University of Hawaii

Windward Community College Campus

University Student Launch Initiative
2012-2013

Critical Design Review
(CDR)

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1.0 CDR Summary

1.1 Team

1.1.1 Team Name

Ke kime kao lele keu loa

1.1.2 Location

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

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

1.1.3 Team Summary

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

1.1.4 Team Official

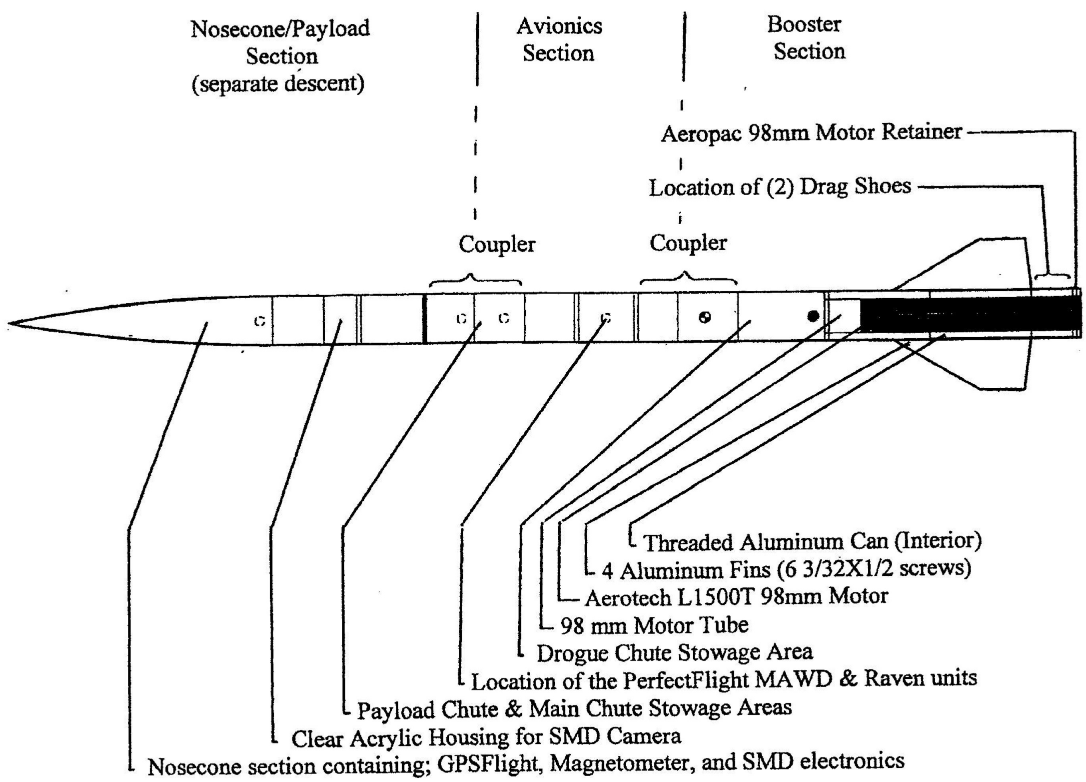
Dr. Jacob Hudson (Team Official) is the Coordinator for the NASA Aerospace Education "Flight Lab" facility, and a lecturer of Physics and Astronomy at the Windward campus of the University of Hawaii. Dr. Hudson has been developing the curriculum for an introduction to Rocket Sciences, which will be integrated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

1.2 Launch Vehicle Summary

- The team rocket is to be 124 inches in length, with a 6 inch diameter.
- The rocket has an estimated loaded weight of just over 45lbs.
- The rocket is designed to accept an Aerotech L1500T 98-mm diameter motor fitted into an AeroPac 98 mm motor retainer. We estimate this motor yields a thrust to weight ratio of 7.4.
- The rocket is designed to have a dual deployment recovery system incorporating a 42-inch drogue deployed at apogee. This will cause a descent rate of ~70 feet per second. A 144-inch main chute is to be deployed at 2500 feet altitude, causing the final descent rate to be~21 feet per second.
- The rocket is designed for an 8 foot launch rail. According to our simulation results, our rocket reached the minimum safe speed at a height of 68 inches. We are planning on using 10-10 standard rail buttons for our rail guidance. Having a separation distance of 18 inches between the two buttons, and an offset distance between the bottom of the rocket and the lower button of 4 inches, yields a launch rail length of 95 inches (~8 ft).

Team Hawaii
USLI 2012 – 2013
Proposed Rocket Design

Length:	124 inches	**CG (from tip):**	81.70 inches
Mass (w/motor):	724 ounces	**CP (from tip):**	98.73 inches
Motor:	L1500T	**Stability:**	2.84
Casing:	98/7680	**Thr:wt Ratio:**	7.4



1.3 Payload Summary

This years' payload consists of a hybridization of two parts; a magnetometer in parallel with three accelerometers, and an Arduino ScienTific Research

Interaction Device (ASTRID), our version of the Science Mission Directorate (SMD). The payload project is affectionately named "Wilfred" from the FX show of the same name.

The magnetometers' purpose is to passively 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 (read Whiffle ball). 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 along with concurrent accelerometer data can be used to determine the rocket's orientation throughout the flight. The study is to determine whether orientation of the rocket can be determined given induced voltage values alone.

The magnetometer will be hybridized along with our SMD project called ASTRID. This part of the payload shall fulfill the following conditions:

- The payload shall take data for studying the atmosphere during descent and after landing. Measurements shall include pressure, temperature, relative humidity, solar irradiance and ultraviolet.
- Measurements shall be made every 5 seconds on descent and every 60 seconds after landing. Surface data collection operations shall terminate 10 minutes after landing.
- The payload shall take at least two pictures on descent, and three after landing.
- The payload shall remain in an orientation during descent and after landing such that the pictures taken portray the sky toward the top of the frame and the ground toward the bottom of the frame.
- The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations.
- The payload shall carry a GPS tracking unit. Minimum separation altitude shall be 2500.

A more detailed description of our payloads is given in the payload section.

2.0 Changes Made Since Preliminary Design

2.1 Flight profile changes

No significant changes have been made to the flight profile since PDR. A few minor changes have been made to the vehicle. We have decided to have the payload section have only a small portion of the clear tubing instead of the entire section. Also, the avionics section of the rocket will be shortened from 24 in to 18 in, and the payload section will be longer from 24 in to 27 in.

2.2 Changes made to Payload

A change made to the payload since the Preliminary Design Review is that we decided to use the Arduino Mega 2560 R3 instead of the Arduino Mega 1280. Due to availability it was decided to go with this updated version of the Mega. Additionally, due to inexperience and budget, we also decided not to have a custom circuit board fabricated for our payload. Purchasing shields for the Mega would be more cost efficient than creating circuit boards.

2.3 Changes Made to Activity Plan

No significant changes have been made to the activity plan since PDR.

3.0 Vehicle Criteria

3.1 Mission

3.1.1 Mission Statement

In general, with outreach being the main focus of WCC's USLI Variable Drag Configuration (VDC) rocket, our vehicle must be able to successfully carry different payloads for various outreach projects. These payloads must stay within our dimensional and weight limitations to guarantee the safety of the rocket, payload, and observers. As well as to ensure that it will be successfully recovered.

In order to continue its efforts at promulgating interests in science, technology, engineering, and mathematics, the 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 VDC system, consisting of two external drag shoes, and different engine selections. It will also have the ability to maintain 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. The 'voice-over' will not be used for the USLI launch. its launchers. The targeted altitude can change with the incorporation of our VDC system, consisting of two external drag shoes, and different engine selections. It will also have the ability to maintain 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. The 'voice-over' will not be used for the USLI launch.

3.1.2 Mission Requirement and Success Criteria

Vehicle Full success: Project flies as designed
Vehicle Partial success: Deployment of payload and main chute too early
Any other vehicle design malfunctions result in a flight failure.

For our team, we feel a full payload success would be obtaining data from all components along with a complete wireless transmission. A partial payload success would constitute full or partial data collection with transmission. A partial failure would be full or partial data collection with no transmission. A full failure, for our team, would be no data collection and no transmission.

Vehicle Requirement	Verification	Status
Vehicle shall deliver a scientific payload to a mile	Vehicle is designed with a payload carrier for delivering a scientific payload of not larger than a specific size to a predetermined altitude.	Ready for construction
Commercially available barometric pressure sensor for altitude	Perfect Flight Feather Weight Raven	Purchased and flight tested
Vehicle shall remain subsonic	Hand calculations and RocSim confirm	We will remain subsonic
Vehicle shall be reusable	Vehicle shall be reusable	Vehicle shall be reusable
Vehicle shall have a max of four independent sections	Vehicle sections include a booster section, avionics section, payload section, and nosecone. The payload will not be deployed from the vehicle.	Ready for construction
Vehicle shall be launch ready in two hours with a pad life of an hour	Vehicle preparation will take less than two hours. We will use new batteries to insure pad life can be a minimum of one hour.	After rocket construction, requirement will be satisfied
Motor shall be commercially bought no higher than a L-class	L1500T	Will be purchased closer to the launch date
Teams shall conduct a full scale test of their rocket	We will conduct a full scale test on the Marine Base	March 3, 2013
Vehicle shall cost no more than $5000 on the pad	Estimated cost $3200	Confident the price will not exceed the cap price of $5000
Capable of launching on an eight foot launch rail	Calculations and RocSim confirm we reach the safe speed before the 8 feet	Confident of rocket stability
Shall be capable of being launched by the standard launch equipment provided at the range	We will used all standard launch procedures and equipment	Once constructed, the vehicle will be compatible
Recovery System Requirements	**Verification**	**Status**

Duel deployment	We will used redundant systems to ensure the deployment of both chutes	Full scale test will confirm, we are very confident in our avionics
Each independent piece of the rocket shall have a kinetic energy that does not exceed 75 foot pounds	After calculations, all of the pieces do not exceed the limit	The booster section is very close to the limit, we are working at cutting the weight
Designed to land within 2500 ft of the launch pad with 15 mph wind	Calculations show that we will not drift out of the distance.	If the winds are higher than 15 mph we have calculated if we deploy our chute at 1950 feet we will stay within the bounds
Avionics shall be independent, redundant, commercially available, contain a dedicated power supply, shall not be interfered with by any other electronics and be locked on the pad for launch, and be 6 feet above the base of the vehicle	We have purchased and designed avionics to meet all the requirements	We are very confident in the design it has been tested in flight and has never had any issues.
Shall use low current commercially available e-matches	Designed to comply	We will purchase new e-matches to insure their reliability.
Payload Requirement	**Verification**	**Status**
Gather atmospheric data (pressure, temperature, humidity, solar irradiance, and ultraviolet radiation) during descent and landing Voltage readings across coils	BMP085 sensor to gather pressure, temperature, and altitude. DHT11 sensor is used to gather the relative humidity. Two TSL2561 light sensors are used to measure solar irradiance and ultraviolet radiation data. A filter will be used on one of the	All sensors have been tested individually. Sub-system testing has been done with the DHT11 and camera with the micro-SD. The sensors are wired as a system and coding is currently being worked on.

	light sensors when measuring UV. 3 perpendicular coils wrapped around a nonmagnetic sphere with A/D converters.	
Measurements made at least every 5 seconds	We plan to program our sensors to gather data every second after apogee.	We have not been able to test this as a system yet. It was tested for each individual sensor. It will be tested again when the components have been integrated together.
Measurements made every 60 seconds after landing	We plan to program our sensors to gather data every minute once the payload has landed.	We haven't been able to test this yet. We will test through a mock simulation of a launch with the payload unit. We will also test this during test launches (if we are granted access to Kaneohe Marine Corps Base).
Surface data collection should stop after 10 minutes of landing	We plan to program our sensors to cease data collection once it has been landed for 10 minutes.	We have not been able to test this yet. The payload contains a Real Time Clock, and will be using the data from the accelerometer to understand that it has been on the ground for 10 minutes. We will also test this through the simulation of a launch using the payload unit and also during a test launch.
Payload should take at least 2 pictures during descent and 3 on the ground	We plan to have the camera take three pictures, one every 1000 feet. Once it has	We have not been able to test this yet. This will be tested through mock

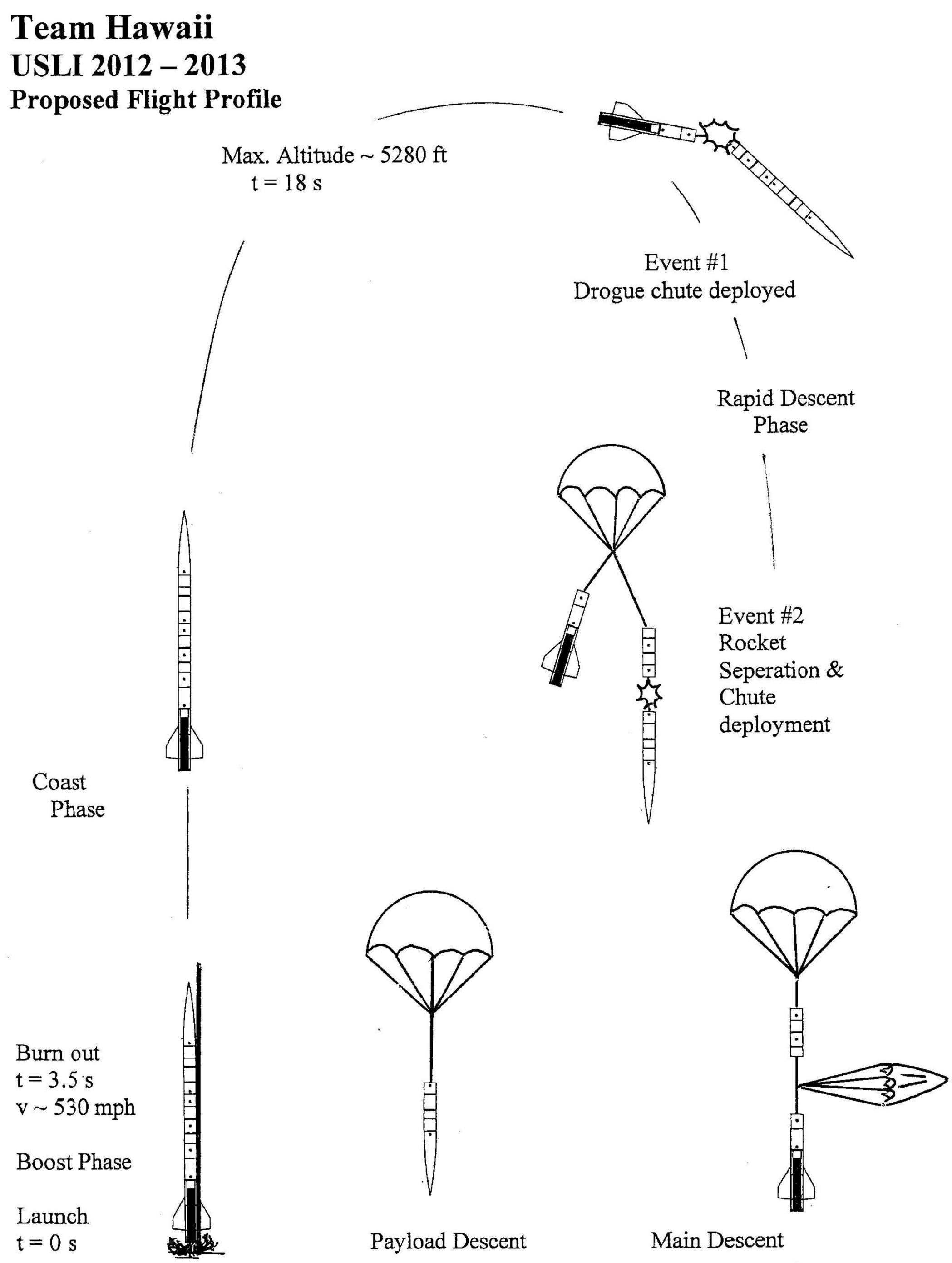
	landed we plan for the camera to take a picture once every minute.	simulations and during test launches.
Camera should remain in orientation during descent and upon landing	We plan to fulfill this requirement by weighting the end of the camera. Using its own weight, the camera will orientate itself.	We have not been able to start testing for this unit being that we would like to construct a special area for the camera in the rocket.
The data from the payload shall be stored onboard and transmitted wirelessly to the team's ground station at the time of completion of all surface operations	To fulfill this requirement, we plan to have all data be stored to micro SD cards. The data would be transmitted wirelessly using a 3DR Radio Telemetry.	We have not been able to test this part of the unit yet. Prior to testing the transmitter with the sensors, we would like to test the transmitter itself to ensure it fulfills the requirement of transmitting data at a range of a mile. We will be testing if data can store when the individual sensors are tested and when the components are incorporated.
Separation of payload components at apogee will be allowed, but not advised	Our payload itself is not being deployed. To ensure that the requirement is met, we have made sure to tether it to the nosecone of our rocket.	This will be tested during a test launch.
Payload should carry a GPS unit	We have include the GPSflight SD-900 to our payload unit	We will be testing this unit separately and with other components to ensure it works.
Minimum separation altitude shall be 2,500	We plan for our payload to separate at	We would like to test this deployment, but

feet AGL	2,500 feet.	due to ceiling cap in Hawaii, we are not able to do a full launch. We will do a smaller scale launch with separation.

3.2 Flight

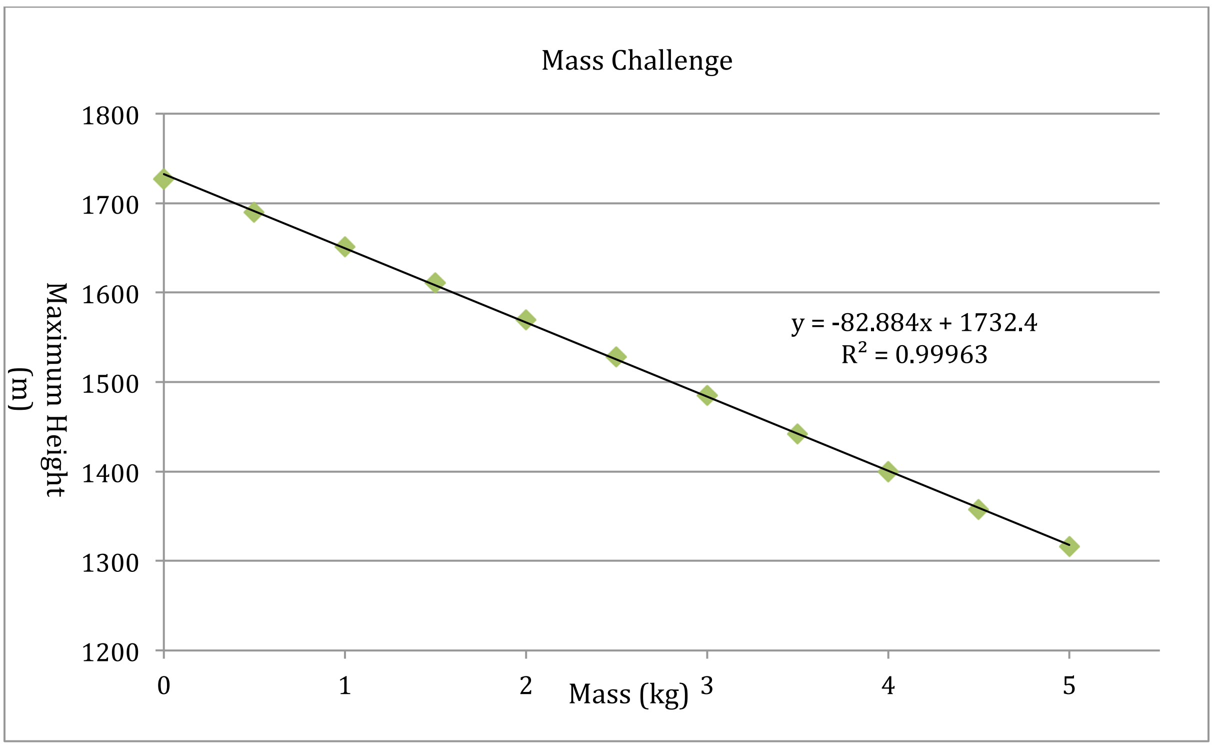
3.2.1 Flight Profile Diagram

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 L1500T motor will produce an average thrust of 380 lbs (giving us a thrust to weight ratio of ~7), with a burn time of just over 3 seconds. The maximum estimated acceleration is ~10 g's (334 ft/s/s, or ~103 m/s/s), with an estimated maximum speed of ~430 mile/hr (~630 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 ~ 80 ft/s. When the descending rocket reaches an altitude of 2500' a 144-inch main chute will be deployed, slowing the rocket descent rate to less than 24 ft/s, which we believe to be a safe descent rate. Also at that height, the nosecone (containing the magnetometer and SMD) will separate from the rest of the rocket and descend under a separate chute.


Team Hawaii
USLI 2012 – 2013
Proposed Flight Profile
Max. Altitude ~ 5280 ft
t = 18 s
Event #1
Drogue chute deployed
Rapid Descent Phase
Event #2
Rocket Seperation &
Chute deployment
Coast Phase
Burn out
t = 3.5 s
v ~ 530 mph
Boost Phase
Launch
t = 0 s
Payload Descent
Main Descent

3.2.2 Mass Challenge

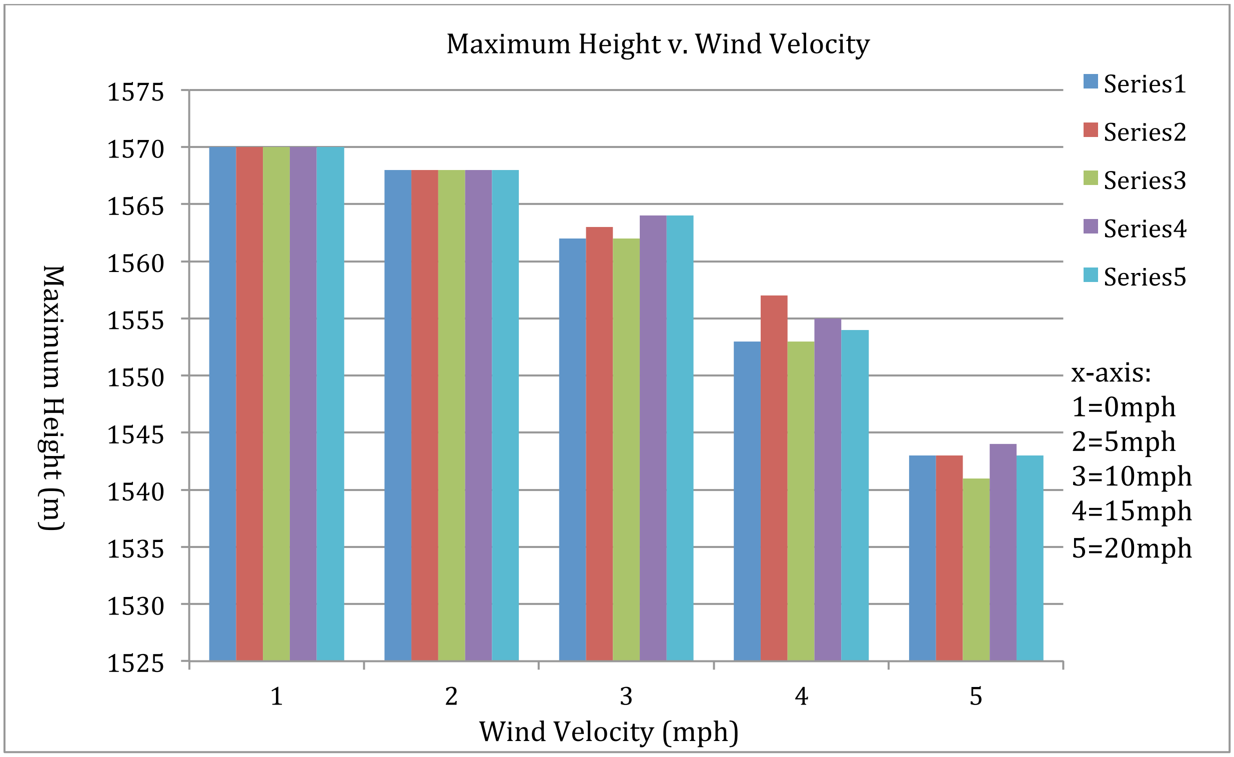
Estimation of the payload mass, as well as incidental mass increase involved with the construction of the rocket has been made as accurate as possible. However, since no one on the team claims to be a prognosticator, concern about a variation in the mass of the final design was raised. Since the final lift-off mass has a direct relation to the overall flight characteristics of rocket, as well as to safety concerns, this issue is a concern. Using the OpenRocket flight simulations, an estimate of the apogee of the rocket, varying the payload mass of the rocket were run and the results are presented below. Each data point represents the average altitude of 5 simulated flights.



What is clear is that, if possible, the mass of the payload (and any other incidental mass increase) should be less than 1.5 kg in order for us to reach one mile altitude (1625 m).

3.2.3 Wind Challenge

A concern about how the ambient winds will affect our estimations in rocket apogee was considered. Using OpenRocket simulations and an estimated payload mass of 2.0 kg. Each wind velocity was run five times, and the data is presented below.



Since the same wind that affects the apogee of the rocket can also have a tremendous effect on the drift distance of the descending rocket, we also considered the lateral drift distance at the same time. The following results were obtained from the RocSim flight simulations for various payload masses.

Lateral Drift Distance (Main chute deployment at 2,500ft.)
0-2 mph wind
0.0 kg. payload: 202 ft
0.5 kg payload: 197.6 ft
1.0 kg payload: 186 ft
1.5 kg payload: 150.4 ft
2.0 kg payload: 136.2 ft
3-7 mph wind
0.0 kg. payload: 920 ft
0.5 kg payload: 788 ft
1.0 kg payload: 758 ft
1.5 kg payload: 692 ft
2.0 kg payload: 645 ft

8-14 mph wind
0.0 kg. payload: 2050 ft
0.5 kg payload: 1800 ft
1.0 kg payload: 1660 ft
1.5 kg payload: 1610 ft
2.0 kg payload: 1490 ft
15-25 mph wind
0.0 kg. payload: 3890 ft.
0.5 kg payload: 3800 ft.
1.0 kg payload: 3390 ft.
1.5 kg payload: 3130 ft.
2.0 kg payload: 2960 ft.

We are aware that the max lateral drift distanced allowed is 2,500ft. The only time we are shown to go over that is in extreme wind conditions. We are not planning to launch if the wind speeds are above 15 MPH. However, should it be that permission for a lower main chute deployment altitude is allowed, and safety is not mitigated, we could launch with a main chute deployment altitude lowered to 1950 feet from the required 2500 feet. Several OpenRocket simulations were run using this lower deployment altitude, under high wind conditions, the average lateral drift distance worked out to be 1776 feet +/- 53 feet, which is well below the maximum drift limit.

3.3 Vehicle

3.3.1 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 than 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. After reviewing data from two successful full-scale flights of the rocket at a previous ARLISS launch, we came to the conclusion that the L1500 was within acceptable limits for our rocket.

In the absence of air resistance, the maximum height a rocket will ascend to under a vertical launch situation is given by summing the height at motor burn-out and the height the rocket will coast to thereafter. As it turns out, a height determination can be found from knowing the mass of the rocket and the mass of the un-burned and then burned motor. If M_o is the initial lift-off mass of the rocket, M is the mass of the rocket at burnout, and $\dot{M} = (M_o - M)/t_{bo}$ is how quickly the motor is ejecting mass at an assumed constant speed of v_e.

$$h = \left\{ v_{ex} \frac{M_o}{\dot{M}} \left[1 - \frac{M}{M_o} \left(\ln \frac{M_o}{M} + 1 \right) \right] - \frac{g}{2} \left(\frac{M_o}{\dot{M}} \right)^2 \left(1 - \frac{M}{M_o} \right)^2 \right\} + \left\{ \frac{1}{2g} \left[v_{ex} \ln \frac{M_o}{M} - g \frac{M_o}{\dot{M}} \left(1 - \frac{M}{M_o} \right) \right]^2 \right\}$$

Whereas this method appears to give us all the information that we would require to make a proper motor selection, it does however neglect air friction, which we have found to be significant – especially with our variable air drag assembly. To get a sense of how much air friction plays apart, using flight data from a previous flight, a theoretical height determination using the above relation can be made. Last year's rocket had a pad weight of 27.7 kg, a propellant mass of 2.35 kg, a motor burn-time of 3.3 s, and a given Impulse I of 5120 Ns. These values combine to yield a mass loss rate of $\dot{M} = 0.712$ kg/s, an average thrust of $(\bar{F} = I/t)$ 1470 N, and an exhaust velocity $(v_{ex} = \bar{F}/\dot{M})$ of 2065 m/s. Insertion of these values into the above yields an estimated altitude for the rocket of 13,295 meters. The actual height attained was 1519 m; roughly, only 11% of the estimated height.

The better way to establish a height determination would be to deal with discrete time elements, determining the motor mass loss, the average acceleration for that time interval, the instantaneous velocity at the end of that time interval, the drag force at the end of the time interval, which is then used to determine the next time interval's average acceleration, and the whole process is then iterated until a maximum height (corresponding to a zero vertical velocity) is reached. This is what OpenRocket and RocSim does for us - in a very much quicker manner than done by hand, we might add.

Determination of the motor that is to be used in USLI was problematic. It is our plan to over-power the rocket to carry a payload to a height greater than 1 mile. By suitably deploying drag shoes (open to a specific angle with respect to the rocket body) throughout the flight, along with an estimated 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 choice of the L1500 motor.

Subsequent flights using a rocket very similar in design to that of our present design, using an Aerotech L1300 motor, never reached an altitude greater than 4550 feet (with zero-degree deployed drag shoes). RocSim had estimated a maximum height of 5648 feet. This corresponds to a difference between expected and actual of 19.4%. Because of this, we decided to target an altitude above 6400'. Subsequent RocSim results suggested an Aerotech L1500T, which predicts a maximum height of 6722'. OpenRocket yields an estimated altitude for the same motor of 5525'. Either way, this corresponds to an estimated drag-shoe deployment angle of 1 to 6 degrees. We are aware of the USLI protocol that forbids us about exceeding 5600' – something that we will endeavor not to do.

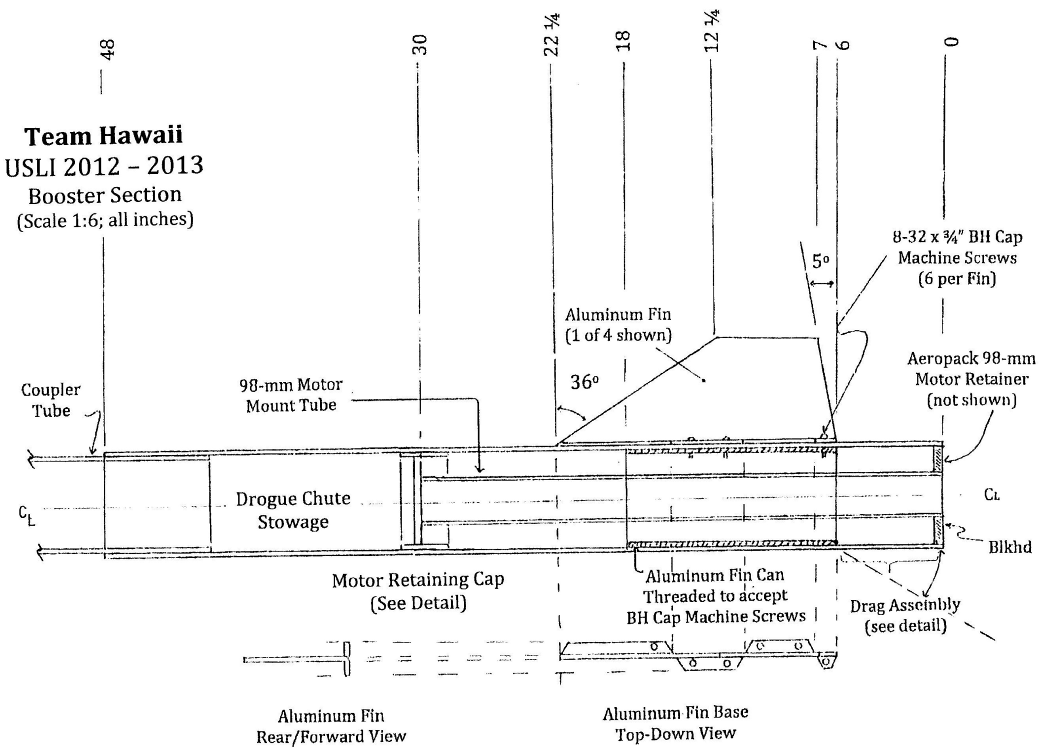
3.3.2 Rocket Details

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 nosecone, standard ogive 1:5.17, yields a nosecone length of 31 inches. The choice of this type of nose cone was dictated by the fact that this shape is commercially available. This is where the data acquisition electronics, monitoring the rocket flight profile and status of the payload, will be located. The payload section of the rocket is 27.5 inches in length; 6 inches as the nosecone shoulder, 16.5 inches as the payload section (including a 3 inch transparent section), and 5 inches is the lower coupler length. Below the payload section of the rocket is the avionics section, chosen to be 18 inches in length; 5 inches to accommodate the forward coupler and stowage of the main chute, 7 inches for the avionics electronics, and 6 inches to accommodate the aft coupler. The avionics electronics will consist of Featherweight Raven flight controller, and a PerfectFlight MAWDs as a redundant back-up system. Both of these units have been flown several times, and have shown themselves to be very reliable. 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 5 inches of coupler, and act as the drogue 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 124 inches (10 feet 3 inch).

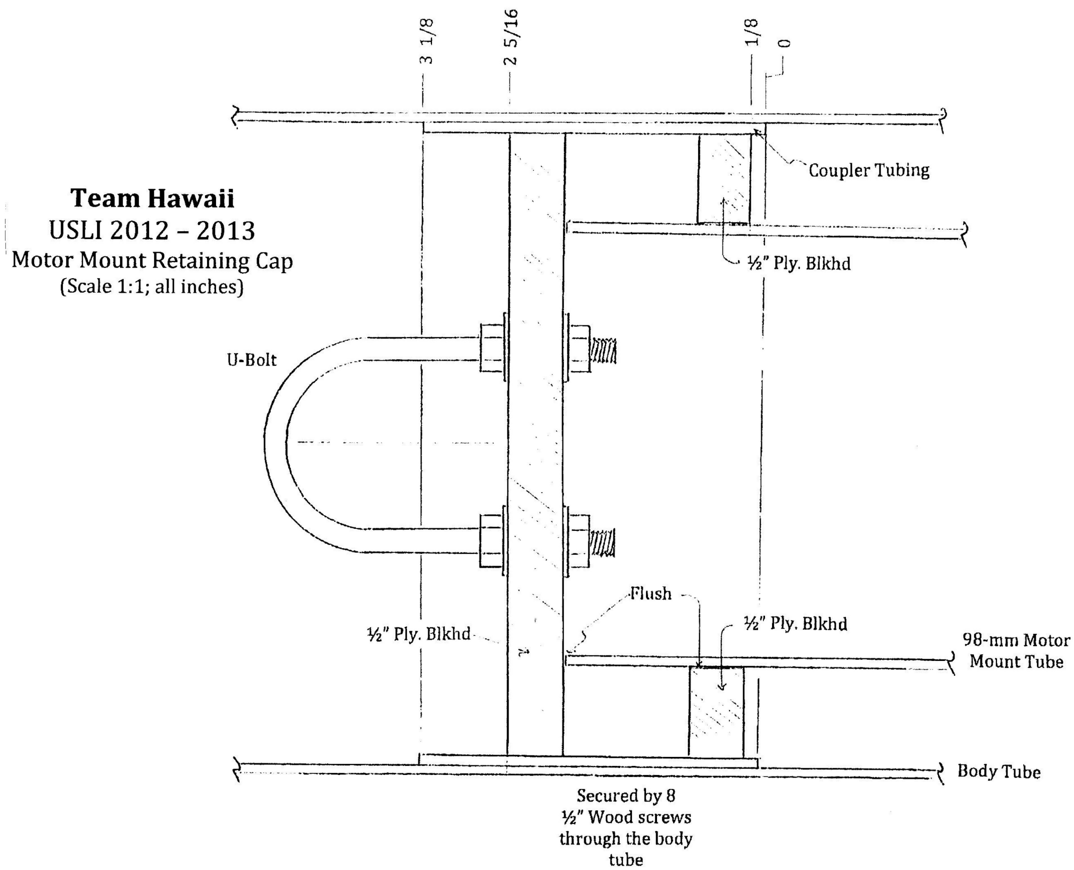
We estimate the un-loaded weight of our rocket to be just over 31 lbs, and a pad weight of just over 45 lbs.

3.3.3 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^o wind angle) epoxy fiberglass. The tubing is commercially available from Hawk Mountain Industries, and is extremely strong. All bulkheads will be constructed using ½ 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.

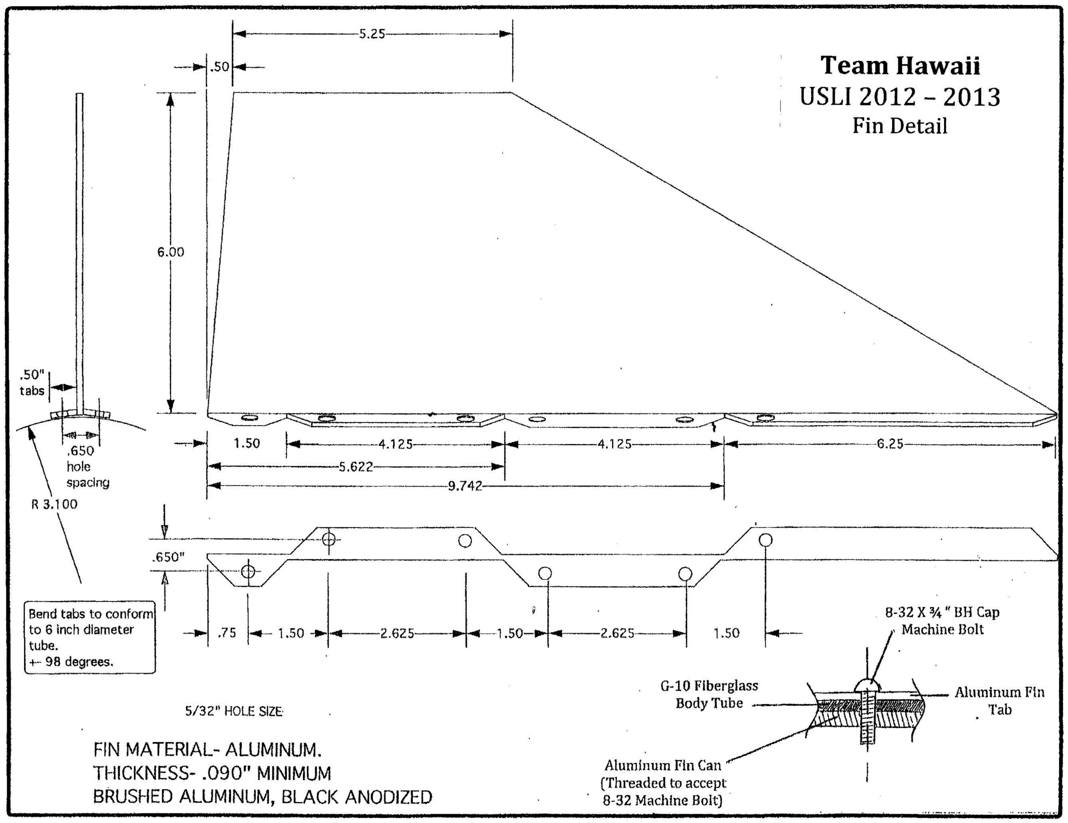


An Aeropack 98-mm motor retainer will be attached to the aft bulkhead by means of 6 nut and bolt assemblies. What is not clearly shown is the Motor Retaining Cap (MRC). It is at the MRC where the final U-bolt is placed. This is where the shock cord joining the avionics section, and associated with the main chute, is attached.



3.3.4 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. The idea of removing the fins for ease of transport has appeal. Our rocket 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%.

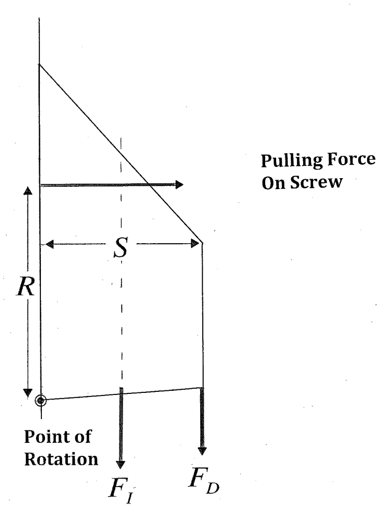
Previously, a concern about the obvious possible points of failure, the screws fastening the fin to the rocket, has been raised. A very pessimistic over estimate of the pulling force acting on a screw can be made. The net pulling force that would be acting on a screw is the sum of the drag force acting on a fin, and the inertial consideration of the fin itself. For our force estimate, we shall consider a fin of surface area A (i.e. area that is parallel to direction of travel) equal to $(1/2)(0.5in)(6.0in) + (5.25in)(6.0in) + (1/2)(10.25in)(6.0in) = 63.5$ square inches (or $3.68X10^{-2} m^2$), a cross-sectional area A_{cs} (i.e. area that is perpendicular to direction of travel) of $(0.1in)(6.0in) = 0.6$ square inches (or $3.43X10^{-4} m^2$), 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 pessimistic over estimate we shall take the extreme value ;of $C_D = 2.0$. This yields a drag force of…

$$F_D = \frac{1}{2}C_D\rho A_{CS}v^2 = \frac{1}{2}(2.0)(1.29\frac{kg}{m^3})(3.43X10^{-4}m^2)(218\frac{m}{s})^2 = 21.0N$$

…where we have used our maximum RocSim speed of 218 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 (again, very pessimistically) that the drag force acts at the extreme span of the fin, we have a pulling force on the forward screw of…

$$F = \left(\frac{S}{R}\right)F_D = \left(\frac{6.00"}{9.75"}\right)(21.0N) = 12.9N$$

…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 103 m/s/s. This yields a force of…

$$F_I = ma_{max} = (0.238kg)(103\frac{m}{s^2}) = 24.5N$$

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…

$$F = \left(\frac{S/2}{R}\right)F_I = \left(\frac{3.00"}{9.75"}\right)(24.5N) = 7.54N$$

Using these results, we estimate a total pulling force on the forward screw of 12.9 N + 7.5 N = 20.4 N, or about 4.6 lbs. Whereas, these results are for the forward screw, the force on the other screws should be lower than this result – at the very worse; it should not exceed this value.

At the request of MSFC, a simple extrusion test was performed on the 8-32 BH screw threaded into an aluminum metal strip of the same composition, and thickness, of the aluminum fin-can. By varying the hanging masses, dependent from the screw, it was found that an extrusion force of 60 +/- 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 (albeit unevenly) over the six screws that attach the fin to the booster section. With regard to the 13+ year history of similar fin constructions flown at ARLISS events, all without a single incident involving detached fins, we believe this to be safe and acceptable.

A question about whether fin flutter would add a stress that could become an issue to flight stability arose. The fin flutter speed, or the speed that yields an extraction of energy from the air stream flowing over the fins, could result in a deformation of the fin. This deformation could in turn lead to an over-stress on the screws that hold the fin to the fuselage. Since the overall stability of the rocket is based on the fins remaining attached, it was crucial to see that the rocket does not attain this critical speed. A simple formula to determine the fin flutter speed v_f , is outlined in a NACA article (TN 4197), and also mentioned in Sport Rocketry Magazine (March/April 2012 p. 18-22).

$$\frac{v_f}{a} = \sqrt{\frac{G_E}{\left[\frac{39.3A^3}{(t/c)^3(A+2)}\right]\left(\frac{\lambda+2}{2}\right)\left(\frac{P}{P_o}\right)}} = \sqrt{\frac{G_E}{\frac{1.337A^3P}{(t/c)^3(A+2)}\left(\frac{\lambda+2}{2}\right)}}$$

Where G_E is the effective shear modulus of the material that the fin is constructed from, (t/c) is the ratio of the fin thickness to the chord length, A is the panel aspect ratio, P is the atmospheric pressure, λ is the taper ratio (the ratio of the tip chord to the root chord), and a is the speed of sound. For our rocket, we take $G_E = 70MPa$, which corresponds to Aluminum, $A = b^2 / S = 2b/(c_t + c_r) = 0.545$, $\lambda = 0.375$, $P = 98kPa$ (assuming a height of ~290 m, corresponding to where our maximum speed of ~182 m/s will occur), and a speed of sound of 339 m/s yields a flutter speed of ~445 m/s which is considerably greater than the maximum speed encountered by our rocket. Fin flutter is not an issue.

3.3.5 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…

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

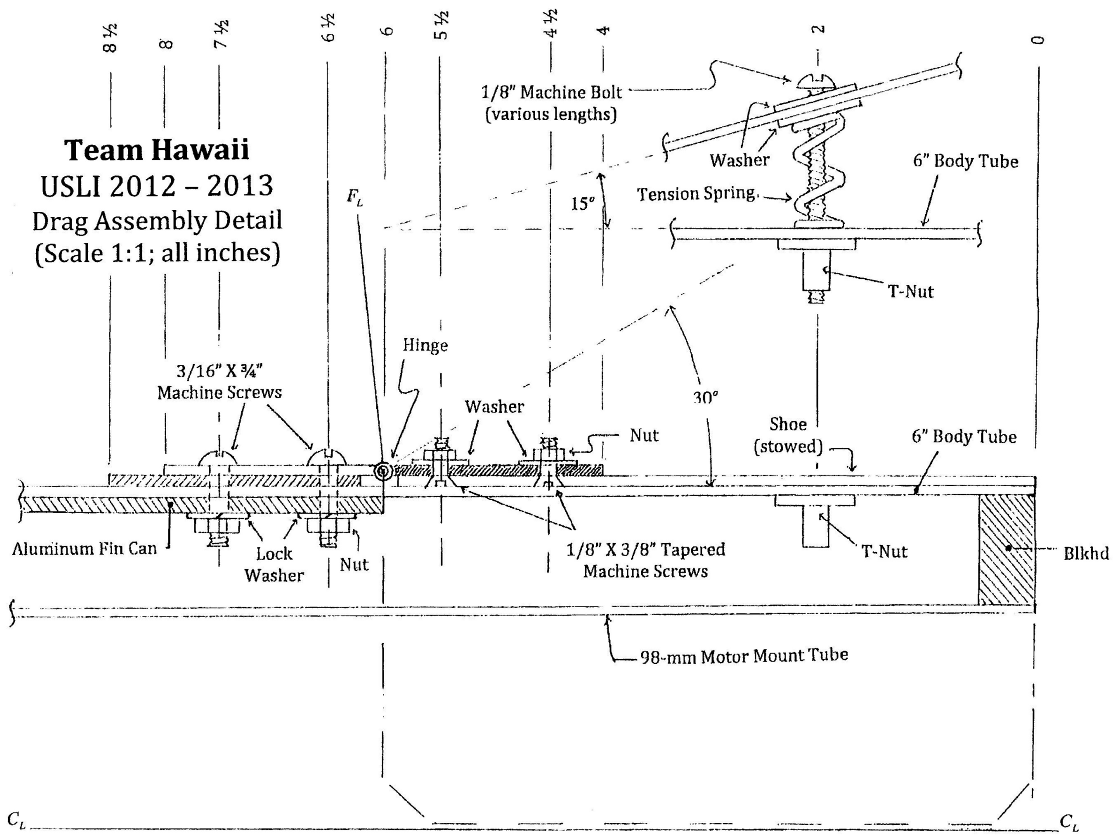
…to the drag force for the situation where the drag shoes are not deployed…

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

…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…

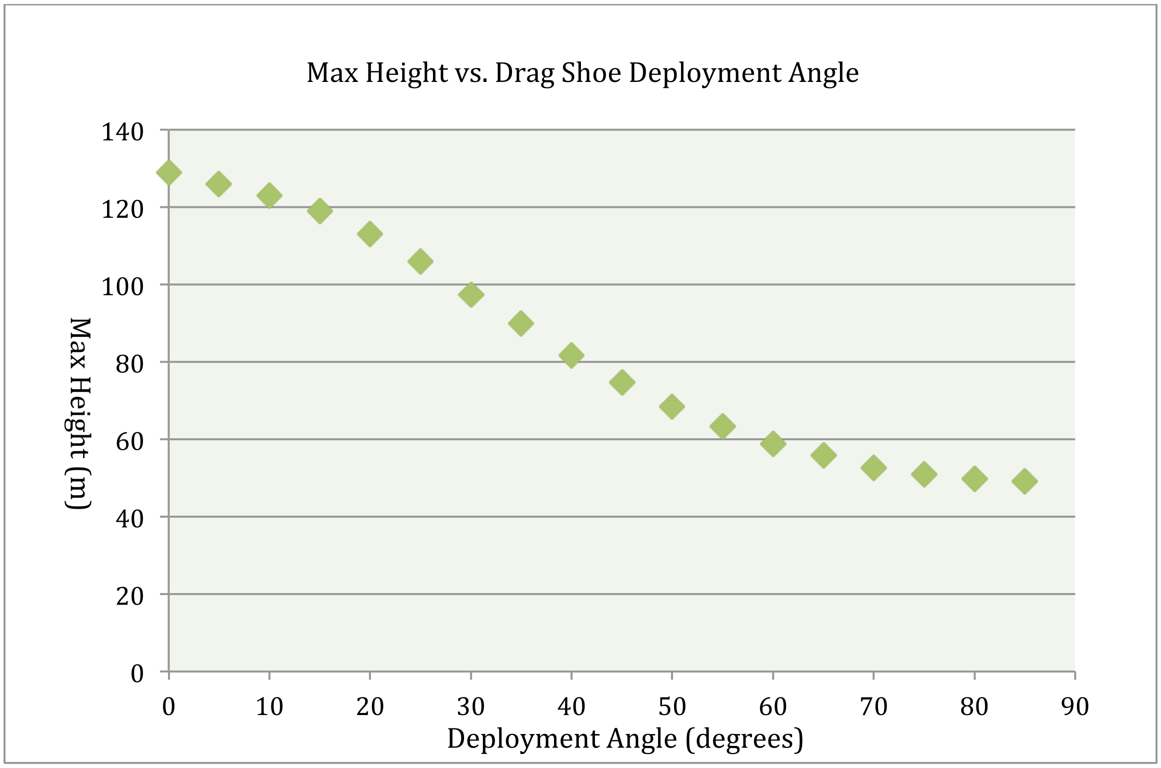
$$\frac{F_{D-Open}}{F_{D-Closed}} = (1 + \frac{2l}{r}\sin\theta) = \left(1 + b\sin\theta\right)$$

…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^o. Previous testing, using a similar designed rocket, using Aerotech L1300R 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 previous designs, and we are expecting similar results.



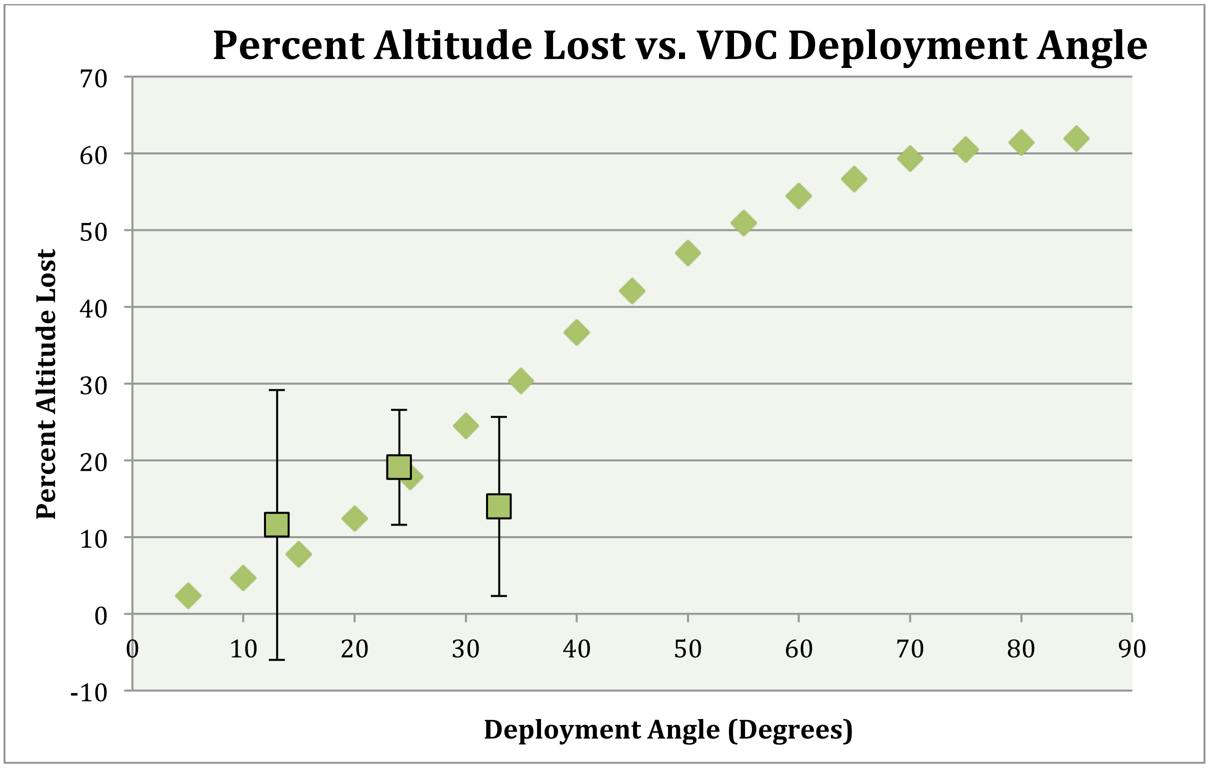
One observation that should be mentioned is that when the drag shoes are deployed, the CP of the rocket is lowered (~3% at full deployment, using center of area estimates), and enhances the stability of the rocket. Subsequent testing of our expectations, using a 1:3.7 scale model has been done, and has confirmed a loss of ~1% of altitude for every degree that the drag shoes are deployed.

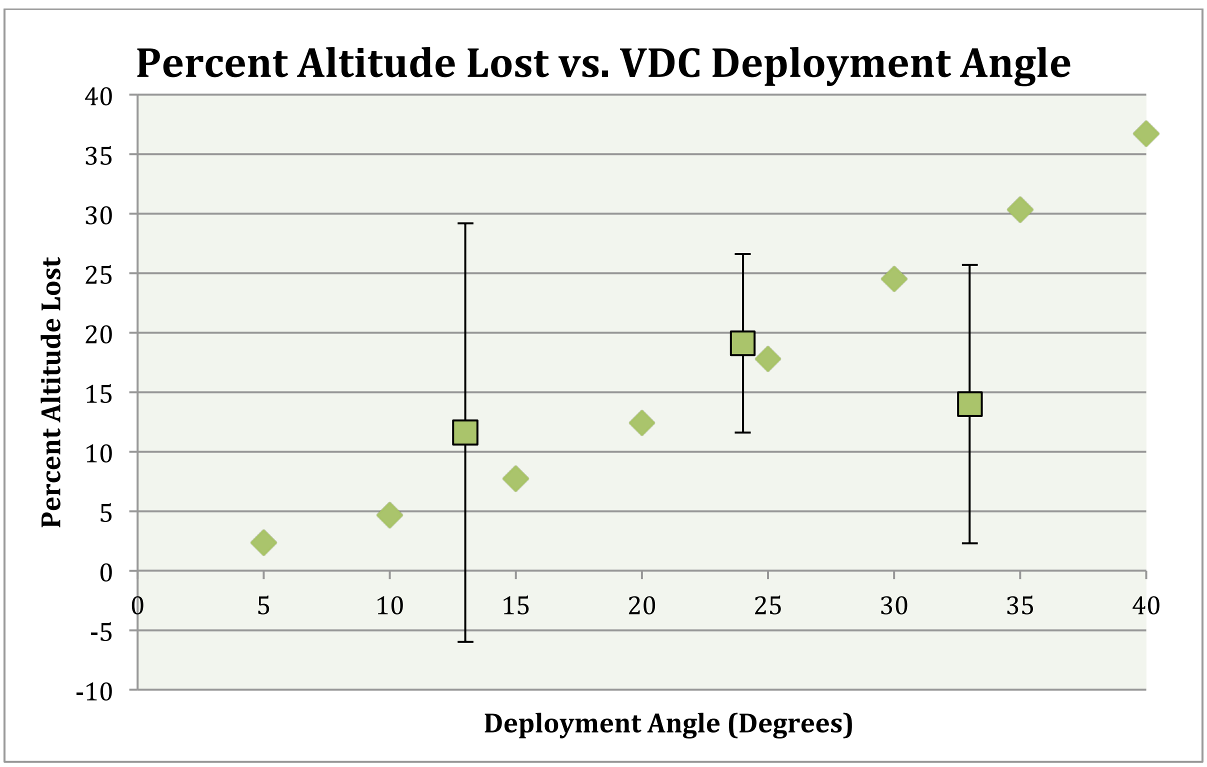
Simulating the 1:3.7 scale rocket using OpenRocket software, with a Variable Drag Configuration (which consisted of using a curtailed transition section at the base of the rocket), and a D12-3 motor, has yielded altitude expectations shown below.



The above results show that we expect a loss of ~0.5 % of altitude per degree deployed out to about 15 degrees deployment angle, and ~0.8% loss for every degree deployed out to 30 degrees. It is hoped that with a proper choice in motor, and a judicious adjustment in deployment angle, the desired altitude of 5280 feet can be obtained. We do not plan on a deployment angle of greater then 30^o. Our current RocSim projections, without the drag shoes being deployed, show a maximum altitude of 6722 feet, which corresponds to an (27%-19% =) 8.3% over-shoot, corresponding to a deployment angle of ~6 degrees.

Due to weather concerns, and field availability, we have had only one chance (so far) to test our expectations. Preliminary data obtained from small-scale launches, using the 1:3.7 model of our rocket, has shown some agreement with the above expectations. With drag-shoe deployment angles set at 0, 13, 24, and 33 degrees, using fixed motors of D12-3, the altitude of each flight was measured via a small on-board altimeter. Each deployment angle was flown three times, and the following data was obtained.

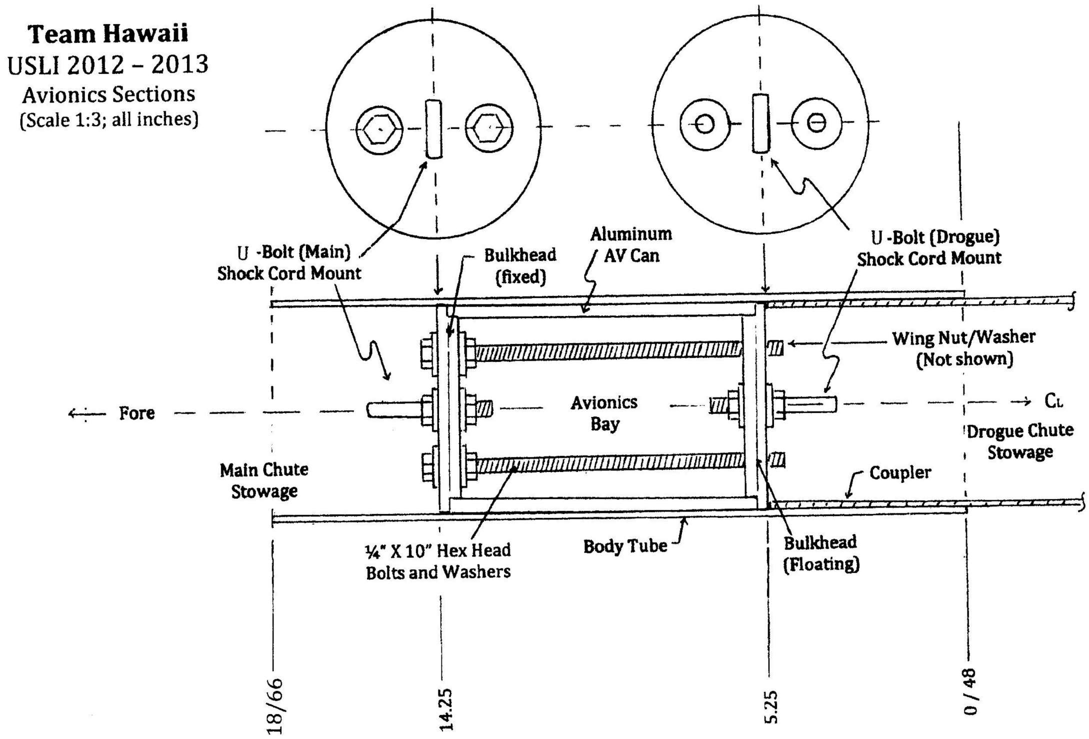

Percent Altitude Lost vs. VDC Deployment Angle
Percent Altitude Lost
Deployment Angle (Degrees)
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90


Percent Altitude Lost vs. VDC Deployment Angle
Percent Altitude Lost
Deployment Angle (Degrees)
40
35
30
25
20
15
10
5
0
-5
-10
0
5
10
15
20
25
30
35
40

What the above shows is that there is (roughly) a -0.54% loss in altitude for every degree we deploy the drag shoes to up to 25 degrees. We are not sure why there is a "depression" in the percent altitude lost at deployment angles above 30 degrees. Aside from edification, and since we are not deploying the drag-shoes at any angle greater than 30 degrees, this is not really a concern. What remains to be seen is whether the above expectations will hold up under further testing at lower angles of drag-shoe deployment (less than 10 degrees). This is something that will be studied at future launch opportunities.

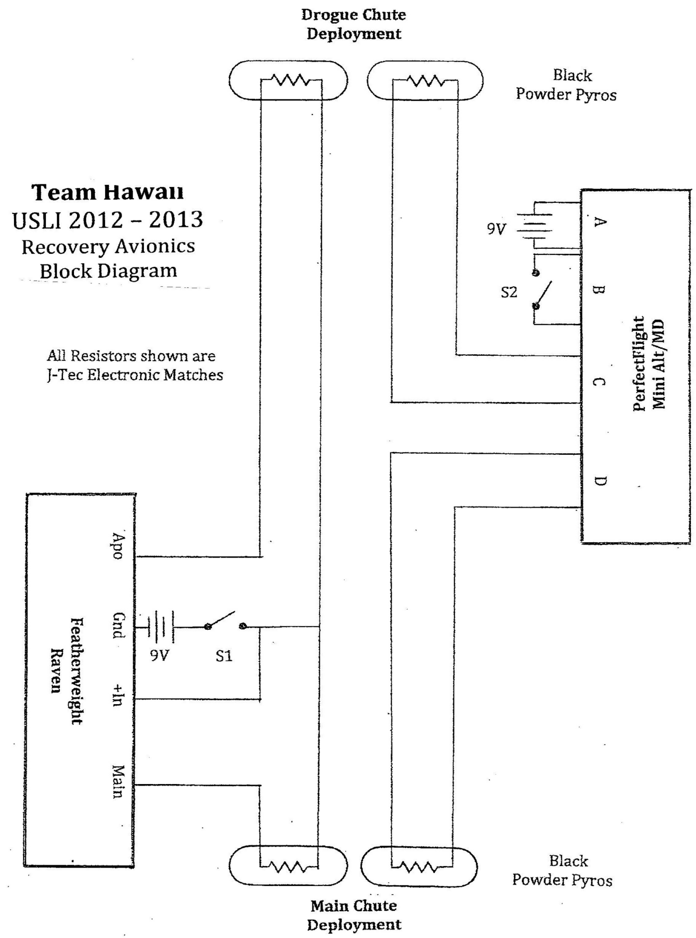
3.3.6 Avionics Section

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 U-bolt. The shock cord associated with the drogue chute, and connecting this part of the rocket to the booster section, is attached at this U-bolt. Another circular plywood bulkhead, also with a center mounted U-bolt, is attached to the other end of the avionics bay by means of two ¼" X 10" long bolts and associated wing-nuts. This bulkhead will be removable for access to the avionics section, and is where the shock cord to the Main chute assembly is attached. Both plywood bulkheads will require holes for the pyro charge wires to pass through (not shown). Also not shown is the two ½" diameter holes that are to be drilled thru the body tube into the avionics bay, for the pressure sensor to equalize with ambient, and allow arming of the pyrotechnic charges at the pad.



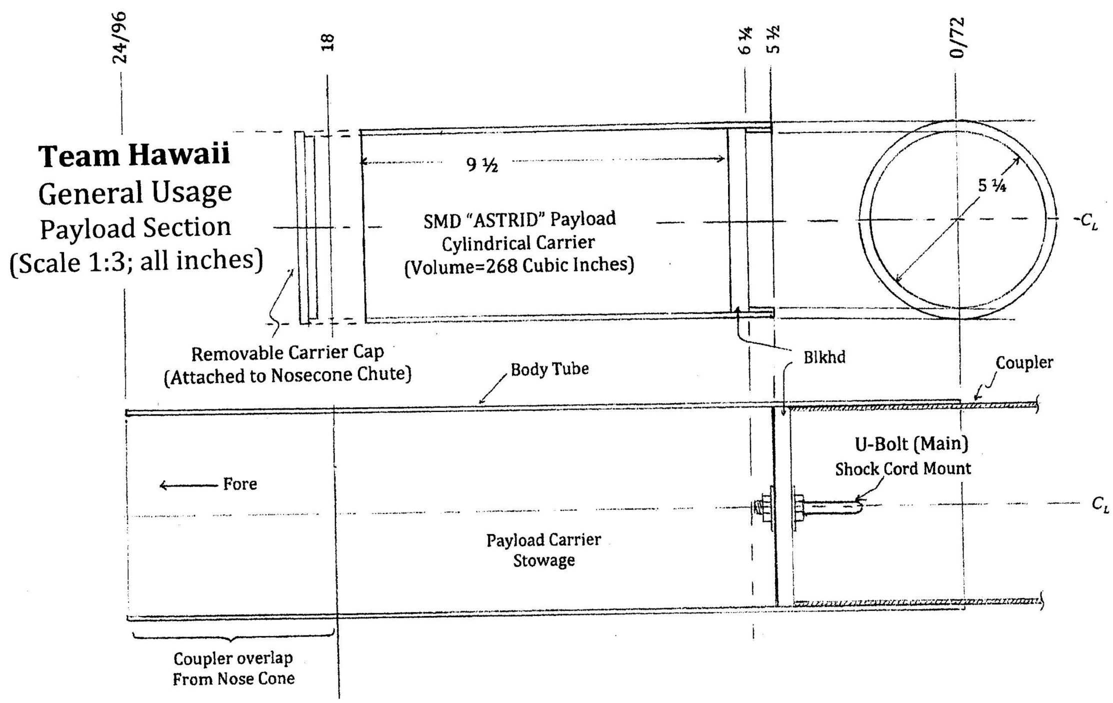
One change that had to be made was to shorten the length of the Avionics tube from 24 inches to 18 inches overall. This change was made, ostensibly to ease the access to the placement of the main chute deployment charges, but also to aid in reducing the overall weight of the section.

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



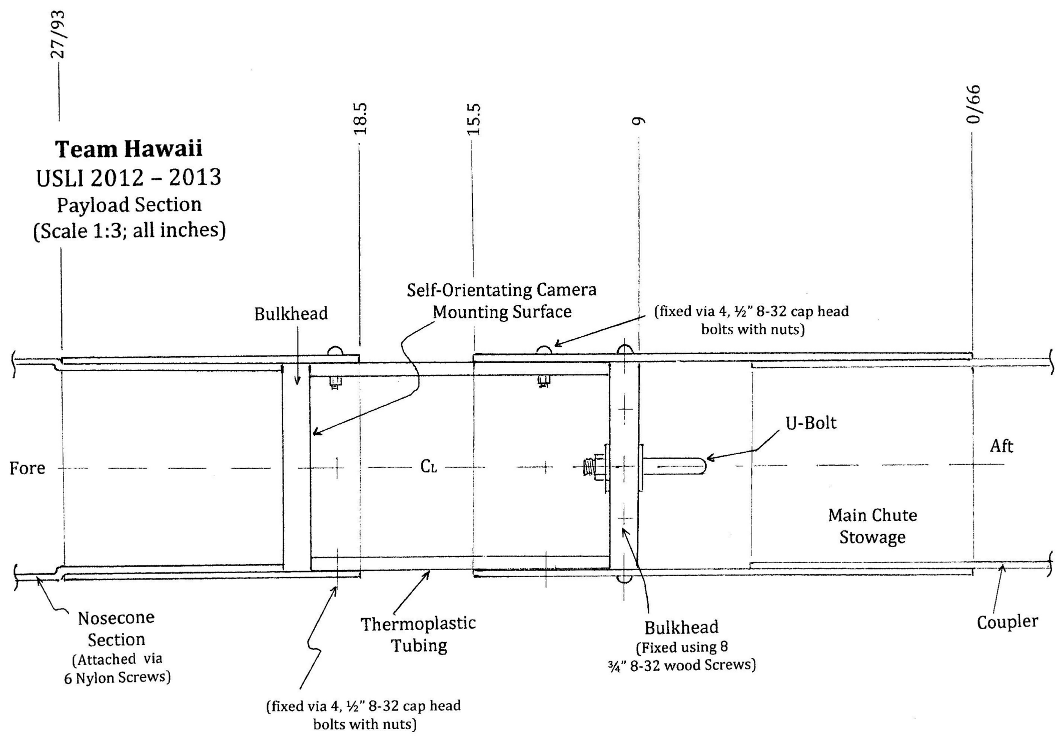
3.3.7 Payload section

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). This section generally consists of a 24" long tube, of the same material as the booster section, with a circular ½" thick plywood bulkhead epoxied into it. This section is attached to the rest of the rocket by a shock cord, which is mounted to the bulkhead via a U-bolt. The shock cord is also attached to the avionics section, and is where the main chute would be attached.



What is not shown is the tether cord and mount that attaches the payload carrier to the payload section at the aft bulkhead.

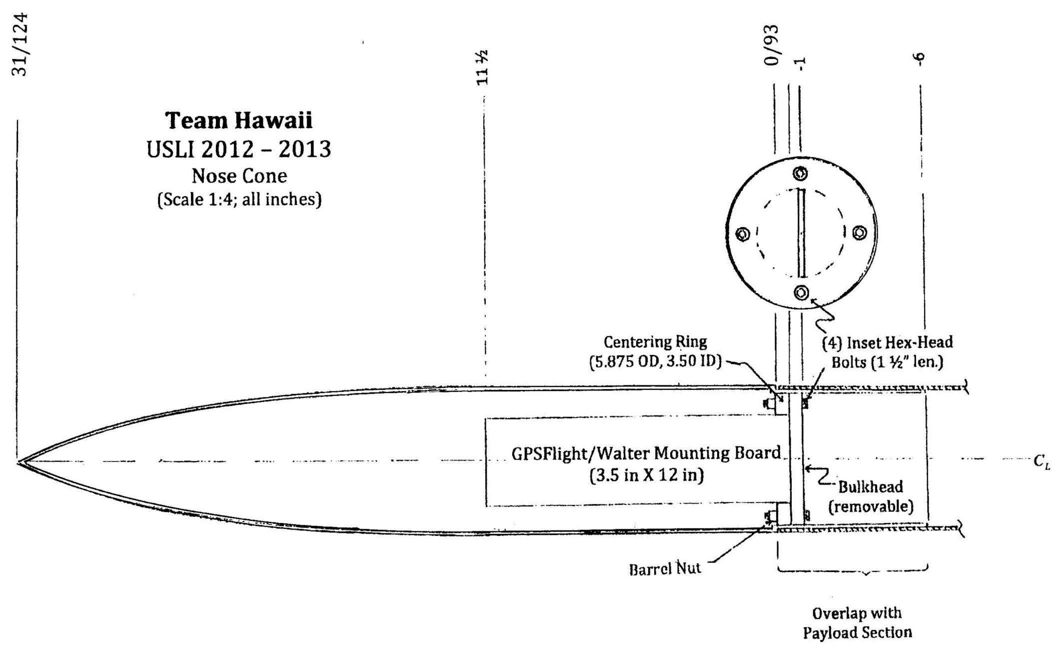
For the USLI launch, the usual payload configuration is not satisfactory for our SMD conditions. This section, while not actually carrying a payload for the USLI flight, is still referred to as the payload section. Since the self-orienting camera requires visual access through the tube in all directions, this section consists of a clear rigid tube. Basuda Manufacturing makes high stress clear, high impact tubing (said to be extruded from the most weather resistant butyrate compounds, and having a tensile strength of 33.1 MPa) which is perfect for our needs. There will be two bulkheads, one that the SMD payload camera will be mounted to, and the other will have the U-bolt by which the payload chute will be attached to.



Originally, the plan (at CDR) was to have the entire body tube be made out of the thermoplastic tubing. However, upon receiving the tube, it was noticed that the tube thickness was 3/16 inches, which is not thin enough to allow the nosecone, let alone the wooden bulkheads, to be inserted into it. Another problem was that the outer diameter was just under the 6.00 inches (5.935 inches) that the rest of the body tubes were manufactured to be. Fortunately, the thermoplastic tubing was able to slide (with a little effort) into the standard body tubes that we have been using. While there is no real change to the overall payload section design, the current plan is to have a section of the thermoplastic tubing inserted into a 6.0-inch by 15.5-inch long body tube. This will then be bolted in place using 4 8-32 nut and bolt assemblies. The aft bulkhead, where the U-bolt holding the shock cord to the payload-chute, is to be fixed using 8 ½-inch wood screws inserted through the body tube. A second section of body tube is then inserted down onto the thermoplastic tubing, leaving a three-inch gap between the two body sections. The second section of body tube is to be fixed to the thermoplastic tubing also using 4 8-32 nut and bolt assemblies. The second bulkhead, where the self-orienting camera is to be installed, will be held in place by the top of the thermoplastic tubing and the bottom of the inserted nosecone.

3.3.8 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 SMD payload and the GPSFlight (SD1900) transceiver assembly required for the tracking of our Wilfred payload.



3.4 Rocket Stability

The stability of our designed rocket is determined by comparing the location of the center of pressure (i.e. the point where all aerodynamic forces are considered to act, and is purely dependent on the geometry of the rocket) and the center of gravity (the single point at which the rocket would rotate about given an external torque). Calculating the Center of Pressure (CP) for a rocket can be done several ways; calculating of the center of area for the rocket (albeit this is somewhat pessimistic), using the Barrowman equation, or using an intrinsic RocSim algorithm. Stability requires that the rocket's CP be located at least a body diameter below the CG. For our rocket, both the Barrowman Equation and the RocSim calculations were used: it being understood that if either showed instability, then a design change would be initiated.

The Barrowman equation for CP location is…

$$X_{CP} = \frac{(C_n)_N X_N + (C_n)_F X_F}{(C_n)_N + (C_n)_F}$$

Where…

$$(C_n)_N = 2$$
$$X_N = 0.466 L_N$$

…for a given ogive nosecone. And…

$$(C_n)_F = \left(1 + \frac{R}{S+R}\right)\left\{\frac{16\left(\frac{S}{d}\right)^2}{1+\sqrt{1+\left(\frac{2L_F}{C_R+C_T}\right)^2}}\right\}$$

$$X_F = X_B + \frac{X_R}{3}\frac{(C_R + 2C_T)}{(C_R + C_T)} + \frac{1}{6}\left[(C_R + C_T) - \frac{(C_R C_T)}{(C_R + C_T)}\right]$$

…for a four fin arrangement. For our given rocket, the designed geometry yields the following values: L_N = length of the nosecone $= 30.625"$, C_R = the fin root chord $= 16.25"$, C_T = the fin tip chord $= 5.25"$, S = the fin semi-span $= 6.00"$, d = the body diameter $= 6.00"$, L_F = the length of the mid-chord line of the fin $= 6.06"$, $R = d/2$ = the radius of the body $= 3.00"$, X_R = the parallel distance from the root of the leading edge of the fin to the leading edge of the fin tip $= 10.04"$, and X_B = the distance from the nose tip to the root of the leading edge of the fin $107.4"$. Using these values gives…

$$(C_n)_N = 2$$

$$X_N = 0.466(30.63") = 14.27"$$

$$(C_n)_F = \left(1 + \frac{3.00}{9.00}\right)\left[\frac{16\left(\frac{6.00}{6.00}\right)^2}{1 + \sqrt{1 + \left(\frac{12.12}{21.50}\right)^2}}\right] = 9.93$$

$$X_F = 107.37" + \frac{10.04"}{3}\left(\frac{26.75}{21.50}\right) + \frac{1}{6}\left[21.50" + \frac{85.31"}{21.50}\right] = 115.77$$

Which yields a CP location of…

$$X_{CP} = \frac{(2)(14.27") + (9.93)(115.77")}{2 + 9.93} = 98.73"$$

…as measured from the tip of the nosecone. The OpenRocket simulation has calculated this value to be 98.348 inches.

The mathematical method for determination of the CG is straight forward using center of torque considerations.

$$X_{CG} = \frac{\sum_i m_i X_i}{M}$$

However, this approach is problematic because it relies on the knowledge of all mass elements and their location within, and on, the rocket. No doubt, this is how RocSim determines the value for CG but it does not include all incidental masses (such as epoxy, screws, paint, etc.) that may have to be added during construction.

Never the less, since the RocSim component weights *are* suspect, it was necessary to make an estimate of the Center of Gravity, as well as the Stability Margin. That calculation is straight forward and follows…

Component	Wt (oz)	Est. CG (in)	$(Wt.)r$
Nose Cone	38	24	912
GPSFlight	50	30	1500
Exper: SMD/Wilfred	32	30	960
Payload Tube	40	48	1920
Bulkhead	5	31	155
Bulkhead	5	37	185

Payload Chute	8	60	480
Main Chute	20	60	1200
Bulkhead	5	54	245
Coupler	20	60	1200
Avionics Tube	40	63	2520
Bulkhead	5	67	335
AV Al Can	16	71	1136
Avionics	35	71	2485
Bulkhead	5	73	365
Coupler	20	76	1520
Booster Tube	80	103	8240
Motor Mount	50	112	5600
Cen. Ring	3	97	291
Drogue Chute	8	89	712
Fin/Fin-can	60	109	6900
VDC Assembly	10	109	1090
Cen. Ring	3	121	378
Motor Retainer	5	121	630
L1500R Motor	161	113	18193
	$\sum(Wt.) =$ 724 oz.		$\sum(Wt.)r =$ 59,152oz-in

Therefore: $CG = \frac{\sum(Wt.)r}{\sum(Wt.)} = \frac{59{,}152}{724} = 81.70$ inches from the nose cone tip.

Since the Center of Pressure has been calculated to be 94.39 inches, our stability margin is…

Margin = $\frac{|98.73 - 81.70|}{6.0} = 2.84$

This indicates that our rocket will be stable, with a thrust to weight ratio of 7.4. A marginally stable rocket is a cause for concern, and some of the team are concerned that we are very close to being marginally stable. An easier approach to determining the center of gravity is to just find the location of the center of torque using the 'hang test'. This test will be done prior to each flight, after the motor has been mounted, and just before taking the rocket to the pad. Should it be the case that the rocket is marginally stable; a small weight can be inserted into the nosecone to raise the CG. If, on the other hand, the rocket becomes over-stable then a weight can be added to the base of the rocket to lower the CG.

3.5 Deployment Charge Determination

Determination of the pyrotechnic charges for the chute deployment is found using the Missile Works empirical relationship*. This empirical relationship is determined using several assumptions: the gas produced by burning black-powder is essentially ideal; the composition of the black-power is 75% KNO3, 14% C, and 11% S; the burning temperature is 2091K, the expansion volume of the produced gas is ~11,000 times the solid propellant volume, and that the produced pressure must be greater than the weight of the forward components, shear pins, and the frictional forces that hold it in place. As it turns out, the amount of black-powder needed to adequately deploy the chute is a direct proportion to the volume that the gas must expand to fill (i.e. the chute stowage volume). This relationship is approximately given by…

$$A_{BP} \approx \left(\frac{1}{130}\right)V_{Compartment} = \left(\frac{1}{130}\right)\frac{1}{4}\pi d^2 L_{Main} = \left(\frac{\pi}{520}\right)\left(6.00''\right)^2\left(18.00''\right) = 3.91 grams$$

$$A_{BP} \approx \left(\frac{1}{130}\right)V_{Compartment} = \left(\frac{1}{130}\right)\frac{1}{4}\pi d^2 L_{Drogue} = \left(\frac{\pi}{520}\right)\left(6.00''\right)^2\left(24.00''\right) = 5.22 grams$$

Based on these results, we expect a 4.0 gram charge for the drogue deployment, and 5.5 gram charge for the drogue chute deployment. Despite the many years of empiric testing that went into the above relationship, nothing beats an *in-situ* deployment test to validate these results. This is something that will be done before the completion of construction.

3.6 Parachute Size Determination

The drag force acting on an object, having a cross-sectional area *A,* moving with a velocity of *v*, through a fluid is given by…

$$F_D = \frac{1}{2}C_D \rho A v^2$$

…where it is standard practice to take the dimensionless drag coefficient C_D to be 0.75, and $\rho = 1.3$ kg per cubic meter is the density of air. For a steady descent rate, we require the drag force to balance the weight of the rocket, $F_D = mg$. Assuming a circular shape for the parachute $A = \pi r^2$, and solving for the radius, yields the following:

* The main outline of this is mentioned in How to Make Amateur Rockets (2ed.) J. H. Wickman p.18-1

$$r = \sqrt{\frac{2mg}{C_D \rho \pi v^2}}$$

We estimate a spent rocket mass of 15.0 kg, and for the requested speeds of 50 – 100 ft/s (~ 25 m/s) for drogue chute descent, and 17 – 22 ft/s (~6 m/s) for main chute descent. We estimate chute radii of…

$$r_{drogue} = \sqrt{\frac{2(15.0kg)(9.8m/s/s)}{(0.75)(1.3kg/m^3)\pi(25m/s)^2}} = 0.39m$$

$$r_{main} = \sqrt{\frac{2(15.0kg)(9.8m/s/s)}{(0.75)(1.3kg/m^3)\pi(6m/s)^2}} = 1.63m$$

Based on these calculations, we expect a drogue chute diameter of around 31 inches, and a main chute diameter of about 130 inches. For our RocSim predictions, we chose a drogue chute having a diameter of 42 inches, which gave a descent rate of ~70 ft/s. The main chute diameter chosen was 12 feet, which gave a descent rate of ~21 ft/s. Even though the RocSim chute diameters are greater than those calculated, we have decided to keep these results with the idea that safer is always better.

Estimating the chute size for the nosecone and the SMD payload follow same process outlined above for a mass estimate of 4.1kg (our current best estimate);

$$r_{nosecone} = \sqrt{\frac{2(4.1kg)(9.8m/s/s)}{(0.75)(1.3kg/m^3)\pi(6.8m/s)^2}} = 0.75m$$

Based on these calculations, we expect a nosecone chute diameter of around 60 inches.

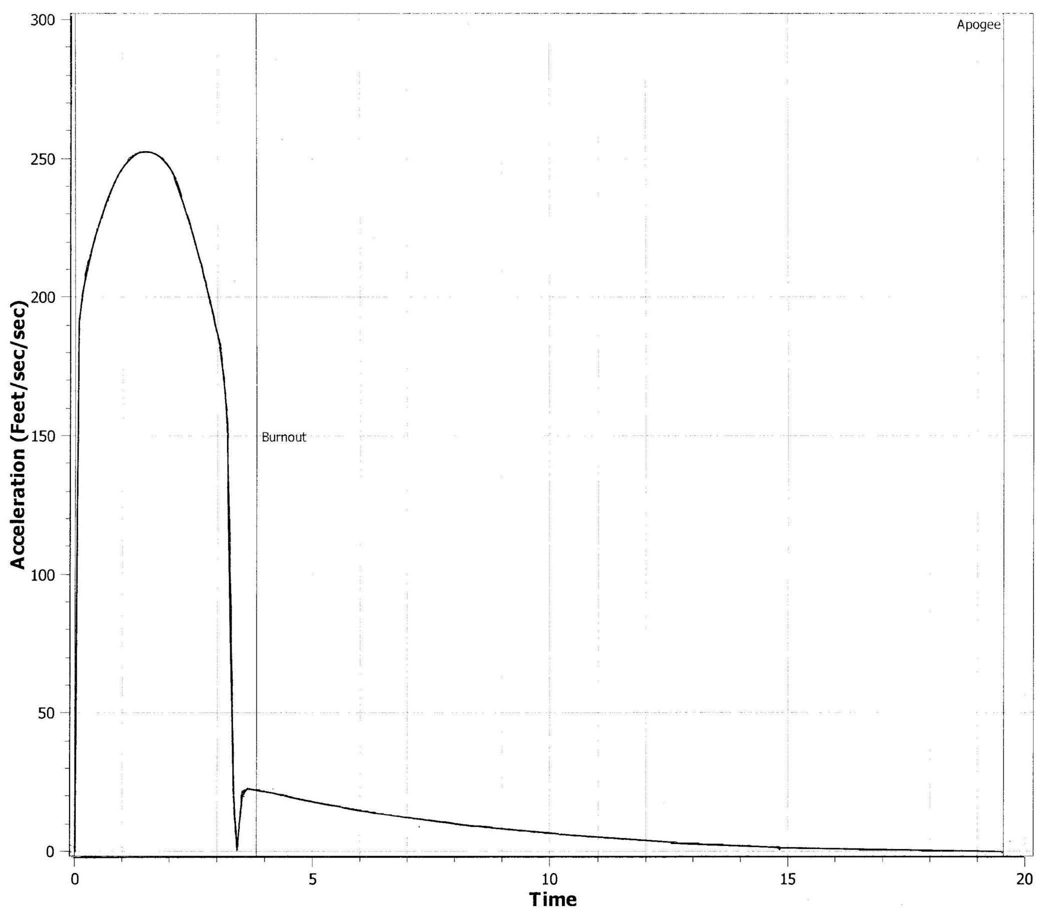
All chutes will be connected to their respective units using 20 foot long (2 ton) shock tethers, attached using heavy duty quick links. All materials will be procured from the company that is manufacturing our chutes; Fruity Chutes. We have had very successful results using their equipment in the past.

3.7 Launch Rail Length

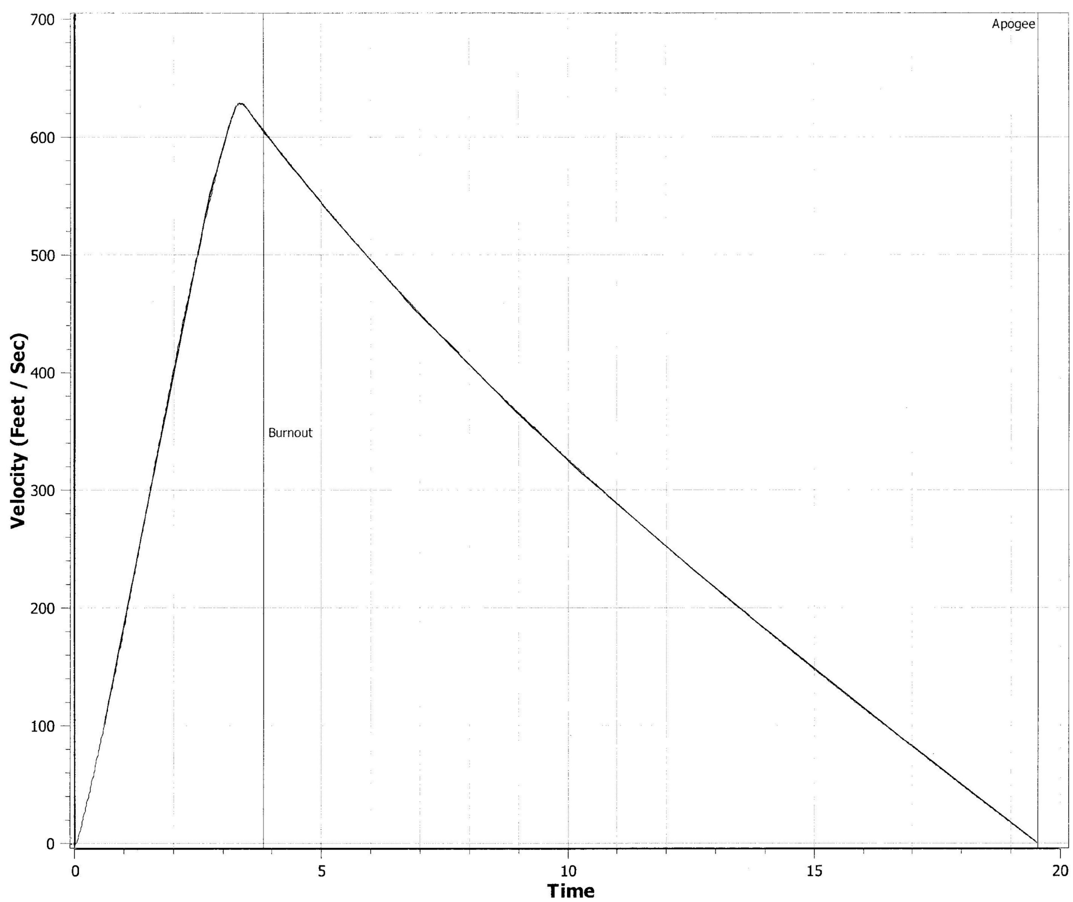
A launch rail length determination is essential for the safety of the team members as well as for any on-looker. This year the requirement of an 8 foot rail has caused some concern among the team. Our launch rail length, for the RocSim predictions, was set to 144 inches (12 ft) to guarantee that there was sufficient length for our rocket to reach a minimum safe speed. The minimum safe speed for our rocket was set to be 44 ft/s which is the RocSim default minimum speed. According to our simulation results, our rocket reached the minimum safe speed at a height of 68 inches. We are planning on using 10-10 standard rail buttons for our rail guidance. Having a separation distance of 18 inches between the two buttons, and an offset distance between the bottom of the rocket and the lower button of 4 inches, yields a launch rail length of 95 inches (~8 ft). This has mitigated our concern we are confident that the new 8 foot rail requirement will be met.

3.8 Flight Characteristics

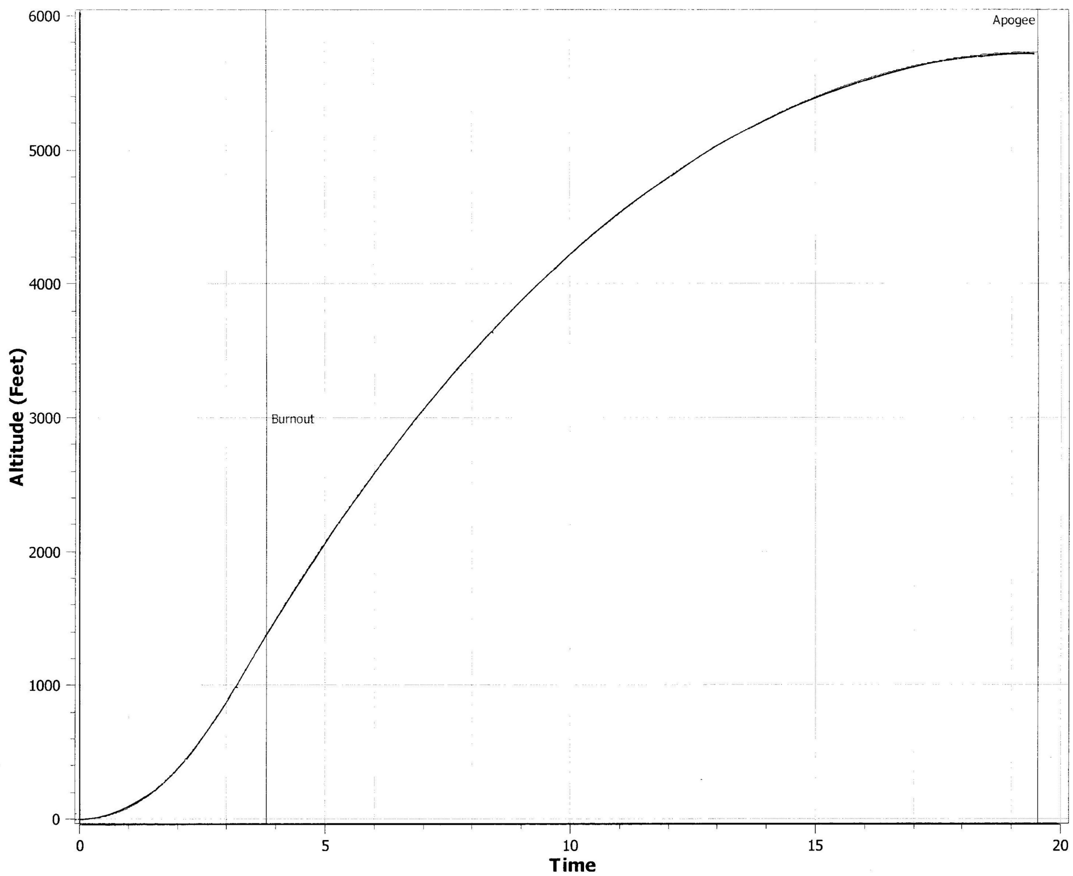
The RocSim prediction for the time development of the magnitude of the acceleration follows. Note that this plot does not indicate direction. As such, the discontinuity that occurs at ~3.8 s is where the rocket makes the transition from acceleration to deceleration. The simulation estimates a maximum acceleration of 344.1 ft/s/s during ascent; and a maximum deceleration of 59 ft/s/s shortly after burnout.



The RocSim prediction for the time development of the magnitude of the vertical velocity follows. The simulation estimates a maximum velocity of 628.5 ft/s at ~3.8 s. The rocket then coasts, with a reducing speed to apogee.



The RocSim prediction for the time development of the vertical height follows. The altitude curve follows an expected profile, having a rapid ascent rate until burnout. Burnout corresponds to a point of inflection for the altitude curve. The simulation estimates a maximum altitude of 5725.9 ft at 19.7 s.



3.9 Kinetic Energy Calculations

The determination of kinetic energy values for our descending sections of our rocket follows; the kinetic energy for any moving object is given by…

$$KE = m_o c^2 \left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \right) = \frac{1}{2} m_o v^2$$

…for non-relativistic speeds.

During the initial descent, when our rocket is descending under drogue, the rocket is relatively integral (in one section) with a spent propellant weight of 40 lbs (mass equivalent to 1.25 slugs). The Kinetic Energy is then…

$$\frac{1}{2}m_o v^2 = \frac{1}{2}(1.25 slugs)(76 ft/s)^2 = 3610 ft - lbs$$

During the final stage of descent, our rocket will consist of three sections; the main part of the rocket consisting of the booster and avionics section with a weight of 12 lbs, (0. 38 slugs), and 15 lbs (0.46 slugs) respectively. The second section is the nosecone, carrying the GPSFlight and SMD, having a weight of 10.5 lbs (mass equivalency of 0.33 slugs). All units will be descending at 18 ft/s. The kinetic energy for each section then follows…

$$KE_{AV} = \frac{1}{2}m_o v^2 = \frac{1}{2}(0.38 slugs)(18 ft/s)^2 = 61.6 ft - lbs$$
$$KE_{Booster} = \frac{1}{2}m_o v^2 = \frac{1}{2}(0.46 slugs)(18 ft/s)^2 = 74.6 ft - lbs$$
$$KE_{NC/SMD} = \frac{1}{2}m_o v^2 = \frac{1}{2}(0.33 slugs)(18 ft/s)^2 = 53.5 ft - lbs$$

Although the descent speeds are less than the 22 ft/s that we have been working with for the theoretical chute size determination, it is in keeping with the simulation results that we have run. It is also closer to previous Full-scale low-power flights that we have had. Current construction values for the masses of the payload section, avionic section, and booster sections, have mass estimates that are close to our estimated values. There is continuing concern about the mass of the descending booster, its subsequent resultant kinetic energy, and how close it is to the maximum value. Care will be taken to reduce this final mass. If it is not possible to reduce this, or it looks like the final booster mass will have a descending kinetic energy above the maximum, increasing the chute diameter will have to be considered.

3.10 Payload Integration

To insure the successful integration of the payload, we will fly the completed unit during our full-scale flight of the rocket.

3.11 Launch Operations Procedures (Checklist)

To ensure that all proper steps are taken in the preparation of the rocket this checklist will be used on launch day to make sure that nothing is overlooked.

<u>Overall:</u> The rocket, and its payloads, is to be assembled/integrated in order from the nosecone to motor.

1.) Payload integrated to Payload Section:
- ◊ Wilfred (Magnetometer/SMD) into Nosecone
- ◊ Nosecone Wilfred/GPSFlight Powered and Secured
- ◊ Nosecone Base-plate secured via (4) bolts
- ◊ External Senor Cable attached to Wilfred
- ◊ Nosecone/Wilfred attached to Payload Section
- ◊ Camera/Sensors visually inspected
- ◊ Payload Chute Tether attached to aft bulkhead of Payload Section
- ◊ Payload Chute Folded and attached to tether

Fore [NC/Wilfred/Blkhd//Blkhd/Camera/Blkhd/Payload Chute] Aft

2.) Rocket Pre-Flight:
- ◊ (2) Main Chute Pyros (6g, short leads) connected to Fore Avionics Section
- ◊ Tether to Main Chute attached to Fore Blkhd Avionics Section
- ◊ Nomex Wrapped Payload Chute inserted into top of AV Section
- ◊ Main Chute folded
- ◊ Main Chute secured to shock tether
- ◊ Main Chute inserted into Aft end of Payload Section
- ◊ Payload Section attached to AV Section tube
- ◊ 4 nylon (4-40) shear pins inserted securing Payload Section to AV Section Tube

Fore [NC/Payload//Main-Chute/Payload-Chute/Nomex/Pyro//Avionics FBlkhd]Aft

- ◊ Shock Cord Tether secured to Fore U-bolt of Motor Mount Retaining Cap (MMRC)
- ◊ Motor Inserted into Motor Mount and secured via Retaining Ring
- ◊ Main Pyros connected to Avionics via phone-jack
- ◊ (2) Drogue Chute Pyros (~4g, long leads) placed atop MMRC blkhd
- ◊ (2) Drogue Chute Pyro leads attached to Aft Blkhd of Avionics section
- ◊ Pyros connected to Avionics via phone-jacks
- ◊ Avionics Continuity test/Consistent signals
- ◊ Avionics power dis-armed
- ◊ Avionics inserted into Avionics Bay
- ◊ Aft Avionics Bkhd secured to Avionics Bay via (2) Wing Nuts
- ◊ Shock Cord Tether attached to Aft Avionics Blkhd of Avionics

Section
- ◊ Drogue Chute folded
- ◊ Drogue Chute Nomex wrapped
- ◊ Drogue Chute secured to Aft Blkhd of Avionics Section
- ◊ Drogue Chute Packed
- ◊ Avionics/Booster Sections integrated
- ◊ 3 nylon (4-40) shear pins inserted securing Avionics section to Booster

Fore [Avionics A-Blkhd/Drogue Chute/Nomex/Pyros/MMRC/Motor] Aft

3.) General/Overall:
- ◊ Fins Secured
- ◊ Air Pressure Sensors holes clear
- ◊ Rail Buttons Usable
- ◊ Brake shoes deployed
- ◊ Balance test for stability

Fore [NC/Payload Section//Avionics Section//Booster Section] Aft

4.) Clearance to Pad
- ◊ Pass Hardware Inspection
- ◊ Pad Assigned by LCO
- ◊ Twiddle Thumbs until Rail/Pad is cleared
- ◊ Carry Rocket to Assigned Pad

5.) 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

4.0 Payload

This year “Wilfred” is our two-phase payload of the Science Mission Directorate (SMD) and a magnetometer. This payload will take atmospheric data, take pictures upon decent and on ground, and measure induced voltages as it travels through the earth’s magnetic field to determine our rockets orientation.

4.1 Scientific Value

4.1.1 Theory and Challenge

Our experiment is to test the Faraday Law of Electromagnetic Induction. We predict it is possible to determine the rocket's 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. If this is successful, there are several possible applications. By integrating this unit into a proper feedback network, a rocket stability system could be implemented.

The payload consists of three mutually perpendicular coils wrapped around a nonmagnetic sphere. 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 a micro SD card via the Arduino Nano. Additionally, there will be an accelerometer which will be used to compare data. 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).

4.1.2 Theory

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

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

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

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

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

Where $\mu = 8 \times 10^{22} J/T$ is the Earth's magnetic dipole moment, $\mu_o = 4\pi \times 10^{-7} Tm/A$ is the magnetic permeability constant, $\lambda_m = 32.5^o$ is the magnetic latitude of our location in Hawaii (this is based on the latitude of Hawaii being given by $\lambda = 21^o$ combined with the 11.5^o offset between the rotational north pole and the magnetic north pole), and $r = R_E = 6.4 \times 10^6 m$ is the radius of the Earth. These two expressions can be combined together…

$$B = \frac{\mu\mu_o}{4\pi r^3}\sqrt{1+3\sin^2\lambda_m} = \frac{\left(8\times10^{22}J/T\right)\left(4\pi\times10^{-7}Tm/A\right)}{4\pi\left(6.4\times10^6 m\right)^3}\sqrt{1+3\sin^2 32.5^o} = 41.4\mu T$$

…to determine the magnetic field intensity at Hawaii's latitude.

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

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

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

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

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

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

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

Our rocket diameter is 6 inches, and assuming this to be the maximum diameter of our coil, the Area is given by $A = \pi r^2 = \pi(0.027m)^2 = 0.0163m^2$. Given an ascent speed of 300 m/s, the induced electromotive force for the ascent term is then approximated to be…

$$E_{Ascent} = -NAv_z \frac{dB_\perp}{dz} = -NAv_z \frac{d}{dz}\left(\frac{\mu\mu_o}{2\pi(R_E+z)^3}\sin\lambda_m\right)$$
$$= -NAv_z\left(\frac{\mu\mu_o}{4\pi}2\sin\lambda_m\right)\frac{d}{dz}\left[\frac{1}{(R_E+z)^3}\right]$$
$$= -2NAv_z\left(\frac{\mu\mu_o}{4\pi}\sin\lambda_m\right)\left[\frac{-3}{(R_E+z)^4}\right]$$
$$\approx 6NAv_z\left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\frac{\sin\lambda_m}{R_E}$$
$$\approx 6N\left(0.027m^2\right)\left(300\frac{m}{s}\right)\left(3.06\times10^{-5}T\right)\frac{\sin 32.5^o}{\left(6.4\times10^6 m\right)}$$
$$\approx N\left(1.25\times10^{-10}V\right)\approx 12.5nV$$

…for a coil of 100 turns.

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

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

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

$$B_{11} = B_H = \left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\cos\lambda_m = \left(3.05\times10^{-5}T\right)\cos 32.5^o = 25.7\mu T$$

$$B_\perp = B_V = \left(\frac{\mu\mu_o}{2\pi R_E^3}\right)\sin\lambda_m = 2\left(\frac{\mu\mu_o}{4\pi R_E^3}\right)\sin\lambda_m = 2\left(3.05\times10^{-5}T\right)\sin 32.5^o \approx 32.8\mu T$$

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

$$E_{Apogee} = N\left(0.0163m^2\right)\frac{|32.8\mu T - 25.7\mu T|}{3s}$$
$$= N\left(3.88\times10^{-8}V\right)\approx 3.9\mu V$$

We estimate that the induced voltage at apogee and its corresponding pitch-over to be roughly 300 times the induced voltage due to ascent. Similar calculations for the latitude of Huntsville have been performed, and we estimated an induced voltage of ~17.8 nV for ascent, and 28.2 mV for pitch-over.

4.1.3 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. Operational amplifiers must be used to magnify the voltage readings. 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.

4.1.4 Answering the Challenge

The key to this project is in the use of analog sensors and the Arduino Mega, which has built-in digital to analog converters (ADCs) along with operational amplifiers, which we as a group, have very little experience in using.

4.1.5 Major Components

Major Parts List:

- Arduino Mega 2560 – controller
- Arduino Nano V.3 – controller
- Micro SD Breakboard – data storage
- ADXL326 – accelerometer sensor
- BMP085 – temperature, pressure, and altitude sensor
- DHT11 – humidity sensor
- TSL2561 – light sensor
- Three hand-wound perpendicular coils
- Lithium batteries

This project will be one that will be flown in our nosecone for the USLI 2012. We will be using micro SD cards as storage.

4.2 Wilfred

This year Wilfred is our two-phase payload of the Scientific Mission Directorate (SMD) and our interpretation of a magnetometer. As part of the SMD criteria, we plan for Wilfred to gather atmospheric data including voltage readings, pressure, temperature, relative humidity, solar irradiance, and ultraviolet radiation. Photos will also be taken upon descent and after landing. The camera is to remain orientated during the descent phase as well as after landing. Ten minutes after Wilfred has landed, data of the flight will be wirelessly transmitted.

Sensors will be used to collect atmospheric data, which meets part of the SMD criteria. Our magnetometer (we hope) will be used to determine the orientation of the rocket. A camera will be used to take pictures, and a transmitter will be used to send our data – again, this will fulfill part of the SMD requirements. Data collection will begin at apogee and continue every second thereafter. Data acquisition stored, and data will be collected from inside a separated payload section. At 2,500 feet, the payload section will be deployed (via black powder charge) from the rocket with the nosecone, separating just above the avionics sections. The payload and nosecone section will descend separate from the avionic and booster sections under its own chute. The payload section will also contain the GPSflight SD-900 to ensure that payload is found. We also plan to have three pictures taken, one every thousand feet, during descent. When the rocket has landed, Wilfred will take data and pictures every minute for ten minutes.

We've decided to use an Arduino Nano V.3 and Arduino Mega 2560 as our controllers. Because of the team's previous experience with the Nano, we have decided to continue our relationship with Arduino. We've also decided to use two controllers to solve some previous issues of our camera baud rate not matching the transmitter's baud rate. Though Dr. Greg Witteman, our payload resource from Honolulu Community College (HCC), recommended use of the Arduino Mega 1280 as our main controller, we decided to go with the more available (not to mention, newer) 2560. All of our sensors and magnetometer will be connected to the Mega 2560, using the Nano to store the camera data. We will also be using micro SD cards, and a micro SD breakout board, for data storage. We have tested both the Nano and the Mega to ensure that they both work.

Wilfred will contain many sensors controlled by the Arduino Mega 2560. Altitude, pressure, and temperature will be collected using a BMP085 sensor (Figure 1a and b). It has a pressure range of 300-1100 kPa, a temperature range of -40 to 85 degrees Celsius. From our previous experience of launch day, we did testing of the BMP085 using lower temperatures to mimic the cold Alabama weather. Test data can be found later in section 4.3.1. Fortunately, these ranges fulfill our desired task.

Because of its low cost, we chose a basic DHT11 sensor (Figure 2.) as opposed to the DHT22. The DHT11 works well in 20-80% humidity ranges with±5% accuracy. Though the DHT11 can collect temperature readings, we plan to get temperature readings through the BMP085 sensor because it has a larger range of data readings with the same accuracy. We also tested our DHT11 sensor individually, and the test data is displayed in 4.3.1.

For solar irradiance, we will use a TSL2561 light sensor (Figure 3.). It has visible and infrared diodes. We were able to test the light sensor to ensure that it works properly. All sensors, when tested alone, have successfully worked. Testing all components together is still a work in progress. We have successfully tested the DHT11 and the micro-SD storage together along with the camera and micro-SD storage. Though we have wired a full system, we are still working on the integration of all the coding for the sensors. Testing the integrated system will be our next step.

The DS1307 is the real time clock we are using in our payload. This clock is battery powered and is used for our Arduino Mega 2560 to keep track of time should the microcontroller be unexpectedly 'reprogrammed', or power was lost. Though it is not a high precision device, we chose this device for 'peace of mind' – besides, it was inexpensive. It is said it may lose or gain about two seconds per day, but for our purposes, the clock shows us how much time has elapsed as opposed to the actual time of the day. We were able to successfully test and set the DS1307.

We are using the TTL Serial JPEG (Figure 4.) from adafruit.com to fulfill the last part of the SMD criteria. It comes with adjustable focus and only requires two digital pins. It has a choice of three resolutions, and compresses the pictures on board making it convenient to transport. This camera will be connected to our Arduino Nano. Last year we faced a problem of being able to send the camera data via the transmitter. The baud rate of the camera data did not coincide with the rate of the transmitter. If we slowed the baud rate of the transmitter to match the camera, the transmission would not send continuous data. To bypass this issue, we plan to use a different transmitter and plan to store the camera data to a micro SD card and have the data from micro SD be sent to our "main" controller (Arduino Mega 2560) as a reassurance if the new transmitter gives us the same issue.

We tested this component (along with the DHT11) to get other members accustomed to the Arduino IDE. With more testing, we were able to find an issue of the time it took for the image to take and store onto the micro-SD card. When the image size was set too large, the process of taking, loading, and saving the image was longer than expected. We did not want to compromise the quality of the image, or fail to meet the necessary picture requirements. After testing we found that taking and storing of pictures (with the best quality) was best done when the image was at a medium size. Once the housing for our camera is created, we plan to do much more testing - focusing more on camera orientation. We also will test to ensure the Arduino Nano will be able to send the camera data to the Arduino Mega 2560.

Our version of magnetometer will also be connected to the Mega. Our magnetometer will be composed of three perpendicular coils wrapped around a nonmagnetic sphere. The voltage difference read from these wires during decent will be stored onto the micro SD card. After our flight, we plan to compare the data with other data from the other sensors. Like the other sensors, we plan to test our magnetometers alone. After continuous data runs and verification of it being able to work alone, we will incorporate it with the other sensors and the Mega.

We will also include an ADXL326 accelerometer (Figure 5.). According to adafruit.com, it is popular for its quality of MEMS devices. This sensor takes 5V and outputs a 3.3V. It also has three analog outputs for X, Y, and Z-axis measurements. We also plan to compare the data from the ADXL326 with the data of the magnetometer to determine the rockets orientation. This sensor was tested successfully. We have yet to test it integrated with the other sensors.

The 3DR Radio Telemetry 915 Mhz is our choice for a transmitter. It is open source, more cost efficient, and according to the specifications, has a superior performance to the Xbee. It has a one-mile range. This transmitter uses APM Mission Planner for support configuring. It has a ground station, which is powered via USB. The air unit is powered via lithium ion battery. After numerous tests, the longest range we have been able to reach with the transmitter is about 0.2 of a mile. We are currently researching amplifying methods. The DIYdrones site we have been using as a reference uses a Shireen 900 MHz 2 watt outdoor amplifier. We are looking for similar amplifiers that may be more budget friendly. Complete testing of the transmitter system is still a work in progress. Further down the line, we would like to test the transmitter at our Full-Scale Low-Powered (FSLP) launch to mimic launch day.

We chose these components due to our previous experience with them, cost efficiency, and accessibility. Because these are simple parts, our team, regardless of experience, will be able to work with them. Though we have a limited budget, we decided spending more on our transmitter would be worthwhile being that it is the most important component of the payload. If the payload cannot transmit, the amount of data collected will not matter. Though the testing of the full payload system has not been completed yet, we plan to test the transmission of sub-scale systems at future launch opportunities.

In development of the payload system, we have decided to not create a specific circuit board. Instead we have decided to use shields to hold all our sensors. We decided to do this because of our inexperience in circuit board manufacturing and budget. Purchasing shields will be cheaper for us than creating a circuit board.

4.2.1 Test Data

BMP085 Test Data:

BMP085 Test Code V.1.2
Temperature: 24.80 deg C
Pressure: 101093 Pa
Temperature: 24.80 deg C
Pressure: 101087 Pa
Temperature: 24.80 deg C
Pressure: 101075 Pa
Temperature: 24.80 deg C
Pressure: 101090 Pa
Temperature: 23.90 deg C
Pressure: 102554 Pa
Temperature: 13.20 deg C
Pressure: 99977 Pa
Temperature: 12.80 deg C
Pressure: 101193 Pa
Temperature: 15.20 deg C
Pressure: 101179 Pa
Temperature: 16.80 deg C
Pressure: 101169 Pa
Temperature: 17.90 deg C
Pressure: 101166 Pa
Temperature: 18.60 deg C
Pressure: 101165 Pa
Temperature: 19.10 deg C
Pressure: 101158 Pa

DHT11 Test Data:

Humidity: 35.00 %   Temperature: 25.00 *C

Humidity: 35.00 %   Temperature: 25.00 *C
Humidity: 35.00 %   Temperature: 25.00 *C
Humidity: 35.00 %   Temperature: 25.00 *C
Humidity: 37.00 %   Temperature: 25.00 *C
Humidity: 37.00 %   Temperature: 25.00 *C
Humidity: 37.00 %   Temperature: 25.00 *C
Humidity: 37.00 %   Temperature: 25.00 *C
Humidity: 45.00 %   Temperature: 26.00 *C
Humidity: 45.00 %   Temperature: 26.00 *C
Humidity: 45.00 %   Temperature: 26.00 *C
Humidity: 45.00 %   Temperature: 26.00 *C
Humidity: 48.00 %   Temperature: 27.00 *C
Humidity: 48.00 %   Temperature: 27.00 *C
Humidity: 48.00 %   Temperature: 27.00 *C

TSL2561 Test Data:

IR: 65535   Full: 0 Visible: 1   Lux: 209923
0
IR: 65535   Full: 0 Visible: 1   Lux: 209923
0
IR: 65535   Full: 0 Visible: 1   Lux: 209923
0
IR: 65535   Full: 0 Visible: 1   Lux: 209923
0
IR: 65535   Full: 0 Visible: 1   Lux: 209923
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 512   Full: 0 Visible: 65024   Lux: 261736
0
IR: 65535   Full: 0 Visible: 1   Lux: 209923
0

Camera Test Data:

Real Time Clock Test Data:

```
WCC - RTC Test1 - v1.03
Date - Dec 28 2012
Time - 12:35:26
2012/12/22 14:5:55
 since 1970 = 1356185155s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:25

2012/12/22 14:5:58
 since 1970 = 1356185158s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:28

2012/12/22 14:6:1
 since 1970 = 1356185161s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:31

2012/12/22 14:6:4
 since 1970 = 1356185164s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:34

2012/12/22 14:6:7
 since 1970 = 1356185167s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:37

2012/12/22 14:6:10
 since 1970 = 1356185170s = 15696d
 now + 7d + 30s: 2012/12/29 14:6:40

2012/12/22 14:6:13
 since 1970 = 1356185173s = 15696d
```

```
now + 7d + 30s: 2012/12/29 14:6:43
```

4.2.2 Sensors and Wiring

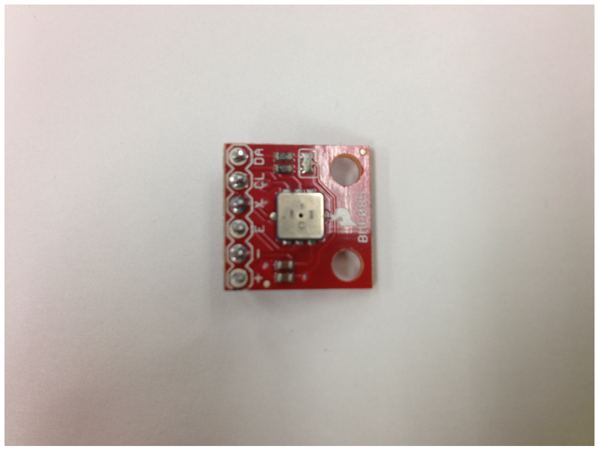


Figure 1a

Figure 1b.

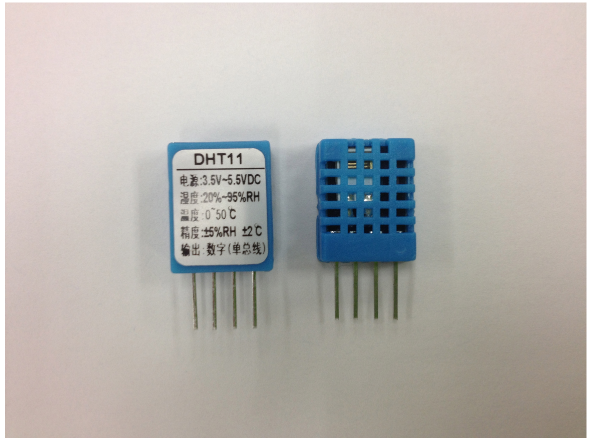


Figure 2.

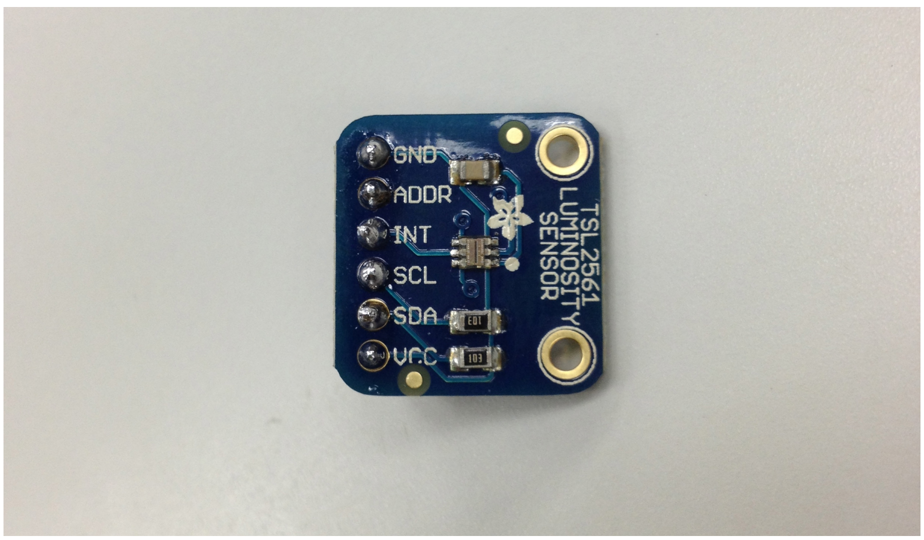


Figure 3.

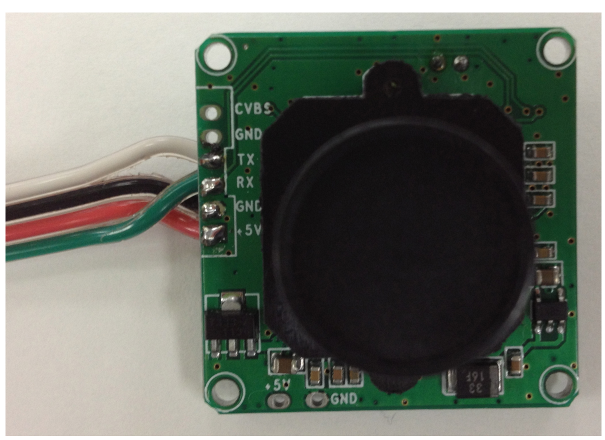


Figure 4.

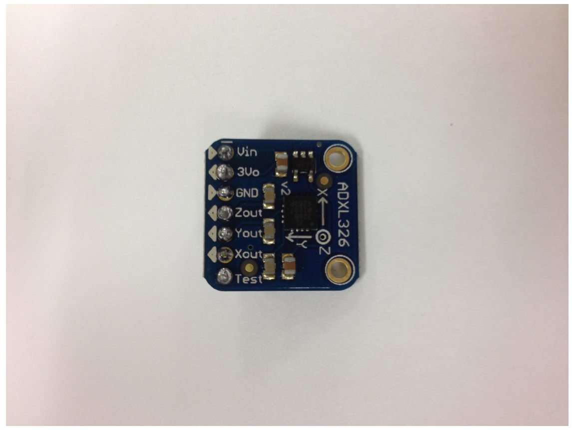
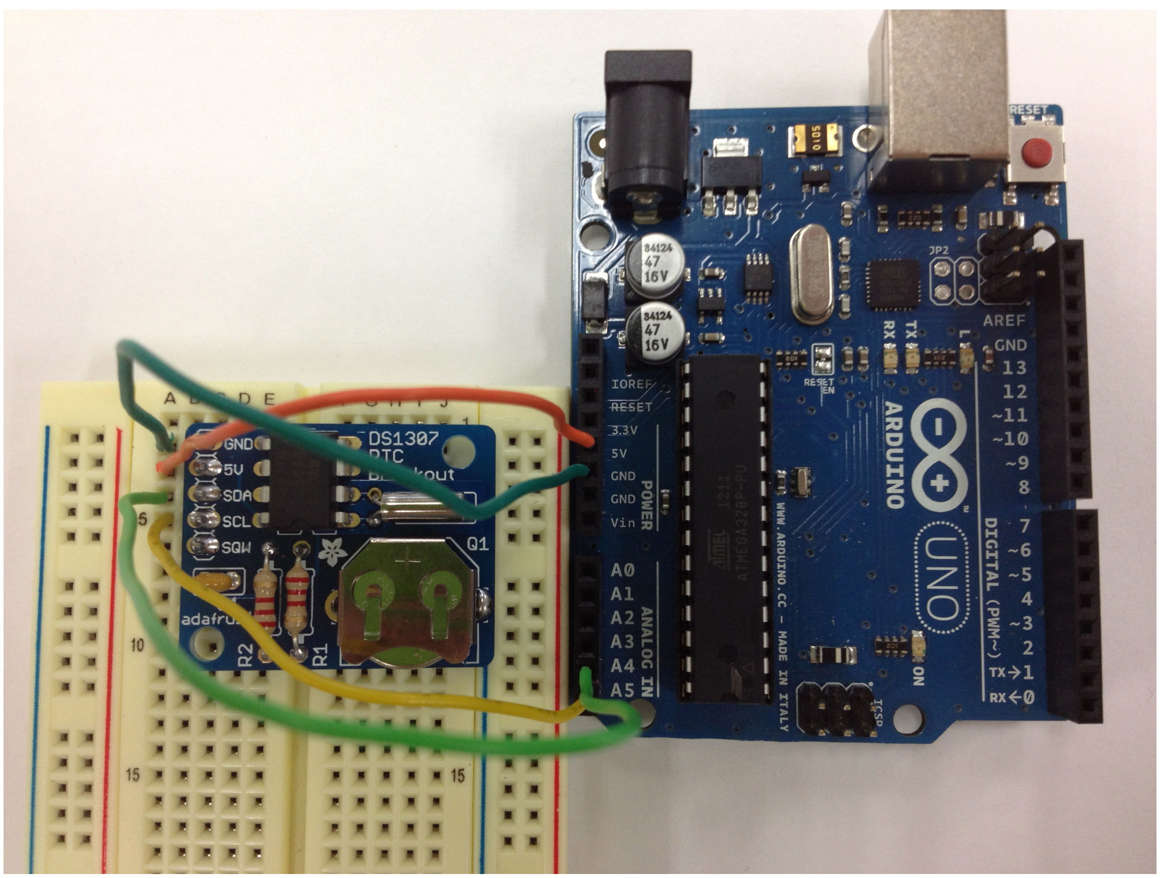
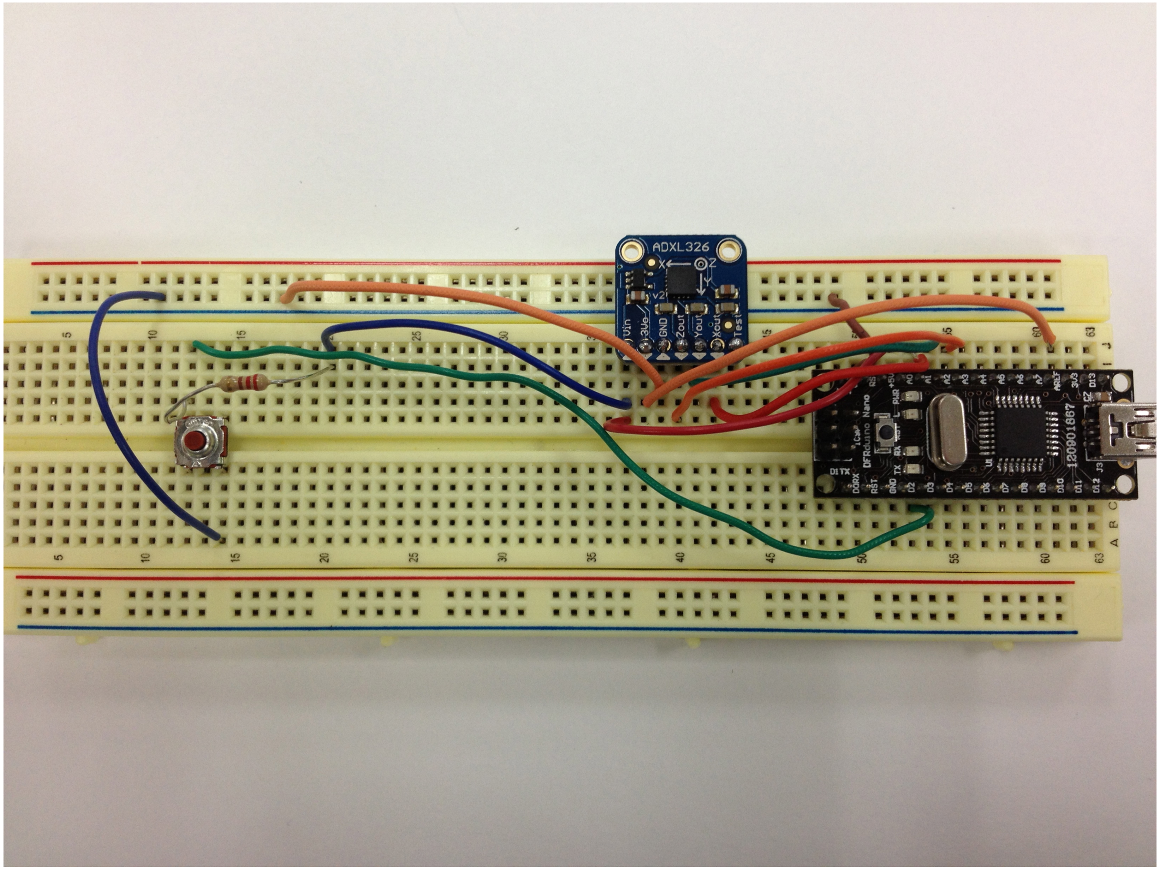


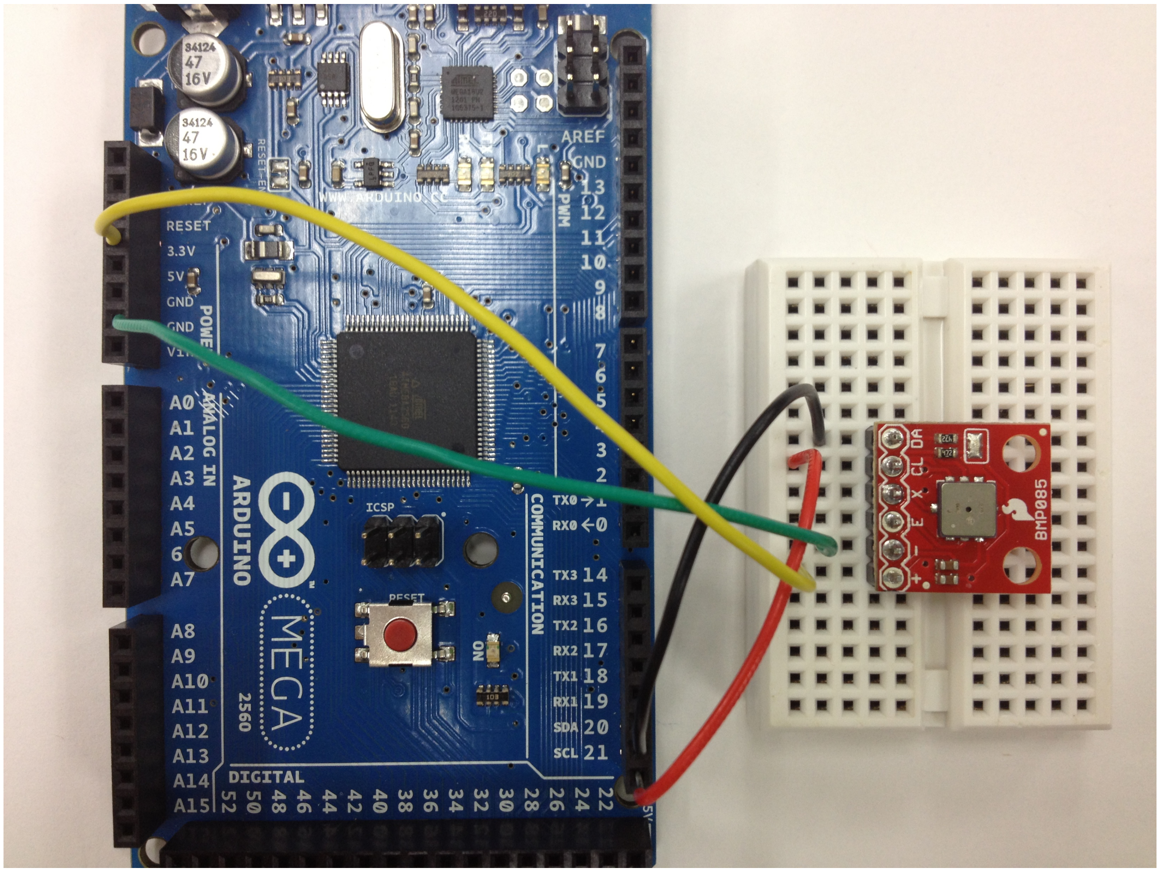
Figure 5.



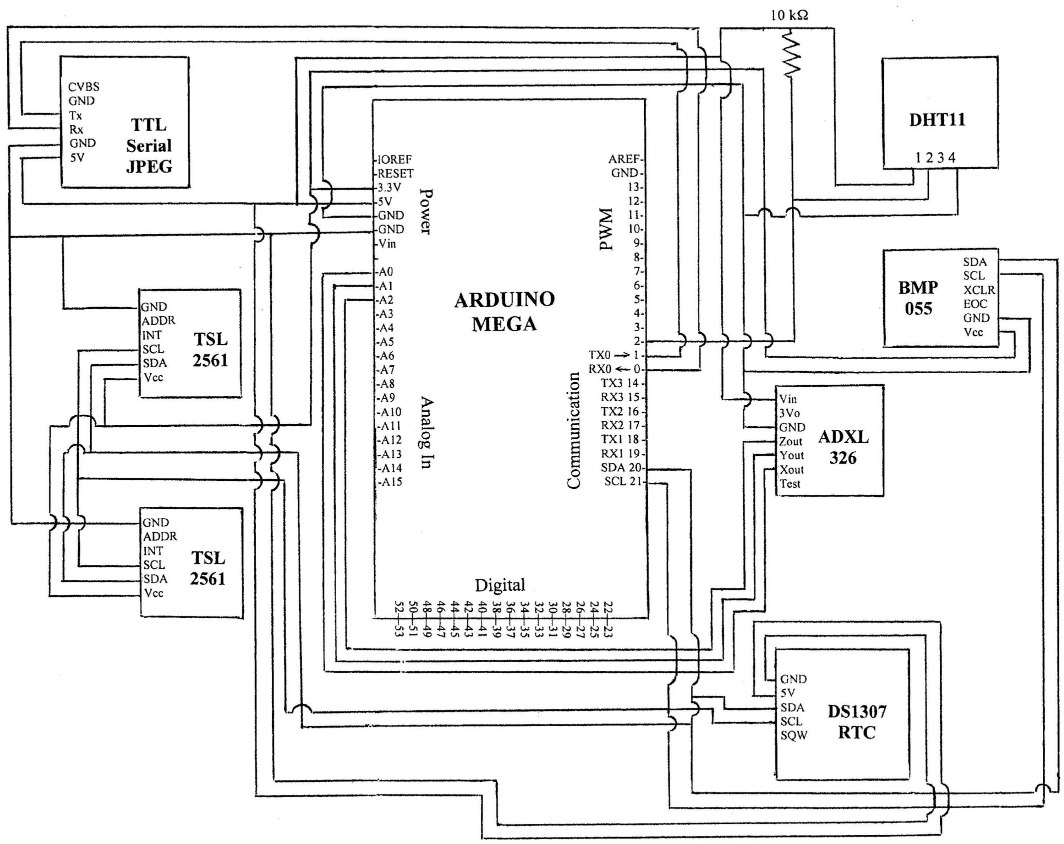
Wiring of the DS1307 Real Time Clock



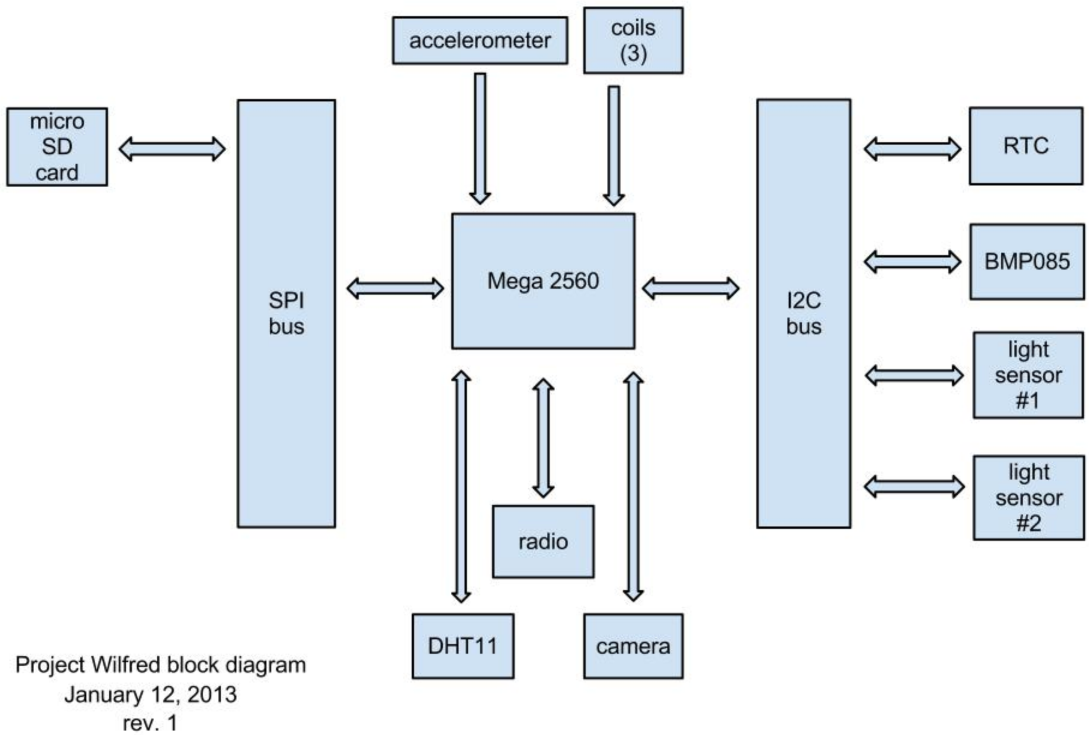
Wiring of the ADXL326 Accelerometer


Wiring of the BMP085

4.2.3 Schematic and Block Diagram



System Wiring Diagram



System Block Diagram

4.3 Payload Success Criteria

For our team, we feel a full payload success would be obtaining data from all components along with a complete wireless transmission. A partial payload success would constitute full or partial data collection with transmission. A partial failure would be full or partial data collection with no transmission. A full failure, for our team, would be no data collection and no transmission.

5.0 Safety

5.1 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.

5.2 Safety Officer

Dr. Jacob Hudson has been assigned as the safety officer of the team. He has the most experience with preparations and flights with regards to high power rocketry, and also holds a level 3 certification from both NAR and TRA. Because of this we believed him to be the most ideal choice to overlook and implement the safety plans of the team.

5.2.1 Safety Officer / Team Official Contact Information

Dr. Jacob Hudson
Phone Number: (808) 347-8246
E-mail: jacobh@hawaii.edu

5.2.2 Team Safety

The team's current mentor, Dr. Hudson, is 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.

The team will be following all the NAR/TRA safety protocols. Dr. Hudson has briefed students on hazard recognition, accident avoidance, and will be conducting pre-launch briefings.

The WCC team has two level 3 certified members (Dr. Hudson and Kristi). It also has a level 2 certified member of NAR/TRA (Joleen) and also a level 1 certified TRA member (Kristin). These certifications ensure that the team is adequately acquainted with Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C, and also has sufficient knowledge on handling and using low-explosives (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 aware and will to be compliant of all federal, state, and local laws concerning the use of unmanned rockets and their components. References to safety regulations can be found in **Appendix C-E.** To ensure that no safety precautions are overlooked a very detailed preflight checklist will guarantee that all rules and regulations are followed concerning the preparation and launch of our rocket.

A flight card will be used before each launch. The team's 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.

Dr. Hudson, as well as all team members, will ensure that all proper safety measures are taken while using the tools and equipment that will be needed to complete the project. This includes the use of protective gear necessary to operate some of the tools and equipment.

The team will also be aware of and post the Material Safety Data Sheets (MSDS) for the materials needed for the project. Hazard mitigations regarding these materials are showed in the table in **Appendix F**.

The Hawaii team will be purchasing our motor from a local vendor. From the time of purchase through the point of use the motor will be handled properly and the team shall follow all proper guidelines defined in all applicable federal laws and NAR/TRA regulations.

All team members understand and will abide to the range safety inspection of our rocket before its flight, and will comply with the determination of this safety inspection. The team also understands that The Range Safety Officer has the final say on all rocket safety issues, and as such has the right to deny the launch of our rocket for safety reasons.

5.3 Rocket body Safety and Failure analysis

Failure Mode	Cause	Effects	Risk Mitigation
Loss of fin	Damage in shipping	Loss of stability & aesthetics. Falling debris	Rigorous pre-flight inspection
Loss of Drag shoe	Damage in shipping	Loss of aesthetics, slow torque along z-axis. Falling debris	Rigorous pre-flight inspection

5.4 Deployment Safety and Failure analysis

Failure Mode	Cause	Effects	Risk Mitigation
Drogue chute deployment failure	Main avionics failure	Rocket craters	Back-up Avionics
Main chute deployment failure	Main avionics failure	Rocket craters	Back-up Avionics
Drogue chute deployment failure	Main and back-up avionics failure	Rocket craters	Checklist for avionics
Main chute deployment failure	Main and back-up avionics failure	Rocket craters	Checklist for avionics
Drogue chute deployment failure	Main pyro failure	Rocket craters	Back-up pyro
Main chute deployment failure	Main and back-up pyro failure	Rocket craters	Checklist for avionics
Separation of	Shock cord	Falling debris,	Checklist

sections	severed	rocket damage	
Separation of sections	Shock cord anchor points	Falling debris, rocket damage	Checklist

5.5 Payload Requirements

For our team, we feel a full payload success would be obtaining data from all components along with a complete wireless transmission. A partial payload success would constitute full or partial data collection with transmission. A partial failure would be full or partial data collection with no transmission. A full failure, for our team, would be no data collection and no transmission.

Failure Mode	Cause	Effect	Risk Mitigation
No deployment	Misfire of pyro	Rocket will land safely and be disarmed	Thorough pre-flight inspection Payload deployment test
Deployment and separation of chute	Shock too great or the chute was not assembled correctly	Payload craters into ground	Thorough pre-flight inspection Payload deployment test
Chute does not fully deploy	Parachute gets tangled or get tangled around nose cone	Chute and nose cone will fall at a faster rate than expected (though not fast enough to be at a ballistic rate)	Follow pre-flight check list Pack nose cone chute correctly
Wilfred separation	Broken tether between payload and nose cone	Free fall of Wilfred to ground	Proper mounting between tether and mounting points of Wilfred Follow pre-flight checklist
No data collected	Incorrect wiring No battery	Payload does not operate correctly	Do a pre-flight test of payload.
Data not transmitted	Incorrect wiring Interference	SMD requirement not met	Do a pre-flight test of

			transmission

6.0 Activity Plan

6.1 Budget

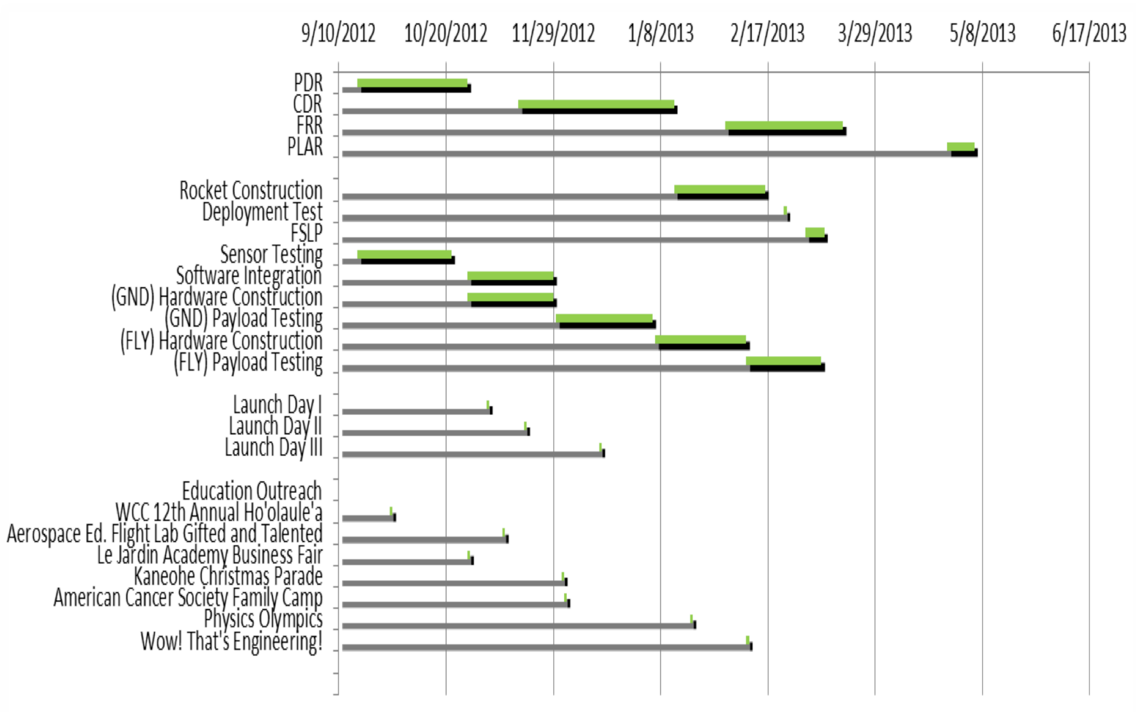
Structure	Airframe tubing	$600.00	
	Fin/Fin can Assembly	$300.00	
	Nosecone	$100.00	
	Additional	$200.00	
			$1,200.00
Propulsion	L1500T motor	$500.00	
	98/5120 Casing	$400.00	
			$ 900.00
Recovery	42” Drogue	$200.00	
	144” Main	$250.00	
	Additional	$150.00	
			$ 600.00
Avionics	PerfectFlight MAWD Altimeter	$150.00	
	Featherweight Raven-2 Controller	$150.00	
	GPSFlight Unit	$200.00	
			$ 500.00
Payload	Microcontrollers	$200.00	
	ADCs	$200.00	
	Sensors	$400.00	
	Cameras	$400.00	
	Additional	$200.00	
			$ 1400.00
Subtotal			$4,600.00
Travel		$10,000.00	
Total			$14,600.00

6.2 Funding Source

The funding for WCC’s USLI project comes for the New Horizons Innovation (NHI) AOULI grant, through the Hawaii Space Grant Consortium (HSGC). This grant is touched upon in a little more detail in **Appendix I.**

6.3 Schedule

10/29	Preliminary Design Review (PDR) report due
Nov. 11/9	(?) PDR Teleconference
11/10	HSGC Presentation
Jan. 1/14	Critical Design Review (CDR) report due
1/25	(?) CDR Teleconference
Mar. 3/3	Full-Scale Low-Power (FSLP) test
3/18	Flight Readiness Review (FRR) report due
3/29	(?) FRR Teleconference
Apr. 4/16	Travel to Huntsville
4/18-19	Hardware/Safety Check
4/20	Launch
May 5/6	Post Launch Assessment Review (PLAR) report due



6.4 Outreach

The USLI team at Windward Community College devoted many successful hours into building stronger community ties. We are very excited to bring our love of rocketry to the world.

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. 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. We have included both a Facebook and a Twitter page to our website in hopes this will help us reach the community.

Detailed flyers and brochures to include what the WCC CAE (Windward Community College Center for Aerospace Education) USLI/SLI project has to offer students and how they can get involved in the numerous NASA opportunities encompassing science, technology, engineering and mathematics (STEM) will also be distributed to schools and organizations throughout the state in hopes that it will lead to an open-line communication between WCC CAE and the rest of Hawaii. We also participate in school fairs and events to help promote our school, NASA, and the stem fields. 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.

We have also brought awareness to our local community by participating in the Kaneohe Christmas Parade, where we will be displaying our rocket along with banners that represent WCC CAE & USLI. Following the parade we participated in a launch at Bellows AFB, in Waimanalo in support of The American Cancer Society. In order to support families of cancer survivors, we have gotten the kids to use the rockets as an outlet for their suffering by launching away their pain in hopes of a brighter tomorrow. We look forward to the participation, and the shared learning experiences, that will ensue with this year’s outreach plans. In addition, we have hosted students in the CAE and will continue to do so. We also will be participating in the Physics Olympiad held annually at our school. And we are very excited to go to Waipahu Middle school where we will have the opportunity to engage 200 students. We will have more details about these events at FRR.

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. Support for our educational endeavors are being sought on the islands of Maui and Hawaii (The Big Island).

Appendix A: Rocksim Results and Parts List

USLIROC2013 – Simulation results

Engine selection
[L1500-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: 600.39370 Ft.
- Relative humidity: 20.000 %
- Temperature: 80.000 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: 38.000 Degrees

Launch guide data:
- Launch guide length: 120.00000 In.
- Velocity at launch guide departure: 60.0172 ft/s
- The launch guide was cleared at: 0.386 Seconds
- The user specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 66.8253 In.

Max data values:
- Maximum acceleration: Vertical (y): 344.081 Ft./s/s Horizontal (x): 0.074 Ft./s/s Magnitude: 344.081 Ft./s/s
- Maximum velocity: Vertical (y): 628.5065 ft/s, Horizontal (x): 0.2236 ft/s, Magnitude: 628.5098 ft/s
- Maximum range from launch site: 29.83113 Ft.
- Maximum altitude: 5725.88556 Ft.

Recovery system data

- P: Main Chute Deployed at: 80.396 Seconds
- Velocity at deployment: 75.7206 ft/s
- Altitude at deployment: 1099.97386 Ft.
- Range at deployment: -25.61572 Ft.
- P: Drogue-chute Deployed at: 19.539 Seconds
- Velocity at deployment: 1.5269 ft/s
- Altitude at deployment: 5725.88554 Ft.
- Range at deployment: -29.83113 Ft.

Time data

- Time to burnout: 3.816 Sec.
- Time to apogee: 19.536 Sec.
- Optimal ejection delay: 15.723 Sec.

Landing data

- Successful landing
- Time to landing: 129.931 Sec.
- Range at landing: -21.72994 Ft.
- Velocity at landing: Vertical: -21.7697 ft/s, Horizontal: 02121 ft/s, Magnitude: 2.7977 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 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)

Payload section – Custom, material: Busada Rigid Thermoplastic

- 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)

Trailing 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)

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: 24.0000 In.
- CG: 9.0000 In., Mass: 2.07260 Oz. Radius of gyration: 0.184085 (m), 18.4055 (cm) Moment of Inertia: 0.0019911 (kgm^2), 19911 (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)

Main-Chute – Custom, Material: Rip stop nylon
- 1 parachute, Shape: Round Dia: 144.0000 In., Spill hole: 12.0000 In.
- CG: 12.0000 In., Mass: 29.2393 Oz. Radius of gyration: 0.356412 (m), 35.6412 (cm) Moment of Inertia: 0.02264675 (kgm^2), 264675 (gcm^2)

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

Motor Mount – Custom, Material: G10 fiberglass
- OD: 3.8976 In., ID: 3.8583 In., Len: 30.0000 In. Location: 18.0000 In. From the front of Booster section
- CG: 15.0000 In., Mass: 7.9092 Oz. Radius of gyration: 0.222961 (m), 22.2961 (cm) Moment of Inertia: 0.0111464 (kgm^2), 111464 (gcm^2), RockSim XN: 0.0000 In., CNa: 0

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

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

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

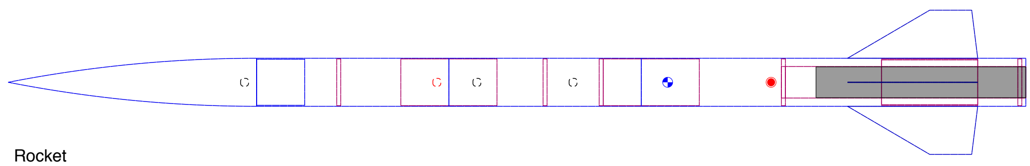
Fin set – Custom, Material: Aluminum
- Planform: trapezoidal, Root chord: 16.2500 In., Tip chord: 5.2500 In., Semi-span: 6.0625 In., Sweep: 10.5023 In., Mid-chord: 7.8598 In., Misc: Location: 26.0000 In. From the front of Booster Section Thickness: 0.0625 In. Profile: square
- CG: 10.1996 In., Mass: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

Drogue-Chute – Custom, Material: Rip stop nylon

- 1 parachute, Shape: Round Dia: 42.0000 In., spill hole: 0.0000 In.
- CG: 3.500 In., Mass: 4.8114 Oz. Radius of gyration: 0.0596 (m), 5.96 (cm) Moment of Inertia: 0.000484523 (kgm^2), 4845.23 (gcm^2)

Appendix B: OpenRocket Results and Parts List

Rocket Design



Rocket
Stages: 1
Mass (with motor): 12925 g
Stability: 2.15 cal
CG: 209 cm
CP: 242 cm

Altitude	1725 m
Flight Time	117 s
Time to Apogee	17.4 s
Velocity off Pad	38.3 m/s
Max Velocity	242 m/s
Velocity at Deployment	N/A
Landing Velocity	32 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
L1500T	1537 N	2.35 s	2381 N	3616 Ns	12.12:1	1644 g	98/665 mm

Parts Detail

Sustainer

Nose cone	Fiberglass ($1.85\ g/cm^3$)	Ogive	Len: 78.74cm	Mass: 1,906.793g
Magnetometer		Dia_{out} 2.5cm		Mass: 226.796g
Payload Section	Acrylic ($1.19\ g/cm^3$)	Dia_{in} 14.84cm Dia_{out} 15.24cm	Len: 60.96cm	Mass: 685.519g
Bulkhead 1	Birch ($0.67\ g/cm^3$)	Dia_{out} 14.84cm	Len: 1.27cm	Mass: 147.176g
Tube coupler	Cardboard ($0.68\ g/cm^3$)	Dia_{in} 14.84cm Dia_{out} 14.84cm	Len: 30.48cm	Mass: 0g
Parachute	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 365.76cm	Len: 2.5cm	Mass: 736.893g
Shroud Lines	Elastic cord (round 2mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 304.8cm	
Avionics Section	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 14.84cm Dia_{out} 15.24cm	Len: 60.96cm	Mass: 1,065.723g
Bulkhead 2	Birch ($0.67\ g/cm^3$)	Dia_{out} 14.84cm	Len: 1.27cm	Mass: 147.176g
Bulkhead 3	Cardboard ($0.68\ g/cm^3$)	Dia_{out} 14.84cm	Len: 1.27cm	Mass: 149.372g
AV Hardware		Dia_{out} 2.5cm		Mass: 0g
Tube coupler	Cardboard ($0.68\ g/cm^3$)	Dia_{in} 14.84cm Dia_{out} 14.84cm	Len: 30.48cm	Mass: 0g
Mass component		Dia_{out} 2.5cm		Mass: 500g
Booster	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 14.84cm Dia_{out} 15.24cm	Len: 121.92cm	Mass: 2,131.446g
Motor Tube	Kraft phenolic ($0.95\ g/cm^3$)	Dia_{in} 9.8cm Dia_{out} 10cm	Len: 76.2cm	Mass: 225.146g
Centering ring	Cardboard ($0.68\ g/cm^3$)	Dia_{in} 10cm Dia_{out} 14.84cm	Len: 1.27cm	Mass: 81.545g
Centering ring	Cardboard ($0.68\ g/cm^3$)	Dia_{in} 10cm Dia_{out} 14.84cm	Len: 1.27cm	Mass: 81.545g
Aluminum Tube	Aluminum ($2.7\ g/cm^3$)	Dia_{in} 14.205cm Dia_{out} 14.84cm	Len: 30.48cm	Mass: 1,192.103g
Trapezoidal fin set (4)	Aluminum ($2.7\ g/cm^3$)	Thick: 0.3cm		Mass: 1,348.255g

Appendix C: NAR 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.

Revision of July 2008

Appendix D: TRA Safety Code

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

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

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

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

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

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

20480.01 - 40960.00	O	26,400	5.00

TABLE 2: SAFE DISTANCE

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

Appendix E: 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 F: Detailed Hazard Mitigation

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

First Fire Jr. Igniter	Ingestion Hazards, Toxic Fumes, Skin Irritation, Eye Irritation, Inadvertent Ignition, Burns to skin	Team members will work in well-ventilated areas and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of hazardous chemicals. Gloves will be worn at all times to prevent skin irritation and burns to skin. Goggles will be worn at all times to prevent eye irritation. Igniters will be kept away from ignition sources such as flames, matches, and heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition.
Rocket Propellant	Skin Irritation, Inadvertent Ignition, Burns to skin	Gloves will be worn at all times to prevent skin irritation. Propellant will be kept away from ignition sources, such as flames, matches, igniters, heat sources, and will be properly stored in Type 3 or Type 4 magazines to prevent inadvertent ignition. After motor burn, the team will wait 15 minutes before disassembling the motor, while wearing insulated gloves to prevent burns to skin.
Epoxy Resin	Toxic Fumes, Skin Irritation, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
5-Minute Epoxy Resin	Toxic Fumes, Skin Irritation, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent Eye Irritation
Sinmast 4 Epoxy Mortar Mix - Normal Cure	Ingestion Hazards, Skin Irritation, Eye Irritation	Team Members will wear face masks at all times to prevent ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles

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

Mineral Spirits	Severe Eye Irritation, Skin irritation, Ingestion hazards	Team Members will wear face masks at all times to prevent Ingestion of the material. Gloves will be worn at all times to prevent skin irritation. Goggle will be worn at all times to prevent eye irritation
Denatured Alcohol	Toxic Fumes, Ingestion Hazards, Eye Irritation	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Goggles will be worn at all times to prevent eye irritation
Carbon Dioxide	Inhalation Hazards	Team members will work in a well-ventilated area to prevent inhalation hazards
Silicone Lube	Ingestion Hazards, Skin Irritation, Eye Irritation, Toxic Fumes	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent eye irritation
White Lithium Grease	Ingestion Hazards, Skin Irritation, Eye Irritation, Toxic Fumes	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Gloves and chemical resistant aprons will be worn at all times to prevent Skin Irritation and contact with clothing. Goggles will be worn at all times to prevent eye irritation
Isopropyl Rubbing Alcohol	Toxic Fumes, Ingestion Hazards, Eye Irritation, Inadvertent Ignition, Burns to Skin	Team Members will work in a well-ventilated area and wear face masks at all times to prevent inhalation of toxic fumes and ingestion of the material. Goggles will be worn at all times to prevent contact with eyes leading to eye irritation. Material will be kept away from ignition sources, such as flames, matches, igniters, heat sources. Team members will wear gloves to protect from burns to skin in the event of an

		inadvertent ignition
Black Powder	Inhalation Hazards, Eye Irritation, Inadvertent Ignition, Burns to skin	Team Members will wear face masks at all times to prevent Inhalation of the Black Powder. The Black Powder will be kept away from ignition sources such as flames, matches, and heat source to prevent inadvertent ignition. Gloves will be worn to prevent burns to skin. Goggles will be worn at all times to protect eyes. Equipment used with or near the Black Powder will be nonstatic producing materials to prevent inadvertent ignition.

Appendix G: Center for Aerospace Education

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

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

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

The goals of the CAE are to:

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

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

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

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

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

Appendix H: Facilities and Equipment

Main Facilities

The location of our main workroom is at Windward Community College, Hale ‘Imiloa Room 112. This houses the Center for Aerospace Education’s (CAE) NASA Flight Training Aerospace Education Lab (NASA AEL) and Hawai‘i Space Grant Consortium at Windward. The NASA Flight Training AEL is a high-tech computer classroom designed to give students in grades 7-12 a project-based learning environment for applying skills in math and science. The AEL is accessible to all USLI students and mentors during normal school hours, 7:00 AM – 9:00 PM. It is also accessible on Saturdays from 8:00 AM – 1:00 PM and is accessible after school hours as afterhours on weekends if the need arises. This is a semi-secure room as it is normally closed and electronically locked. The room is considered semi-secure because other students in pursuit of other endeavors can also access it. Two very small-scale, sub-sonic, wind tunnels are available to the team members thru the NASA AEL.

The team also uses the Project Fabrication Workshop (PFW), which is our new room to construct and store our various rockets, payloads, equipment, and parts. It is a great addition to help facilitate with the construction of our rockets and various parts of our projects. We have twenty-four hour access to the room via secure access cards for the team members. It is a safe and secure facility that is patrolled twenty-four hours by campus security.

Auxiliary Facilities / Events

USLI team members may use the NASA AEL for assembly of rocket & payload parts. However, since construction, fabrication, and/or alteration of said parts may not be suitable for the NASA AEL during lecture hours, all such activities are constrained to weekend hours. As WCC has no machine shop facility, construction, fabrication, and/or alteration of said parts may have to be completed at team members’ residence or an otherwise suitable area.

WCC hosts Sky Performance Rocketry Club of Hawaii’s launches on the third Saturday of each month from the hours of 2:30 p.m. – 5:30 p.m. from which the USLI team can do small launches for testing.

The CAE at WCC, with permission, has launched from the Kaneohe Marine Corps Air Station in the past and will most likely be able to do so in the future. The KMCAS has considerably more space available for larger launches which would not be capable at WCC.

WCC is a liberal arts community college known for its Hawaiian language and science programs and does not have an Industrial program or machine shop. WCC will partner with sister college Honolulu Community College (HCC) in hopes of recruiting students for the USLI program, or to at least have HCC students fabricate parts for the WCC USLI program as needed.

Appendix I: Continuance

This is the fourth year that the WCC CAE team has entered USLI. More then half of the students are new to the team. In many respects, it was needed to have a continuance for this team; industry contacts (limited as they are for this state), established by last year's team members, needed to be maintained and pursued. Whereas this project has shown much interest from the private sector, as of this writing, no monies have been forth coming. The CAE wrote, and subsequently obtained, a grant from the Hawaii Space Grant Consortium to fund this year's team, both in material and travel expenses[1]. The outcome of the New Horizons Innovation (NHI) AOULI grant proposal depended on students, from last year's effort, continuing their established efforts for this year. Additionally, education outreach programs, previously outlined, are being pursued by the same students that initiated them last year. Relations established with the Kaneohe Marine Corp Air Station, are still being maintained and expanded upon.

The NHI/AOULI grant also funded two other endeavors; the establishment of A Rocket Contest for Hawaiian Skies (ARCHeS), and the implementation of an Introduction to Rocketry class as part of the WCC curriculum. Students, enrolling in the Introduction to Rocketry class will fulfill part of the requirements for a 3/2 program for pre-engineering students, and fulfill part of an Astronomy Engineering certificate. As of this writing, a new science course (AERO 150 Introduction to Rocketry) has been accepted in the catalog of courses for WCC. ARCHeS was being developed by our team, and was to be in conjunction with the Sky Performance Rocketry Club of Hawaii (SPRCH), but has since been halted due to a lack in funding. ARCHeS was to be a contest open for all interested high schools. Participating high school students were to be tasked to design, build, and fly a rocket that will carry a payload, of one to two eggs, to specific heights while satisfying several flight parameters. It was hoped, that the school that won the competition would get invited to take part in SLI. In March, after much work (but luckily before the contest announcement) we were informed that the promised funding had been reallocated. Because of this, ARCHeS has been put on hold until more funding can be found. It is the team's greatest desire to finish this endeavor, and have a Hawaii High school take part in SLP.

At the 2012 USLI launch our team's rocket did not have a successful flight. Due to a defective tether cord, the main chute separated from the rest of the descending rocket (and still hangs over Huntsville for all we know). The rocket descended, safely, under drogue and was recovered intact. However, since the descent rate was greater then anticipated, the batteries for the Walter payload as well as the micro-SD card, were dislodged and data was lost. The team would like to get a successful flight and conclusion to this experiment. Additionally, due

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[1] Aerospace Opportunities for Underrepresented Learners and Instructors (AOULI) A Joint Proposal by Windward Community College & Honolulu Community College; J.E. Ciotti, Principle Investigator.

to a last minute redesign of the SMD/ASTRID payload housing, the team was not able to integrate the payload safely into the rocket before flight. Since time was becoming an issue, the SMD was not flown.

Appendix J: Travel Proposal

Travel to USLI Competition
Estimated Costs

Request: Windward Community College is requesting $9,456 ($4,968 from an HSGC/NHI grant and the remaining $4,488 from Dr. Colmenares and her funding sources) so that it can attend the University Student Launch Initiative (USLI) competition, April 17th to the 22rd, 2013. The attending WCC USLI team consists of 8 students (Kristi Ross, Warren Mamizuka, Lyra Hancock, Kristin Barsoumian, and Ada Garcia), and 1 mentor (Dr. Jacob Hudson).

Justification: The USLI project is a competition that challenges University students to design, build, and launch a reusable rocket to one mile above ground level with a scientific payload. The project is an 8-month commitment for teams, and culminates with a hardware review of their projects, rocketry symposia, and the flight of their rockets.

Airfare:	$ 990 (UAL Est.) X 6 LV (4/16) HNL 10:00 pm UA42 to DEN DEN 10:40 am UA 6570 to HSV @ 2:19 pm RT (4/22) HSV 6:35 am UA5711 to ORD ORD 9:50 am UA1 to HNL @ 2:04 pm	= $ 5,940
Van Rental:	(Full size van one week; Avis est.) Avis – Huntsville International Airport Huntsville Alabama	= $ 360
Rooms:	$534 (Est. $89/night X 6 nights) X 4 rooms Holiday Inn Downtown (?) (256) 533-1400 (?)	= $ 2,136
Food:	$25/day/student X 6 days X 5 students	= $ 750
	$45/day/mentor X 6 days	= $ 270
		$ 9,456

The WCC USLI has to take part in a Preliminary Design Review (PDR), a Critical Design Review (CDR), and is currently in the construction phase of the competition. The competition rules follow the process used by NASA for design, fabrication and launch of Space Hardware. A team presence is required at the time of the actual launch.

Project Justification: In order to continue its efforts at promulgating interests in science, technology, engineering, and mathematics, the Center for Aerospace Education (CAE) would like to acquire a re-usable rocket to perform diagnostic testing for several of our education outreach projects. The rocket would be designed to carry a non-specific payload, of limited weight and size, to a specific altitude of 1 mile (5280'), and then return safely to its launchers. 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 status of the rocket. To ensure re-usability, the rocket would deploy a drogue chute at apogee, and a larger main chute at a lower altitude – high enough for a safe landing, yet low enough to ensure retrieval in a limited area.

Several projects that would benefit from the lifting body are discussed below.

CanSat: The WCC CanSat program is a project based learning opportunity to instill an interest in science, technology, engineering, and mathematics in college students that would otherwise not pursue such endeavors. Students are tasked with designing, building, and the subsequent testing of a fully operational device that will emulate a space probe gathering an array of data. There are strict physical limitations to the design volume of the CanSat, usually confined to fitting inside of a standard 350 ml soda can. Students are usually required to interact with experts in the engineering community, or faculty experts on other campuses of the University of Hawaii system. Since the majority of students attending the satellite Community Colleges are pursuing a liberal arts certificate, the CanSat program is ideally suited to for these students. Aside from acting as a resource, the CAE would like to be able to provide a means of *in-situ,* rigorous, testing of the involved electronics previous to departure for the competition.

ARLISS: Among the many variants of CanSat is ARLISS (A Rocket Launch for International Students Satellites). ARLISS is hosted by AeroPAC (a recognized high powered rocketry organization) and Prof. Robert Twiggs (recently retired from Stanford University), and takes place in Black Rock Nevada, primarily to foster relations between universities around the Pacific Rim. Students are tasked with designing, building, and testing, an electronics package that emulates a planetary probe. The goals for ARLISS are well defined - the electronic package must, when deployed from a payload bay, autonomously make its way to a GPS target site, all the while gathering external data and transmitting it to a passive ground station. A low-altitude rocket would provide a marvelous opportunity for the multi-faceted testing required for a successful endeavor.

Curriculum Development: Current efforts to develop a rocketry certificate program, requires curriculum development for two courses; Rocket Principles, and Ground Safety Protocols. A re-usable rocket, launched in conjunction with the above two projects, utilizing students from the two classes, provides a *hands-on* situation that can only be beneficial to the learning environment. By having one to two launches a semester, students can come away with a greater understanding of the rocketry principles involved, and the safety procedures followed.

High School Science Fair: Preliminary data collected by the CAE indicates that there is a wide interest in student lead research involving rocketry. By soliciting proposals from High Schools that have flight ready projects, the CAE could host launches involving the students in the Rocketry certificate program. Interested High Schools would submit a proposal to the CAE for a flight request. The accepted High Schools would then submit a Preliminary Design Review, a Critical Design Review, followed by a Flight Readiness Review prior to the project being flown. These would be reviewed, and commented upon, by the students in the Safety Protocols class. Any recommendations would be conveyed back to the particular High School. At the time of launch, interested High School classes would be invited to observe the launch, with the on-board payload carrier electronics performing a ‘voice-over’ of what the rocket is doing at all phases of is flight profile.

Appendix K: Community Support

The Marine Corps Base Hawaii has offered the use of its airfields for aerodynamics and scale 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 an approximate 2,500 foot ceiling, which is 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

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.