right)
\]

\[
\approx 6NAv \left( \frac{\mu \mu_0}{4\pi R_E^3} \right) \sin \lambda_m \frac{R_E}{600m} \left( 3.06 \times 10^{-5}T \right) \frac{\sin 22.56^\circ}{6.4 \times 10^6m}
\]

\[
\approx N \left( 1.78 \times 10^{-10}V \right) = 17.8nV
\]

...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.

\[ E_{\text{Apogee}} = -NA \frac{\Delta B}{t} = -NA \frac{B_{11} - B_\perp}{t} \]

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

\[
B_{11} = B_H = \left( \frac{\mu \mu_0}{4\pi R_E^3} \right) \cos \lambda_m = \left( 3.05 \times 10^{-5}T \right) \cos 22.56^\circ = 28.2\mu T
\]
\[ B_\perp = B_v = \left( \frac{\mu \mu_o}{2\pi R_E^3} \right) \sin\lambda_m = 2 \left( \frac{\mu \mu_o}{4\pi R_E^3} \right) \sin\lambda_m = 2 \left( 3.05 \times 10^{-5} T \right) \sin 22.56^\circ \approx 23.4 \mu T \]

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

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

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 (\(~12.5\text{nV}\) on ascent, and \(~3.9 \text{mV}\) 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 be the actual payload flown for the USLI 2011 event, having three magnetic axis, more storage and sensors.

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:

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

**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/212). 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:
- Parallax Basic Stamp 2p – controller
- Analog Devices Inc. AD7714YNZ – ADC
- National Semiconductor LM34 – temperature sensor
- Microchip Technology MCP3202 – ADC
- Freescale Semiconductor MMA7455 – accelerometer
- Hula-hoop coil

The Analog Devices Inc. AD7714YNZ is a 24-bit ADC, so its sensitivity is at 0.298 µV or 2.98 x 10^-7 volts with V_REF at 5 volts (5 volts/224). The AD7714YNZ also has a pin so that one can set a higher minimum voltage for its detection range. We will be trying to use this project on our small to medium rockets.

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

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

This project will be flown for the USLI 2011. We will be using at least eight 24LC512 EEPROMs for this setup, which should yield 512 Kbytes of storage. At a sample rate of 5Hz, this should allow us an extended pad time of ~60 min, a flight duration of ~7 min, and a rocket retrieval time of ~30 min.
(Left Blank Intentionally)
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V) Safety

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

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

### Deployment Safety and Failure analysis

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Cause</th>
<th>Effects</th>
<th>Risk Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drogue chute deployment failure</td>
<td>Main avionics failure</td>
<td>Rocket craters</td>
<td>Back-up Avionics</td>
</tr>
<tr>
<td>Main chute deployment failure</td>
<td>Main avionics failure</td>
<td>Rocket craters</td>
<td>Back-up Avionics</td>
</tr>
<tr>
<td>Drogue chute deployment failure</td>
<td>Main and back-up avionics failure</td>
<td>Rocket craters</td>
<td>Checklist for avionics</td>
</tr>
<tr>
<td>Main chute deployment failure</td>
<td>Main and back-up avionics failure</td>
<td>Rocket craters</td>
<td>Checklist for avionics</td>
</tr>
<tr>
<td>Drogue chute deployment failure</td>
<td>Main pyro failure</td>
<td>Rocket craters</td>
<td>Back-up pyro</td>
</tr>
<tr>
<td>Main chute deployment failure</td>
<td>Main and back-up pyro failure</td>
<td>Rocket craters</td>
<td>Checklist for avionics</td>
</tr>
<tr>
<td>Separation of sections</td>
<td>Shock cord severed</td>
<td>Falling debris, rocket damage</td>
<td>Checklist, preflight checks, and undamaged shock cored</td>
</tr>
<tr>
<td>Separation of sections</td>
<td>Shock cord anchor points</td>
<td>Falling debris, rocket damage</td>
<td>Checklist, preflight checks</td>
</tr>
</tbody>
</table>
Hazard Mitigation List

In addition to all the mitigation tactics listed below the team will always maintain good hygiene and a clean work environment

<table>
<thead>
<tr>
<th>Materials</th>
<th>Risk</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenolic Powder-Black</td>
<td>Ingestion Hazards, Skin Irritation, Eye Irritation, Respiratory Irritation from Dust</td>
<td>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.</td>
</tr>
<tr>
<td>Phenolic Resin</td>
<td>Toxic Fumes, Skin Irritation, Eye Irritation</td>
<td>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.</td>
</tr>
<tr>
<td>Copperhead igniter</td>
<td>Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin</td>
<td>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.</td>
</tr>
<tr>
<td>Type</td>
<td>Hazards</td>
<td>Precautions</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FirstFire Igniter</td>
<td>Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin</td>
<td>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.</td>
</tr>
<tr>
<td>FirstFire Jr Igniter</td>
<td>Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin</td>
<td>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.</td>
</tr>
<tr>
<td>Rocket Propellant</td>
<td>Skin Irritation, Inadvertent Ignition, Burns to skin</td>
<td>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.</td>
</tr>
<tr>
<td>Material</td>
<td>Hazard</td>
<td>Safety Precautions</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Epoxy Resin</td>
<td>Toxic Fumes, Skin Irritation, Eye Irritation</td>
<td>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</td>
</tr>
<tr>
<td>5-Minute Epoxy Resin</td>
<td>Toxic Fumes, Skin Irritation, Eye Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Sinmast 4 Epoxy Mortar Mix - Normal Cure</td>
<td>Ingestion Hazards, Skin Irritation, Eye Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Compressed Carbon Fiber Sheets</td>
<td>Inhalation Hazards, Eye Irritation, Skin Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Fiber Glass Cloth</td>
<td>Inhalation Hazards, Eye Irritation, Skin Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Material</td>
<td>Hazards</td>
<td>Precautions</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>Ingestion Hazards</td>
<td>Team Members will wear face masks at all times to prevent Ingestion of Material</td>
</tr>
<tr>
<td>Polystyrene Foam</td>
<td>Ingestion Hazards, Skin Irritation, Eye Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Duct Tape</td>
<td>Skin Irritation, Eye Irritation</td>
<td>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</td>
</tr>
<tr>
<td>Masking Tape</td>
<td>No Risks Stated</td>
<td></td>
</tr>
<tr>
<td>Super Glue</td>
<td>Toxic Fumes, Ingestion Hazards, Eye Irritation, Skin Irritation</td>
<td>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.</td>
</tr>
<tr>
<td>Acetone</td>
<td>Toxic Fumes, Ingestion Hazards, Eye Irritation, Skin Irritation</td>
<td>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.</td>
</tr>
<tr>
<td>Mineral Spirits</td>
<td>Severe Eye Irritation, Skin irritation, Ingestion hazards</td>
<td>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. Goggles will be worn at all times to prevent eye irritation.</td>
</tr>
<tr>
<td>Substance</td>
<td>Hazards</td>
<td>Precautions</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Denatured Alcohol</td>
<td>Toxic Fumes, Ingestion Hazards, Eye Irritation</td>
<td>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.</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>Inhalation Hazards</td>
<td>Team members will work in a well-ventilated area to prevent inhalation hazards.</td>
</tr>
<tr>
<td>Silicone Lube</td>
<td>Ingestion Hazards, Skin Irritation, Eye Irritation, Toxic Fumes</td>
<td>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.</td>
</tr>
</tbody>
</table>
| 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.
<table>
<thead>
<tr>
<th>Isopropyl Rubbing Alcohol</th>
<th>Toxic Fumes, Ingestion, Hazards, Eye Irritation, Inadvertent Ignition, Burns to Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Powder</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>
VI) Activity Plan

Educational Engagement

The USLI team at Windward Community College devoted many successful hours into building stronger community ties which has 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 O'lelo we will close the inter-island communication gap. Our plans for the local show O'lelo are underway. We have a plan for a half an hour television program in which will describe 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.). This approach will be 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 will be 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 will 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.

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 through 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. Additionally, 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

10 Feb. - 1st draft O'lelo story-board
14 Feb. - Valentine's Day *kisses*
15 Feb. - Distribute pamphlets
19 Feb. - Community Launch
21 Feb. - Begin TV shoot, and editing, for Olelo
         - Outreach with Iwakuni AFB, Japan project payload
13 March - Full-Scale Low-Power (FSLP) launch at KMCAS
19 March - Community Launch
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:
#### Estimated Rocket Cost

<table>
<thead>
<tr>
<th>Part:</th>
<th>Price Each</th>
<th>Quantity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Tube (FT-6.0)</td>
<td>$45.32</td>
<td>10 ft</td>
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<td>Nosecone (FNC-6.0 30.5” ogive)</td>
<td>$89.95</td>
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<td>$89.95</td>
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<td>Coupler (CT-6.0, 16” length)</td>
<td>$68.00</td>
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<td>Aluminum Fins/Can assembly</td>
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<tr>
<td>Centering Rings (FCR-6.0-3.9)</td>
<td>$16.00</td>
<td>2</td>
<td>$32.00</td>
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<tr>
<td>Bulkheads (CBP-6.0)</td>
<td>$5.93</td>
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<tr>
<td>Motor Tube (FTEX2-3.91, 36”)</td>
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<td>$58.92</td>
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<tr>
<td>Drogue Chute (32”)</td>
<td>$35.00</td>
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<td>$35.00</td>
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<tr>
<td>Main Chute (108”)</td>
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<td>Shock Cord (1” thick)</td>
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<td>Kevlar Patch (9”)</td>
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<td>Kevlar Patch (16”)</td>
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<td>Aero-Pack 98 mm Motor retainer</td>
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<td>Aero-Pack 98-75 mm motor adapter</td>
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<td>$45.00</td>
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Subtotal                                  $1,153.93

### Estimated Avionics/Electronics Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Price Each</th>
<th>Quantity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PerfectFlight MiniAlt/WD</td>
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<tr>
<td>Featherweight Raven-2</td>
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<tr>
<td>GPSFlight (ST900e)</td>
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<td>$695.00</td>
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<tr>
<td>GPS-P25 (Patch antenna)</td>
<td>$30.00</td>
<td>1</td>
<td>$30.00</td>
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<tr>
<td>RPSMA900 (trans. antenna)</td>
<td>$18.00</td>
<td>1</td>
<td>$18.00</td>
</tr>
<tr>
<td>Li-Po Battery Pack</td>
<td>$150.00</td>
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<td>$150.00</td>
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<tr>
<td>9V Dry Cell</td>
<td>$2.99</td>
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<td>$11.96</td>
</tr>
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Subtotal                                  $1,159.91
## Estimated Payload Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Vendor</th>
<th>Part #</th>
<th>qty</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Stamp 2p</td>
<td>Parallax</td>
<td>BS2P24</td>
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<td>$79.00</td>
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<tr>
<td>8 channel 12-bit A/D Converter with SPI Serial Interface</td>
<td>Parallax</td>
<td>604-00062</td>
<td>1</td>
<td>$5.22</td>
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<tr>
<td>MMA7455 3-Axis Accelerometer Module</td>
<td>Parallax</td>
<td>28626</td>
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<tr>
<td>LM34 Temperature Sensor</td>
<td>Parallax</td>
<td>604-00011</td>
<td>1</td>
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</tr>
<tr>
<td>3 inch Jumper wires</td>
<td>Parallax</td>
<td>800-00016</td>
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<tr>
<td>BASIC Stamp Syntax and Reference Manual V2.2</td>
<td>Parallax</td>
<td>27218</td>
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<tr>
<td>Basic Analog and Digital Text V1.4</td>
<td>Parallax</td>
<td>27220</td>
<td>1</td>
<td>$24.99</td>
</tr>
<tr>
<td>StampWorks Manual</td>
<td>Parallax</td>
<td>28129</td>
<td>1</td>
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<td>Applied Sensors Text v2.0</td>
<td>Parallax</td>
<td>28127</td>
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<td>Smart Sensors and Applications Text</td>
<td>Parallax</td>
<td>122-28029</td>
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<tr>
<td>Process Control Text</td>
<td>Parallax</td>
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<tr>
<td>IC ADC 24BIT SIGMA-DELTA 24-DIP</td>
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<td>EEPROM - 64Kbytes</td>
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<td>24LC512-1/P-ND</td>
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Subtotal                                                                                      $538.16

## Budget Total

<table>
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<tr>
<th>Description</th>
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<tr>
<td>Rocket Body/Construction</td>
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<tr>
<td>Rocket Avionics/Electronics</td>
<td>$1,159.91</td>
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<tr>
<td>Payload</td>
<td>$538.16</td>
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<tr>
<td><strong>Total:</strong></td>
<td><strong>$2,852.00</strong></td>
</tr>
</tbody>
</table>
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
- 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: [1.1300R-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
- Hawai'i 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](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.


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.

**Motors**

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.

**Weight and Power Limits.**

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.

**Launch Site.**

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.

**Launcher Location**

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.

**Safe Distances**

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

<table>
<thead>
<tr>
<th>Installed Total Impulse (N-sec)</th>
<th>Equivalent Motor type</th>
<th>Minimum Site Distance (feet)</th>
<th>Equivalent Dist. (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>160.01 - 320.00</td>
<td>H</td>
<td>1,500</td>
<td>0.28</td>
</tr>
<tr>
<td>320.01 - 640.00</td>
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<td>0.50</td>
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<td>1.00</td>
</tr>
<tr>
<td>1280.01 - 2560.00</td>
<td>K</td>
<td>5,280</td>
<td>1.00</td>
</tr>
<tr>
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<td>10,560</td>
<td>2.00</td>
</tr>
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<tr>
<td>20480.01 - 40960.00</td>
<td>O</td>
<td>26,400</td>
<td>5.00</td>
</tr>
</tbody>
</table>

### TABLE 2: SAFE DISTANCE

<table>
<thead>
<tr>
<th>Installed Total Impulse (N-sec)</th>
<th>Equivalent Motor type</th>
<th>Minimum Safe Distance (feet)</th>
<th>Complex Safe Dist.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>100</td>
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<tr>
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<td>I</td>
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<td>640.01 - 1280.00</td>
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<td>200</td>
</tr>
<tr>
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<td>K</td>
<td>200</td>
<td>300</td>
</tr>
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<td>2560.01 - 5120.00</td>
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<tr>
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