December 5, 2009

MADISON WEST

SLI 2010

MADISON WEST ROCKET CLUB

THE EFFECT OF ATMOSPHERIC CONDITIONS AND GROUND FEATURES ON THE INTENSITY OF DIRECT AND REFLECTED SUNLIGHT

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http://www.westrocketry.com

SLI 2010 Preliminary Design Review

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Summary of PDR Report

Team Summary

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Launch Vehicle Summary

The vehicle is ten feet in length and has a six inch payload section transitioning to a four inch booster section. It will fly on an Animal Motor Works L1080BB to an altitude of 5900 feet. We will use a modified dual-deployment system to safely recover the vehicle and payload.

Payload Summary

Direct and reflected sunlight intensity varies based on atmospheric content and ground coverage and reflectivity. By measuring the intensity of sunlight and atmospheric factors, correlations can be found between these factors. Our payload consist of two spherical sensor packages (Argus 1 and Argus 2), each containing sensors for measuring sunlight intensity, temperature, GPS location, altitude, and humidity.

Changes Made Since Proposal

Changes Made to Vehicle Criteria

The design of the Vehicle Payload Integration has been refined.
The design of the Booster-Payload transition has been refined.

Changes Made to Payload Criteria

The light sensors will be mounted evenly over the sphere, as to collect data of available radiation at different angles. A camera will be located at the "South" pole of the sphere to record image data of surface features. Apart from that, we have not made significant changes to the payload.

Changes Made to Activity Plan

There are no current changes in our activity plan. However, as our project progresses changes may occur.

Vehicle Criteria

Selection, Design, and Verification of Launch Vehicle

Mission Statement, Requirements, and Mission Success Criteria

1. Target Altitude: Rocket must reach altitude of 1 mile — (simulations show that our rocket will reach 5900ft using the AMW-L1080BB motor). At this stage of the project we are leaving ourselves a sufficient altitude margin to cover for possible rocket design changes and weight increase.

2. Payload: the rocket carries two scientific payload modules. The payload is not time critical. The payload is reusable.

3. Robustness: Our vehicle must withstand acceleration up to 10 G — we will construct rocket from fiberglass coated phenolic tubing, G10 fiberglass-reinforced balsa (for fins) using industrial strength epoxy glue (West Epoxy) with fillers. We will mount the fins using through the wall construction in order to improve robustness.

4. Safe Recovery: Our vehicle must land undamaged and suitable for re-flight — We will utilize a modified dual deployment scheme with redundant charges and ejection triggers to ensure the ejection and will determine and verify the sizes of parachutes and ejection charges during static tests. Ejection charges will be triggered by commercially available e-matches.

5. Propulsion: Rocket must attain a thrust to weight ratio of at least 5.0 at liftoff. Our configured vehicle has a thrust to weight ratio of 6.5. Our selected motor contains solid ammonium perchlorate based propellant and the total impulse of the vehicle is less than 4,000 Newton-seconds.

6. Stability: Rocket must have a sufficient stability margin. Our rocket has a stability margin of 3.04 calibers.

7. Launch: the rocket can launch from a standard launch tower and it needs a minimum of 8ft launch guidance to achieve the stable flight velocity.

8. Preparation: the vehicle will not take more than 4 hours to prepare for the flight. Our payload is solid-state, minimizing preparation procedures.

9. Data: data will be collected during the descent and analyzed after the vehicle and deployed payload modules are recovered.

10. Recovery: we are using a dual deployment scheme with the payloads modules deployed at an altitude dependent on wind speed in order to minimize drift. Sonic and radio beacons will be used to aid us in vehicle tracking and recovery, should excessive drift occur.

11. Prohibited items: we are not using flashbulbs, rear ejection, forward firing motors, AMW-SK motors or forward canards on our vehicle. The vehicle does not exceed Mach 1.

Major Milestones Schedule

Project Plan		
December 09		
	7th	Acquire supplies for scale model
	14th	Begin work on scale model
January 10		
	11th	Finish scale model
	18th	First test flight of scale model vehicle
	25th	Begin work on full-scale vehicle and payload
February 10		
	21st	Full-scale vehicle completed
	28th	First test flight of full-scale vehicle
March 10		
	22nd	Second test flight of full-scale vehicle
April 10		
	11th	Rocket ready for launch
	15th	Rocket Fair/Hardware & Safety Check
	18th	SLI Launch Day

Table 1: Major milestones schedule for vehicle construction

Design Review at System Level and Required Subsystems

Propulsion System

Motor

The Animal Motor Works L1080BB is the first choice motor. It will provide sufficient thrust for the liftoff of the entire vehicle (thrust/weight ratio is 6.5) and will burn out around 3.4 seconds after accelerating our rocket to about 435mph. For our scale model we will use an Aerotech I-435T which will propel our scale model to an estimated apogee of 1370 feet.

Motor	Length *[mm]*	Diameter *[mm]*	Average Thrust *[N]*	Impulse *[Ns]*	Burn Time *[s]*
AMW-L1080BB	497	75	1080	3700	3.4s

Table 2: Motor Specifications

Motor Alternative

We have selected an alternative should our first choice become unavailable. The motor alternative satisfies the minimum thrust/weight ratio for safe flight.

Motor	Apogee *[ft]*	Thrust to Weight Ratio
AT-L850W	5949	5.1

Table 3: Alternate Motor Performance

The motors will be contained in a phenolic motor-mount centered in the rocket body with plywood centering rings and secured with a Lock’N’Load motor retention system.

Structural System

The structural system consists of 4” fiberglass coated phenolic and 6” fiberglass tubing. The 6” payload tubing was selected to meet the specific size requirements of our payload, while the 4” booster tubing was selected in order to reduce weight and drag. Our G10-fiberglass/balsa composite fins will be attached with through-the-wall construction to the motor mount. Paper tubing and non-reinforced balsa fins are unacceptable, as they are not strong enough to withstand high-power rocket flight.

Vehicle

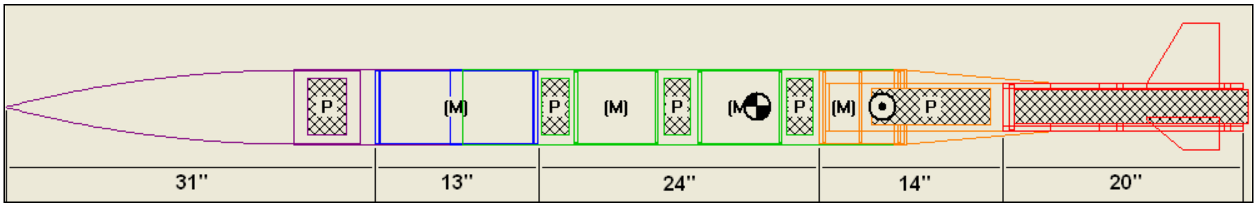

Figure 1: A two-dimensional schematic of our vehicle showing the center of gravity (indicated by a ⊕) and the center of pressure (indicated by a ⊙). Also visible are the lengths of each section. The total length of our rocket is 102 inches. The center of gravity is 65.6 inches from the nosetip, and the center of pressure is 76 inches from the nosetip. From the top, sections are as follows: drogue and payload bay parachute storage, payload electronics bay, payload bay with two payload modules, parachutes, and booster drogue parachute, transition and booster electronics, booster main parachute storage, and booster section including motor mount and fins.

Vehicle Parameters

Length *[in]*	**Liftoff weight *[lbs]***	**Diameter *[in]***	**Motor Selection**	**Stability Margin *[calibers]***	**Thrust to Weight Ratio**
102	36.6	6.155	AMW-L1080BB	1.58	6.5

Table 4: The rocket’s dimensions, stability and propulsion

The vehicle has a six-inch payload bay because of the size estimates for the payload. If we determine that the payload modules will be smaller than initial estimates before construction of the vehicle begins, we will resize the payload section appropriately.

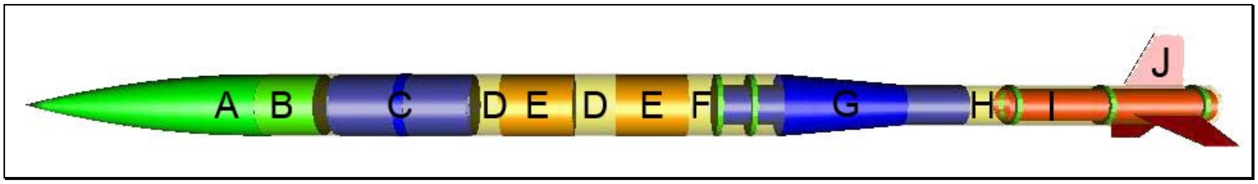

Figure 2: A three dimensional schematic of the entire rocket, showing the payload integration

Letter	Part	Letter	Part
A	Nosecone	***F***	Booster Drogue Parachute Storage
B	Drogue Parachute	***G***	Transition and Booster Electronics
C	Electronics Bay and Electronics	***H***	Booster Main Parachute Storage
D	Payload Parachute Storage Areas	***I***	Motor Mount
E	Payload Modules	***J***	Fins

Table 5: Rocket Parts and Sections

Deployment System

Our rocket will experience three ejection events. The common drogue chute will deploy first with the separation of the nosecone at apogee. Next our payload modules will be deployed at 4000 feet, at which point the booster will separate from the payload tube and will be carried under its own drogue chute. After the deployment of payload modules, the payload tube is light enough to safely land under the common drogue parachute. Finally the booster section will deploy its main parachute at 700 feet.

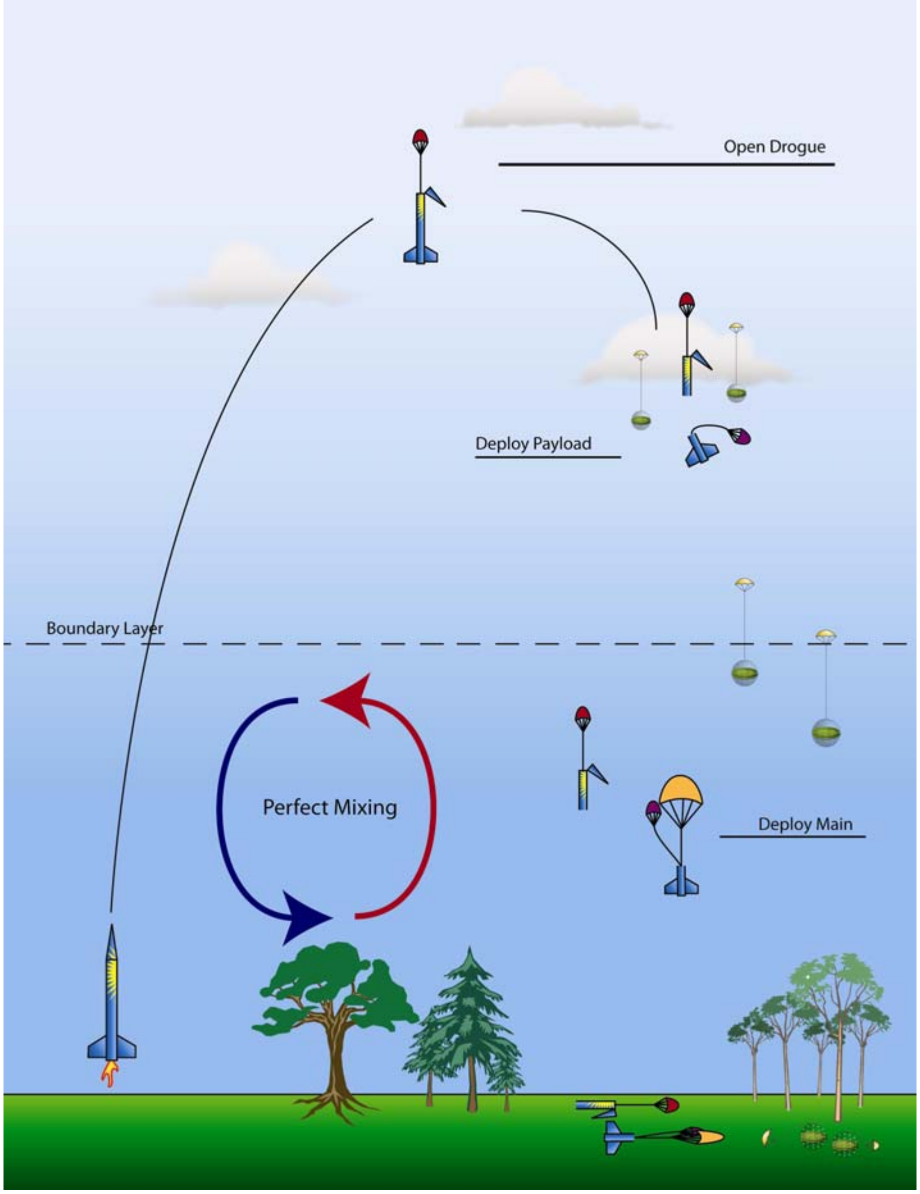

Figure 3: Flight sequence from liftoff to touchdown. At apogee the common drogue parachute deploys. At 4000 feet the payload modules are ejected and the booster section separates from the payload tube, descending under its drogue chute. Without the payload modules, the payload tube is light enough to safely land under the common drogue parachute. At 700 feet the booster main parachute is deployed.

Verification Plan and Status

Verification Tests

V1 Integrity Test: applying force to verify durability.
V2 Parachute Drop Test: testing parachute functionality.
V3 Tension Test: applying force to the parachute shock cords to test durability
V4 Prototype Flight: testing the feasibility of the vehicle with a scale model.
V5 Functionality Test: test of basic functionality of a device on the ground
V6 Altimeter Ground Test: place the altimeter in a closed container and decrease air pressure to simulate altitude changes. Verify that both the apogee and preset altitude events fire. (Estes igniters or low resistance bulbs can be used for verification).
V7 Electronic Deployment Test: test to determine if the electronics can ignite the deployment charges.
V8 Ejection Test: test that the deployment charges have the right amount of force to cause parachute deployment and/or planned component separation.
V9 Computer Simulation: use RockSim to predict the behavior of the launch vehicle.
V10 Integration Test: ensure that the payload fits smoothly and snuggly into the vehicle, and is robust enough to withstand flight stresses.

Tested Components

C1: Body (including construction techniques)
C2: Altimeter
C3: Data Acquisition System (custom computer board and sensors)
C4: Parachutes
C5: Fins
C6: Payload
C7: Ejection charges
C8: Launch system
C9: Motor mount
C10: Beacons
C11: Shock cords and anchors
C12: Rocket stability

Verification Matrix Key:
P: Planned Test
F: Finished Test

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
C1	P			P				P		P
C2				P	P	P				
C3	P				P					
C4	P	P	P	P				P		
C5	P			P						
C6	P				P					P
C7				P	P		P	P		
C8	P			P						
C9	P			P						
C10	P			P	P					
C11			P	P				P		
C12				P	P		P	P		

Table 6: Verification matrix for the vehicle

Schedule Risks

Risks	Consequences	Mitigation
Team members unable to attend meetings	Incomplete project	All meetings will be planned for times when team members are available
Parts are not delivered on time	Incomplete project	All parts will be ordered in advance of testing and construction
Tests not completed	Uncertainty of functionality	All parts of the vehicle will be tested as per the verification matrix before final flight
Project over budget	Incomplete project	Additional fundraising will be undertaken to insure adequate funds
School holidays interrupt project	Incomplete project	Meetings will be scheduled during holidays via email.

Table 7: Risks associated with the timeline of the project

Manufacturing, Verification, Integration, and Operations Plans

Confidence and Maturity of Design

Our rocket has been designed with the principles of high-power rocketry in mind. We are using strong materials: fiberglass-coated phenolic tubing for the body and G10 fiberglass/balsa composite for the fins; we are using through-the-wall fin mounting for extra strength; and we are using a dual-deployment scheme for the entire rocket as a whole and for the booster to make recovery easier.

The rocket performance and stability has been predicted by RockSim simulations and will also be verified by a half-scale model flight. The complete ignition and deployment scheme will be verified during the scale model flight.

Recovery Subsystem

Our rocket will deploy a total of five parachutes. The two parachutes on the booster section will use a standard dual deployment scheme, ejected by one charge per parachute. Each charge will be connected to two dual-event altimeters for redundancy. The payload bay will have one parachute (common drogue) that will maintain a safe landing descent rate after the payload modules have ejected, about 24 ft/sec. Each payload module will also have its own parachute. All five parachutes will be commercially available rip-stop nylon parachutes with nylon shroud-lines. The dimensions of these parachutes and the rocket component descent rates will be as follows:

Parachute	Weight *[kg]*	Parachute Diameter *[in]*	Descent Rate *[ft/sec]*
Booster Drogue	5.5	24	64
Booster Main	5.5	92	17
Drogue/Payload Bay (Drogue)	14.9	50	51
Drogue/Payload Bay (Payload)	3.3	50	24
Payload Module	1.0 (est.)	34	19

Table 8: Parachute dimensions for individual components

All parachutes will be tethered with tubular nylon or Kevlar shock cords and attached to rocket components with quarter-inch U- or I-bolts.

Ejection Charges

Ejection charge sizes will be calculated using the

$$W = dP * V / (R * T)$$

formula, where

W ejection charge weight *[g]*
dP ejection pressure (15 *[psi]*)
V free volume *[in^3]*
R universal gas constant (22.16 *[ft-lb $^oR^{-1}$ lb-mol^{-1}]*)
T combustion gas temperature (3,307 *[^oR]*)

and we will verify them through static ejection testing.

Integration of the Payload

The integration of our payload presents one major challenge: how to swiftly and surely eject the payload modules from the payload bay. If the payload modules were just placed in the payload bay without any guidance, they may twist and jam inside the tube, preventing ejection. We have come up with two possible solutions to mitigate these options, and they will be tested to determine the more secure method.

The two payload modules will be contained in a section of coupler tubing inside the payload bay, the cradle. After descending from apogee under a drogue, the rocket will separate and the cradle, with the modules, will slide out. As their parachutes deploy, the two sensor probes will leave the cradle and descend, and the cradle will remain attached to the payload bay, descending under the drogue/payload bay parachute. This option has the advantages of very high functionality and simplicity of construction, however adding more coupler tubing will increase the weight of the rocket significantly.

Another option is to mount the payload modules on rails within the payload bay to insure that they remain aligned in the payload bay and eject smoothly. This has the advantage of reduced weight for the rocket, but is harder to implement and less certainty of smooth ejection.

Both of these options will be studied through static ejection testing, and we will select the preferred option.

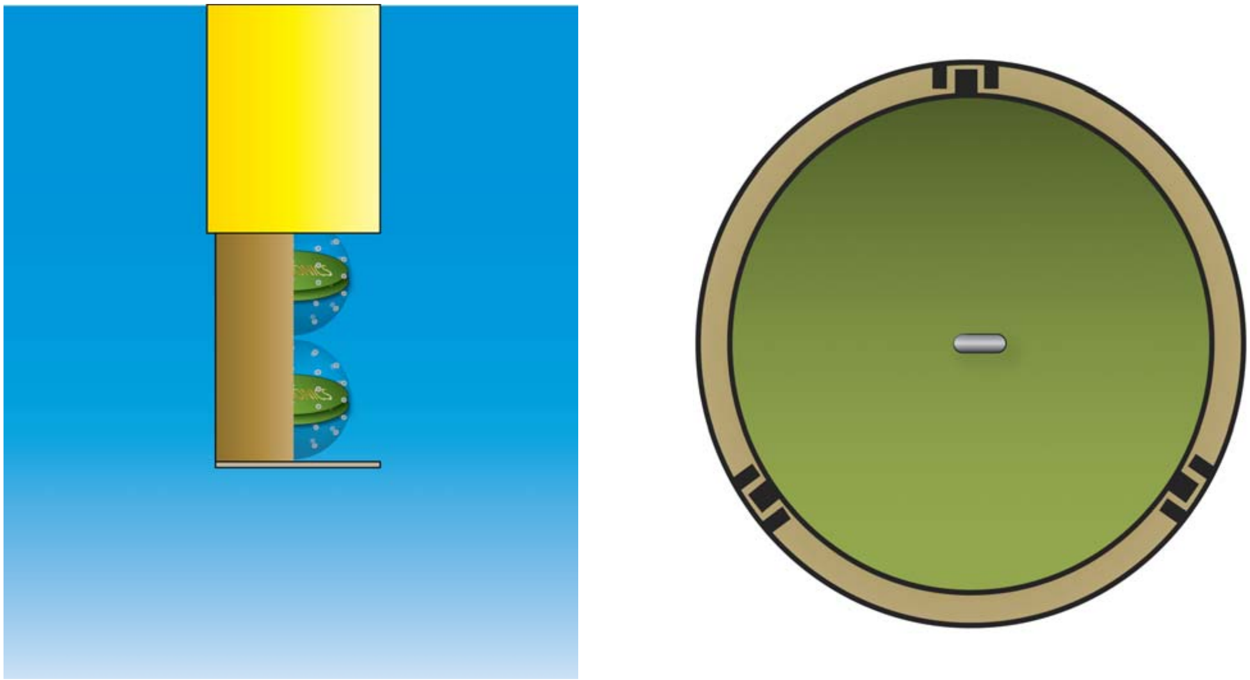

Figure 4: Payload integration and deployment. The payload modules will be housed in a section of coupler tubing inside the payload module. After separation of the rocket, the payload modules will tumble out of the cradle and recover under their own parachutes. Alternately, the payload modules will be deployed from rails mounted on the inside of the payload bay.

Mission Performance Predictions

The graph below shows simulated altitude vs. time with the L1080 motor. The predicted altitude of 5900ft, although above the target altitude of 5280ft, is considered acceptable at this stage in the project as RockSim tends to overestimate vehicle altitudes. Based on the results of our test flights we will adjust the ballast to achieve the final apogee of 5280ft.

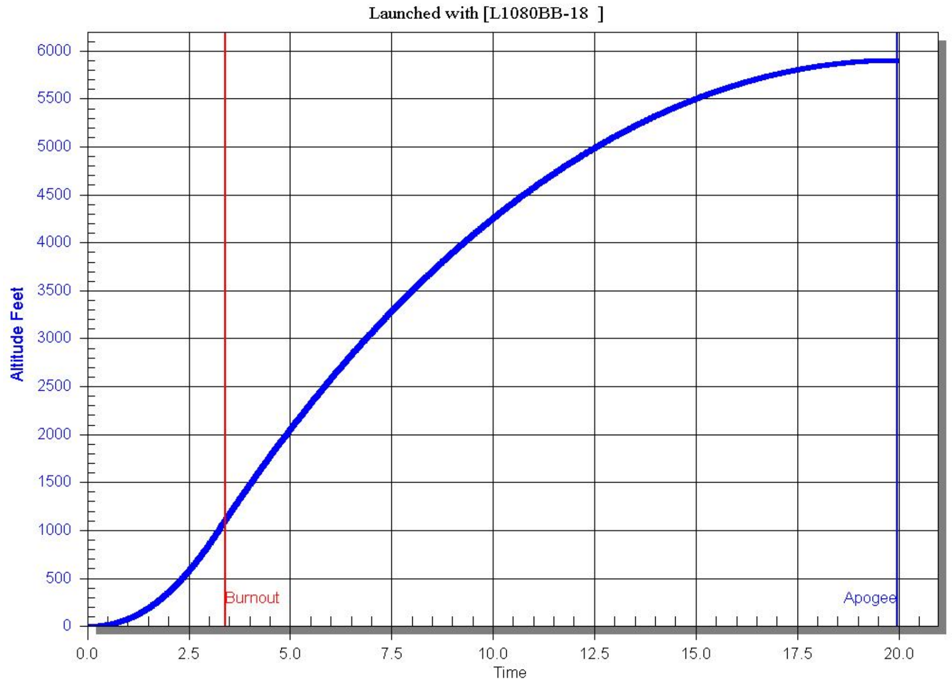

Figure 5: Altitude vs. time graph for the L1080 motor combination. The rocket reaches 5900ft at 20s after ignition.

Wind Speed vs. Altitude

The effect of the wind speed on the apogee of the entire flight is investigated in the table below. Even though under the worst possible conditions (wind speeds 20mph, the NAR safety limit) the flight apogee will differ by less than 4% from the apogee reached in the windless conditions.

Wind Speed ***[mph]***	**Altitude** ***[ft]***	**Percent Change in Altitude**
0	5,904	0.00%
5	5,894	0.17%
10	5,869	0.59%
15	5,832	1.22%
20	5,790	1.93%

Table 9: Apogee vs. Wind Speed

Thrust Profile

The graph below shows the thrust profile of the L1080 motor. The motor provides sufficient initial thrust to carry the vehicle safely off the launch rail.

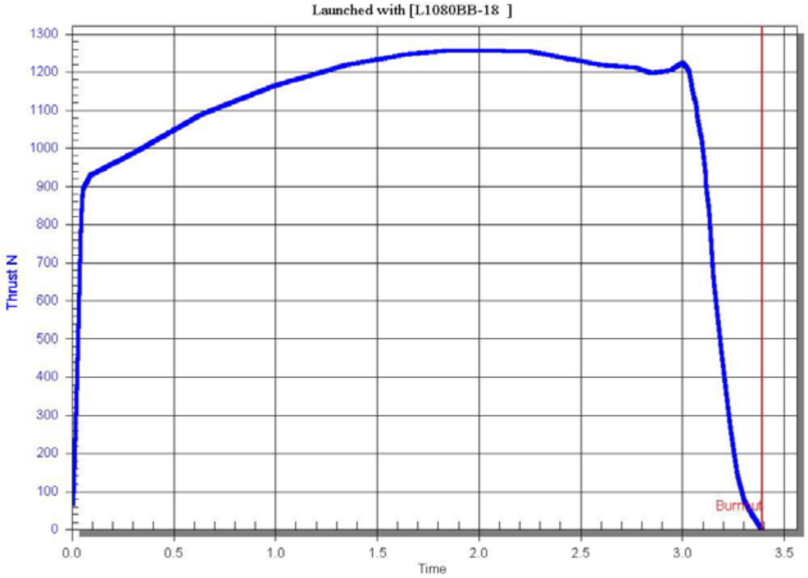

Figure 6: Thrust vs. Time graph. The motor provides a maximum thrust of about 1250 N and burns for 3.4s.

From the velocity profile below we can read that the first stage will accelerate to 640 feet per second, or about 440 miles per hour before the thrust tapers off.

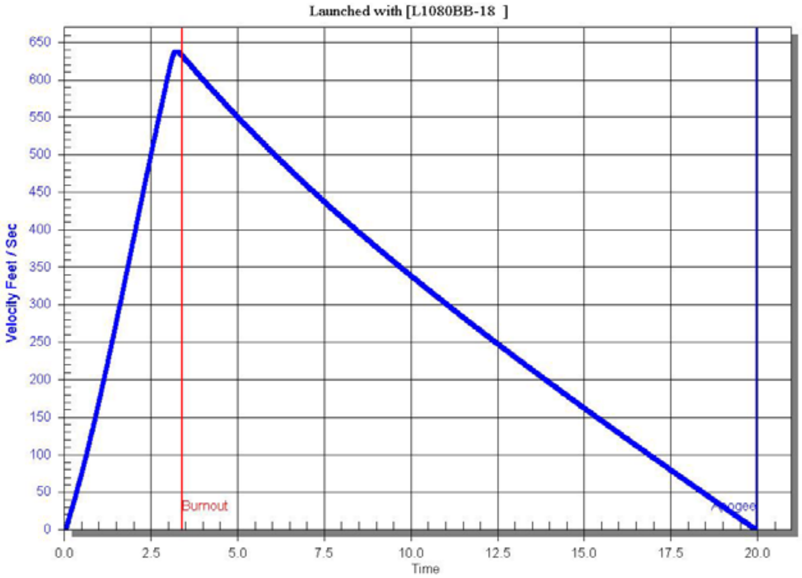

Figure 7: Velocity vs. time graph. The motor burns out just before 3.5s

Acceleration Profile

The graph below depicts the estimated acceleration profile. Our rocket will be robust enough to endure the 8G+ acceleration shocks.

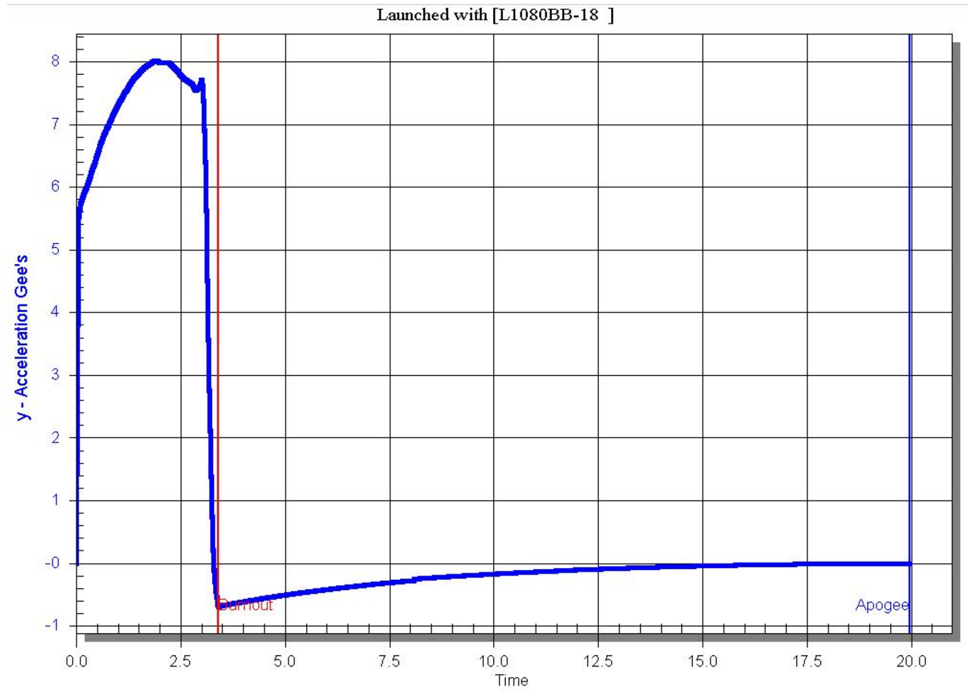

Figure 8: Acceleration vs. time graph. The rocket has a maximum acceleration of 8G

Launch Operation Procedure

The vehicle will lift off from a standard 8 foot launch rail. To ignite the motor we will use a standard 12 volt ignition system with a commercially available igniter.

Final Assembly and Launch Procedures

1. Fold parachutes properly with Nomex protection
2. Attach shock cords to parachutes and to rocket
3. Connect and place charges into rocket; check for continuity
4. Insert parachutes into rocket
5. Insert payload and payload parachutes into the payload bay
6. Fully assemble the rocket and check structural integrity
7. Insert the motor into the motor mount and secure with motor retention system
8. Place rocket onto launch tower and make sure the rocket slides smoothly
9. Place igniter into the rocket and place engine cap over the end to secure it in place
10. Activate electronics, wait for boot and confirm continuity
11. Attach the igniter to the launch system and check for continuity
12. Move 500 feet away from the rocket (minimum safe launch distance of L-class vehicles)
13. Check sky for aircraft
14. Arm ignition system
15. Countdown
16. Launch rocket

Disarming Procedures (only if motor does not light)

1. Remove ignition interlock to prevent accidental ignition
2. Wait designated time by HPR safety code (1 minute)
3. Disarm electronics and remove rocket from pad
4. Replace igniter
5. Place rocket back on pad, re-arm electronics
6. Test continuity

Safety and Environment

The Safety Officer on our team is Jacqueline. The Safety Officer will ensure that proper safety procedures are followed at all times. The NAR High Power Rocket Safety Code will be followed at all times. All personnel will stand 500 feet back from the launch, and all personnel will be on “heads up” while any parts of the rocket are still in the air. All parts of our rocket are reusable and will be recovered after flight and will not pose a risk to the environment.

NAR Safety Requirements

a. Certification and Operating Clearances: Mr. Lillesand holds a Level 3 HPR certification. Dr. Pinkas has a Level 1 HPR certification and plans on having a Level 2 HPR certification by the end of February 2010. Mr. Lillesand has Low Explosives User Permit (LEUP). If necessary, the team can store propellant with Mr. Goebel, who owns a BATFE approved magazine for storage of solid motor grains containing over 62.5 grams of propellant.

Mr. Lillesand is the designated individual rocket owner for liability purposes and he will accompany the team to Huntsville. Upon his successful L2 certification, Dr. Pinkas will become a backup person for this role.

All HPR flights will be conducted only at launches covered by an HPR waiver (mostly the WOOSH/NAR Section #558 10,000ft waiver for Richard Bong Recreation Area launch site). All LMR flights will be conducted only at the launches with the FAA notification phoned in at least 24 hours prior to the launch. NAR and NFPA Safety Codes for model rockets and high power rockets will be observed at all launches. Mentors will be present at all launches to supervise the proceedings.

b. Motors: We will purchase and use in our vehicle only NAR-certified rocket motors and will do so through our NAR mentors. Mentors will handle all motors and ejection charges.

c. Construction of Rocket: In the construction of our vehicle, we will use only proven, reliable materials made by well established manufacturers, under the supervision of our NAR mentors. We will comply with all NAR standards regarding the materials and construction methods. Reliable, verified methods of recovery will be exercised during the retrieval of our vehicle. Motors will be used that fall within the NAR HPR Level 2 power limits as well as the restrictions outlined by the SLI program. Lightweight materials such as fiberglass tubing and carbon fiber will be used in the construction of the rocket to ensure that the vehicle is under the engine’s maximum liftoff weight. The computer program RockSim will be utilized to help design and pre-test the stability of our rocket so that no unexpected and potentially dangerous problems with the vehicle occur. Scale model of the rocket will be built and flown to prove the rocket stability.

d. Payload: As our payload does not contain hazardous materials, it does not present danger to the environment. However, our NAR mentors will check the payload prior to launch in order to verify that there will be no problems.

e. Launch Conditions: Test launches will be performed at Richard I. Bong Recreation Area with our mentors present to oversee all proceedings. All launches will be carried out in accordance with FAA, NFPA and NAR safety regulations regarding model and HPR rocket safety, launch angles, and weather conditions. Caution will be exercised by all team members when recovering the vehicle components after flight. No rocket will be launched under conditions of limited visibility, low cloud cover, winds over 20mph or increased fire hazards (drought).

II. Hazardous Materials

All hazardous materials will be purchased, handled, used, and stored by our NAR mentors. The use of hazardous chemicals in the construction of the rocket, such as epoxy resin, will be carefully supervised by our NAR mentors. When handling such materials, we will make sure to carefully scrutinize and use all MSDS sheets and necessary protection (gloves, goggles, proper ventilation etc.).

All MSDS sheets applicable to our project are available online at
http://westrocketry.com/sli2010/msds/msds2010r.html

III. Compliance with Laws and Environmental Regulations

All team members and mentors will conduct themselves responsibly and construct the vehicle and payload with regard to all applicable laws and environmental regulations. We will make sure to minimize the effects of the launch process on the environment. All recoverable waste will be disposed properly. We will spare no efforts when recovering the parts of the rocket that drifted away. Properly inspected, filled and primed fire extinguishers will be on hand at the launch site.

IV. Education, Safety Briefings and Supervision

Mentors and experienced rocketry team members will take time to teach new members the basics of rocket safety. All team members will be taught about the hazards of rocketry and how to respond to them; for example, fires, errant trajectories, and environmental hazards. Students will attend mandatory meetings and pay attention to pertinent emails prior participation in any of our launches to ensure their safety. A mandatory safety briefing will be held prior each launch. During the launch, adult supervisors will make sure the launch area is clear and that all students are observing the launch. Our NAR mentors will ensure that any electronics included in the vehicle are disarmed until all essential pre-launch preparations are finished. All hazardous and flammable materials, such as ejection charges and motors, will be assembled and installed by our NAR-certified mentor, complying with NAR regulations. Each launch will be announced and preceded by a countdown (in accordance with NAR safety codes).

V. Procedures and Documentation

In all working documents, all sections describing the use of dangerous chemicals will be highlighted. Proper working procedure for such substances will be consistently applied, such as using protective goggles and gloves while working with chemicals such as epoxy. MSDS sheets will be on hand at all times to refer to for safety and emergency procedures. All work done on the building of the vehicle will be closely supervised by adult mentors, who will make sure that students use proper protection and technique when handling dangerous materials and tools necessary for rocket construction.

Rocket Failure Risks

Risks	Consequences	Mitigation
Unstable rocket	Errant flight	Rocket stability will be verified by computer and scale model flight
Improper motor mounting	Damage or destruction of rocket.	Engine system will be integrated into the rocket under proper supervision and used in the accordance with the manufactures' recommendations.
Weak rocket structure	Rocket structural failure	Rocket will be constructed with durable products to minimize risk
Propellant malfunction	Engine explosion	All members will follow NAR Safety Code for High Powered Rocketry, especially the safe distance requirement. Attention of all launch participants will be required.
Parachute	Parachute failure	Parachute Packaging will be double checked by team members. Deployment of parachutes will be verified during static testing.
Payload	Payload failure/malfunction	Team members will double-check all possible failure points on payload.
Launch rail failure	Errant flight	NAR Safety code will be observed to protect all member and spectators
Separation failure	Parachutes fail to deploy	Separation joints will be properly lubricated and inspected before launch. All other joints will be fastened securely.
Ejection falsely triggered	Unexpected/premature ignition/personal injury/property damage	Proper arming and disarming procedures will be followed. External switches will control all rocket electronics.
Recovery failure	Rocket is lost	The rocket will be equipped with radio and sonic tracking beacons
Transportation damage	Possible aberrations in launch, flight and recovery.	Rocket will be properly packaged for transportation and inspected carefully prior to launch

Table 10: Risks associated with the rocket launch

Physical Risks

Risks	Consequences	Mitigation
Saws, knives, Dremel tools, band saws	Laceration	All members will follow safety procedures and use protective devices to minimize risk
Sandpaper, fiberglass	Abrasion	All members will follow safety procedures and use protective devices to minimize risk
Drill press	Puncture wound	All members will follow safety procedures and use protective devices to minimize risk
Soldering iron	Burns	All members will follow safety procedures to minimize risk
Computer, printer	Electric shock	All members will follow safety procedures to minimize risk
Workshop risks	Personal injury, material damage	All work in the workshop will be supervised by one or more adults. The working area will be well lit and strict discipline will be required

Table 11: Risks that would cause physical harm to an individual

Toxicity Risks

Risks	Consequences	Mitigation
Epoxy, enamel paints and primer, superglue	Toxic fumes	Area will be well ventilated and there will be minimal use of possibly toxic-fume emitting substances
Superglue, epoxy, enamel paints, primer	Toxic substance consumption	All members will follow safety procedures to minimize risk emergency procedure will be followed in case of accidental digestion

Table 12: Risks that would cause toxic harm to an individual

Payload Criteria

Selection, Design, and Verification of Payload Experiment

The payload subsystems consist of atmospheric sensors, light sensors, electronic data collectors, and location devices. All payload devices are housed in two identical spherical probes (Argus 1 and Argus 2) with the light sensors on the surface, and electronics boards (PCBs) and batteries to power the electronics in the center of each probe.

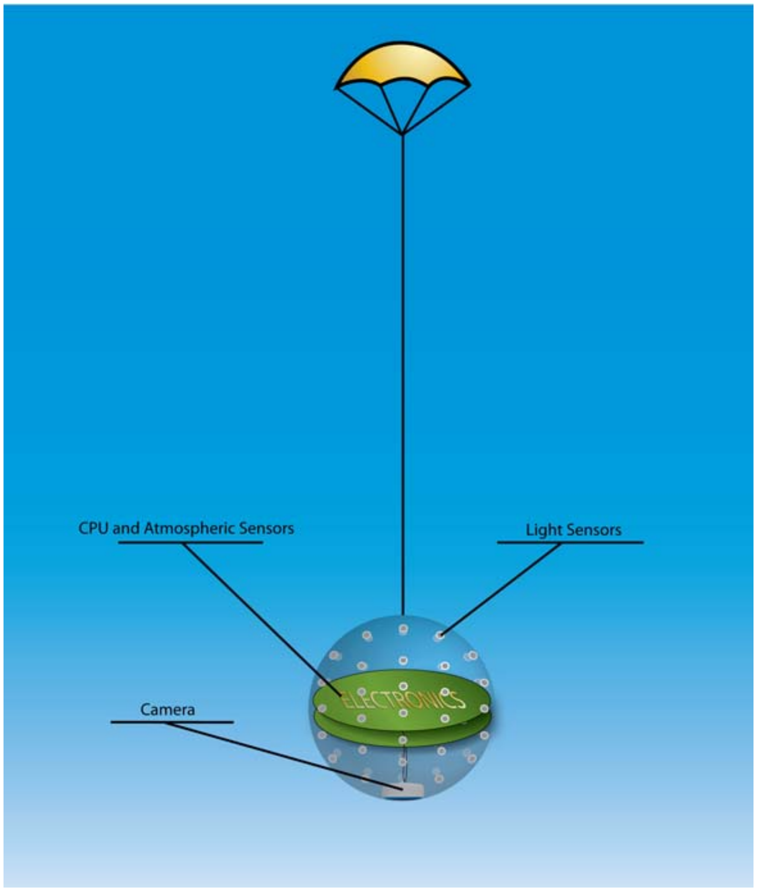

Table 13: Argus probe with primary components labeled

The rocket will carry and deploy two identical probes (Argus 1 and Argus 2). Each probe has numerous light sensors measuring light intensity from all directions. Electronic two-axis compass will monitor the attitude of each probe. Additionally, each module collect atmospheric data: pressure, temperature, humidity and concentrations of selected pollutants. A camera at the bottom of each probe will take pictures of the ground to correlate the ground features with the amount of light reflected by the ground. A GPS chip will allow us to trace the path traversed by each probe. The shock cords connecting each probe to its parachute will be long, reducing the angular obstruction of sunlight caused by the parachute.

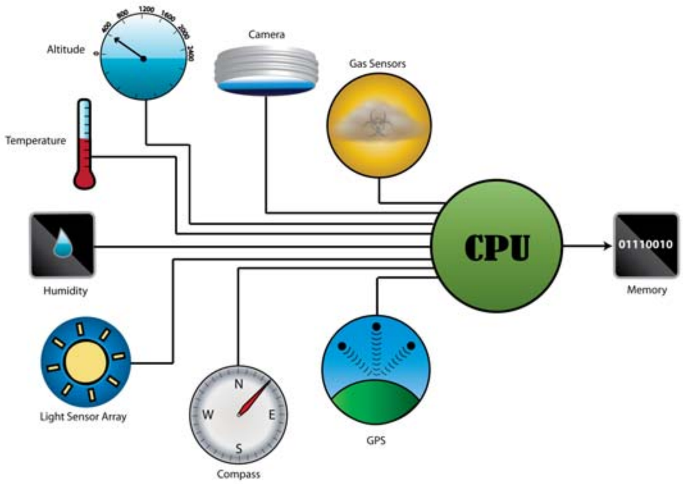

Figure 9: Major electronic components inside each Argus probe

The atmospheric sensors are essential to our experiment. They detect the amounts of particulate pollution that make up the atmospheric composition. These then correlate to sunlight intensity. There will be a humidity sensor measuring the amount of water vapor, an altimeter measuring the pressure to determine altitude, and a thermometer measuring the temperature.

The spherical probes will be enveloped by sensors that will detect sunlight intensity. These sensors will be evenly spaced out on the outside of the sphere so that all portions of the sphere will be evenly represented. Having the sensors evenly placed will provide a better gradient of intensity in our data allowing for more accurate estimation of intensities between points. This will enable us to increase the amount of approximation of intensities from the light sensors.

Figure 10: The very early prototype of the Argus probe

The diagrams above accentuate the placement of our sensors. These are two possible ways we will insure that our light sensors will be evenly placed. A polyhedral with twenty vertices (dodecahedron) will be inserted in our sphere with a snug fit and then where there is a point a light sensor will be placed. The second method also results in evenly placed sensors. We begin by drawing a circle at the top of the sphere and then dividing it into six sectors resulting in each sector being 60º.

Our electronic data collectors, two computers, will be housed at the equator of our spherical payload. One computer will be recording the readings from the top hemisphere and the second computer will be taking data from the lower region. The collected data will be stored in the non-volatile memory (flash memory) and analyzed after the probes are retrieved.

The two axis compass will monitor the attitude of each probe, allowing us to determine the direction that each sensor was facing. This is to counter the effect of payload spinning and swinging.

A camera at the bottom of each probe will record land features and we will later correlate the image information to the light intensities reflected from the ground and measured by the sensors in the bottom hemisphere of each probe.

As we plan to deploy both probes at the high altitude (4,000ft) we have calculated the estimated drift for each probe (assuming the probe descent rate of 15fps).

Wind speed ***[mph]***	**Drift of Payload** ***[miles]***
5	0.4
10	0.7
15	1.1
20	1.5
25	1.9

Table 14: Estimated drift of the Argus probes

For the SLI launch in Huntsville we will reduce the payload deployment altitude as necessary to ensure that neither the probes nor the vehicle itself will drift outside the launch area. All our electronics is easily field programmable and changing the programmed flight sequence takes only a few seconds.

Verification Plan

1. Drop Test	We drop the subsystem to check the structural integrity
2. Battery Connection Test	We connect the subsystem to the battery to check for functionality.
3. Pressure Chamber Test	We place the altimeter in a chamber to make sure the altimeter registers the correct pressure
4. Scale Model Flight	We will place all subsystems in the scale model flight to conform functionality.
5. Cooling and Heating Test	We will place the Temperature Sensor in known temperature solutions to check if the sensor registers the temperature correctly
6. Humidity Levels Test	We will place the Humidity Sensor in known humidity environments to confirm functionality.
7. Wiring Test	We will connect the subsystems to corresponding wire connections to check if each responds accordingly
8. Stress Test	We will run the subsystem for an hour to check if the component can function and withstand that stress
9. Light Sensors Test	We will expose light sensors to known amounts of different wavelengths of light to calibrate the sensors
10. Camera Test	During both ground static tests and scale model flights, we will compare images from camera to known ground features to ensure camera's functioning
11. Electronics Testing	We will use extensive static testing to ensure accuracy and reliability of measurement and electronics
12. Final Test	Test the complete subsystem for its function.

Table 15: The various verification tests for payload components

P = Planned, **F** = Finished	1	2	3	4	5	6	7	8	9	10	11	12
Temperature Sensor	P	P		P	P		P	P			P	P
Circuit Board	P	P		P			P	P			P	P
Altimeter	P	P	P	P			P	P			P	P
Humidity Sensor	P	P				P	P	P			P	P
Light Sensor	P	P					P	P	P		P	P
Gas Sensors	P	P					P	P			P	P
GPS	P	P		P			P	P			P	P
Video Camera	P	P					P	P		P	P	P
Compass	P	P					P	P			P	P
Electronic Wiring	P	P		P			P	P			P	P

Table 16: Verification matrix (tests applied to each payload component)

Preliminary Integration Plan: Please see *Payload Integration* in *Vehicle Criteria* section.

Precision of Instrumentation, repeatability of measurement, and recovery system

To ensure repeatability of measurement we will collect data using two identical probes. These modules will be deployed shortly after apogee, therefore they will collect data under similar location, weather, and time frame. After reducing the data for swing and spin of the probes upon descent, we expect similar data from each of the probes.

The probes will safely descend under separate parachutes. The parachute would be attached to a U-bolt fastened onto the top of each spherical module. We are currently considering installing a sonic and radio beacons inside each probe for ease of recovery.

Instrument	Typical value[1]	Measured Quantity	Accuracy	Units	Resolution	Part Name
Light Sensor	1200 W/m^2	Irradiance	± 0.5%	W/ m^2	1 μW/cm^2	TSL 230
Temperature Sensor	25 ^{o}C	Temperature	± 0.5 %	Celsius	0.0625 ^{o}C	MCP9800
Pressure Sensor	100,000 Pa	Pressure	± 1.5%	Pascals	16-bit 15-115kPa	MPXH6115
Altimeter	100,000 Pa	Altitude	± 1.5%	Feet	10 ft	MPXH6115
Camera	NA	NA	NA	NA	1300x1040 pixels	TCM8240MD
Humidity Sensor	30% RH	Humidity	± 3.5% RH	% RH	16-bit 0-100%	HIH-403

Table 17: Instruments and Accuracy

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[1] Typical values are for ground conditions at expected weather in Huntsville AL

Electronic Components for Argus Probe

Component	Manufacturer	Power	Specification	Price
CPU	Parallax	10-80 mA	80 MHz, 32KB RAM, 8 cores	$8.00
Light Sensor	Texas Advanced Optical Systems	2-3 mA	160 db	$6.00
ADC	Texas Instruments	1.5 mA	16 bit, 100kSps, 4 Chan	$6.50
Camera	Toshiba	100-150 mA	1.3MP, 15fps	$10.00
IO Expander	Texas Instruments	20-200 µA	16 I/O	$2.70
GPS	SkyTraq	28 mA	w/in 2.5m, 14 ch, 10Hz, 29 sec. cold start, 1 sec hot start	$40.00
Temperature	Microchip	200 µA	-55°C ~ 125°C, +/- 0.5°C	$1.76
Pressure	Motorola	6mA	15-115 kPa	$9.29
Gas: CO	Hanwei	160mA		$5.00
Gas: CO2	Hanwei	120-200mA	350-10000ppm	$5.00
Gas: LPG	Hanwei	160mA	200-10000ppm	$5.00
Gas: CH4	Hanwei	160mA	5000ppm-20000ppm CH4	$5.00
3D Accel	STMicroelectronics	0.65mA	1 mg resolution at 40Hz BW	$15.00
2D Compass	Honeywell	10mA	120 µgauss Resolution	$9.00
EEPROM	Atmel	5mA	64KB	$1.99

Table 18: A list of electronic components for our payload modules

Payload Concept Features and Definition

Creativity and Originality

Although there has research on measuring atmospheric pollutants, correlations between ground features and pollution versus sunlight intensity have not been extensively studied. Our new focus on sunlight levels may clarify environmental changes and could show a possible cause for crop failures, change in local flora/fauna and other sunlight related phenomena.

Uniqueness or Significance

As described in the following Science Value section, variances in sunlight intensity levels may be an explanation for environmental changes and decreasing trends in agricultural yield. Because agriculture is vital for the balance in the human civilization, it is necessary to study the effects on its output. A possible factor is a decreased availability of sunlight (often due to significant pollution of the atmosphere), which may impact ecosystems and destroy their fragile balance. Since sunlight is the ultimate source of all energy and life, studying it and understanding how human activity and natural features affect available light is crucial. We understand there is a possibility that other factors that contribute to crop failures are exacerbated by sunlight. Some possible factors include pollutants and pesticides may contribute to sun shielding, further decreasing the amount of available light.

Level of Challenge

Given the intricate nature of our electronics and the extensive correlations we hope to make (see following Science Value section), our experiment and final report will be extremely challenging.

Science Value

Science Payload Objectives

Our objective is to determine the effect of the atmospheric conditions/composition and ground features on direct and reflected sunlight above and within the planetary boundary layer. The planetary boundary layer (PBL) is a fairly recent addition to the scientific knowledge of our atmosphere, and the term refers to the lowest level of the atmosphere which is affected by convection and the close proximity of surface features (orography).

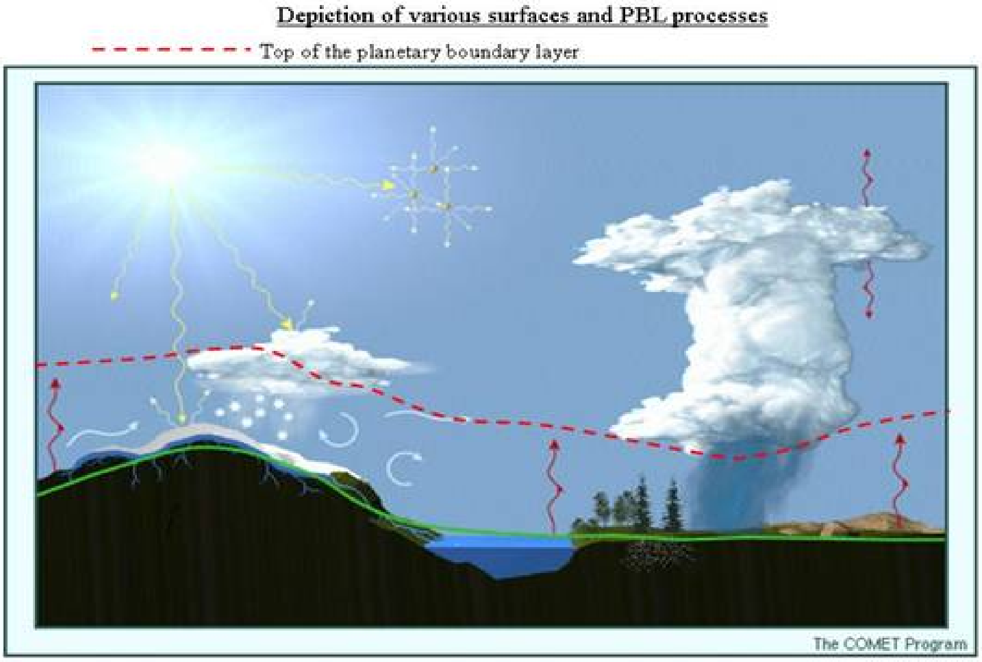

Figure 11: Depiction of sunlight passing through and being reflected in the boundary layer. Atmospheric conditions and composition affect the transmission of the sunlight as well as its reflection. The ground features affect the amount of sunlight reflected back from the ground to the planetary boundary layer. Source: *www.esrl.noaa.gov/.../themes/pbl/img/fig1.jpg*

In theory, perfect mixing occurs within the atmospheric boundary layer; the airborne particles are approximately equally dispersed. The heat from the sun causes the air near the ground to rise to higher altitudes. Air typically ascends at a rate of 2-3 meters per second or slower, if wind is not a factor. The decrease in temperature at higher altitudes cools the air, causing it to sink back to ground level. This constant convection equalizes the relative abundance of particles at different altitudes, creating the boundary layer.

This “perfect mixing” phenomenon sets the boundary layer apart from other atmospheric layers. We predict that the higher density of particles and pollutants within the boundary layer compared to other layers will dramatically affect the amount of sunlight available above versus within the PBL.

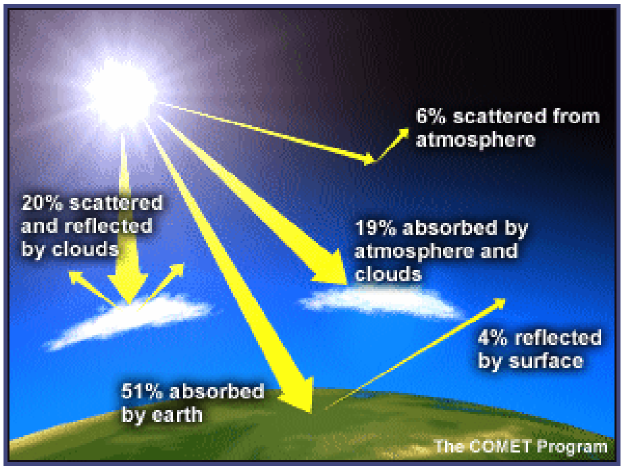

Table 19: The sunlight entering the atmosphere follows several paths. Approximately 6% is reflected back, 20% is scattered and reflected by the clouds, 19% is absorbed by the clouds, 51% is absorbed by the ground and 4% is reflected by the ground back into the atmosphere. (Credit: The COMET Program)
Source: www.*windows.ucar.edu/tour/link=/earth/climate/greenhouse_effect_gases.html*

The atmosphere has varying compositions based on human activity, landscape, and weather patterns. For example, industrialized areas have a higher density of atmospheric pollution compared to rural and uninhabited regions. Solar radiation interacts differently with these atmospheric variations. Airborne particles and humidity diffuse and reflect sunlight, decreasing the amount of available sunlight. Atmospheric particles also absorb the energy of the photon, converting solar energy to heat.

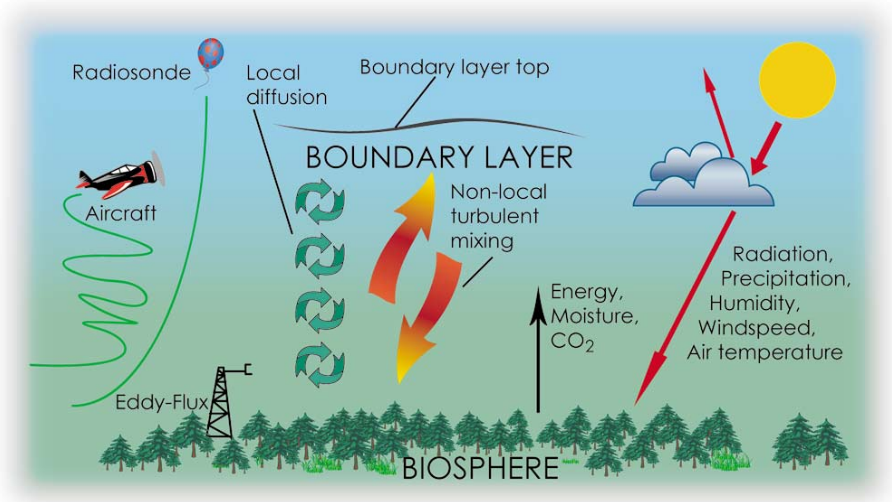

Figure 12: The figure above illustrates the different processes occurring within the boundary layer. It also lists the variables that affect the path of rays within the atmosphere such as precipitation, humidity, wind speed, and air temperature. Source: *www.geos.ed.ac.uk/homes/s0349727/pbl.jpg*

Our experiment has many practical applications in terms of knowledge of the atmosphere, biosphere, and pollutants. Understanding the behavior of solar radiation is vital, since sunlight is the primary source of energy for all living things on Earth. Plants absorb the energy in the photons to synthesize carbon-based molecules that are not only consumed by humans, but can also be burned to generate heat and mechanical energy.

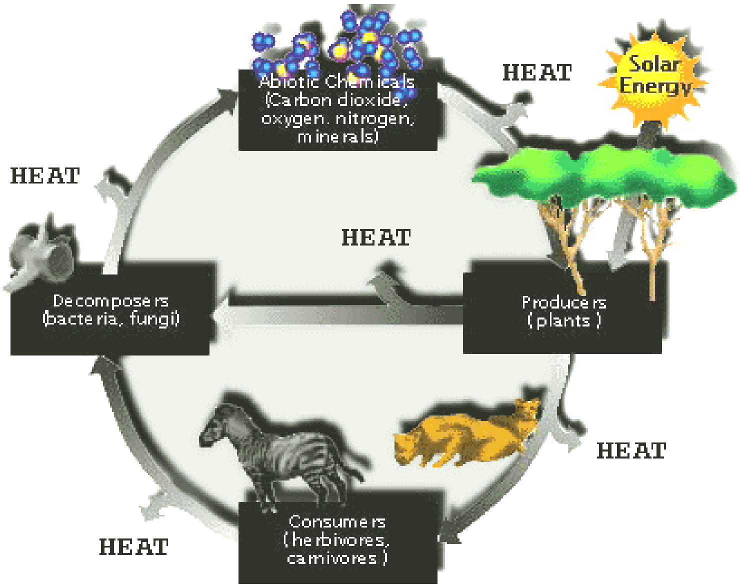

Figure 13: This diagram is a pictorial representation of solar radiation's role as the primary energy source for all life. The arrows show how energy moves through the system. The arrows leading out of the circle display the diffusion of energy as un-useable heat.

Since consumers depend on producers, plants provide the foundation for a stable habitat; therefore the entire ecosystems also predominantly rely on the availability of sunlight. A decreased availability of sunlight due to pollution and air-borne particles may prevent some plants from obtaining the needed amount of light. This gives certain species which are less reliant on direct sunlight a competitive advantage over other plants. Such ecosystem disruptions may then displace local wildlife dependent on the struggling plant. These disruptions not only occur in natural environments, but also in human industries such as farming.

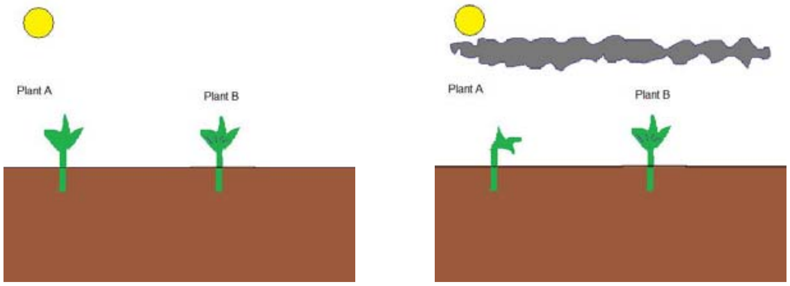

Figure 14: Plants A and B are equally successful with full sunlight, right, however Plant B is less dependent on the amount of sunlight. When the atmosphere becomes polluted, the highly sunlight dependent Plan A vanishes and the ecosystem balance is changed. The extinction of Plant A can subsequently lead to extinction of species dependent on Plant A.

Our research will also contribute to the understanding of atmospheric pollution. We will measure the concentrations of selected pollutants (based on the sensor availability) at different altitudes and correlate the amount of sunlight that reaches a given altitude with the amount of pollutants in the sunlight path (and thus possibly blocking, absorbing or reflecting some of the sunlight.

Our research also has a practical application for agriculture and industry. Since sunlight is the basis of all natural energy, it is crucial to understand how pollutants and human-caused global climate change may impact available sunlight. During times of low agricultural yield, farmers often resort to excessive use of phosphate and nitrate fertilizers, both of which pollute water sources and end up in the air. In turn, these pollutants may block sunlight and the plants, while being provided with abundance of nutrients, will not receive enough sunlight to be able to utilize the extra nutrients and the yield will continue to drop, seemingly without explanation.

Figure 15: This flowchart illustrates the possible incorrect explanation for crop failure. In the first image, the soil in the area with significant atmospheric pollution is producing minimal agricultural profit. The farmers respond by applying increased phosphate and sulfate fertilizers in the second image. This causes increased pollution and air-borne particles (third image), which diffuses and reflects sunlight, preventing it from reaching the crops.

On-going research consistently proves that atmospheric content alters the intensity of solar radiation. Various studies have shown that sunlight intensity differs 1-2% above and within the planetary boundary layer, and a 10% reduction has been observed under conditions of smog and industrial pollution. Another study suggests that highly populated areas suffer a decline in solar radiation by approximately 0.41 W/m^2/yr, whereas sparsely populated areas experience a decline rate of merely 0.16 W/m^2/yr. This difference of sunlight intensities can be attributed to quality of the atmosphere in both the areas. Therefore the content of the atmosphere appears to have a direct effect on the availability of solar radiation on ground level.

We hypothesize that the abundance of various atmospheric pollutants will have a direct correlation with the amount of available sunlight. We also predict that these pollution levels will be higher at the upper edge of the boundary layer, and that there will be more available sunlight above the boundary layer.

Payload Success Criteria

The success of our payload experiment will be evaluated based on the following criteria:

- Independent and dependent variables (see below) are accurately measured by the sensors
- The sensor probes, Argus 1 and Argus 2, are recovered undamaged
- The data between the sensors are reasonably similar
- A measurable difference of the independent variables is seen with a difference of the dependant variables
- The sensors collect measurable amounts of data

For further information on individual subsystems and their success criteria, see the Verification Matrix.

Experimental Logic, Approach, and Method of Investigation

Our goal is to correlate a number of variables with intensities of solar radiation. We will use two sensor probes, the Argus 1 and the Argus 2, to measure our data. They will both collect the same data for redundancy. Both probes will be deployed at apogee. We will measure a number of variables, and use them to try to create correlations between our independent and dependant variables. Our approach to measuring humidity, temperature, pressure, pollutant levels, and ground features in relation to light intensity will help us understand changing trends in available sunlight and contribute to ongoing research in this area.

Independent Variables

This table shows the independent variables that we will be measured:

H	Relative Humidity
B	Location of planetary boundary layer
C	Atmospheric content (selected pollutants)
A	Altitude
G	Underlying ground features
X	Position
T	Temperature
P	Atmospheric pressure

Table 20: Independent variables

Dependent Variables

This table shows the dependant variables that will be measured:

L_v	Intensity of visible light
L_I	Intensity of infrared radiation
L_u	Intensity of ultraviolet radiation

Table 21: Dependent variables

After our data are collected, correlations between our measured variables will be made. These are the primary correlations we will be attempting to make:

Primary Correlations

$\boldsymbol{L} = F(\boldsymbol{H})$ Light intensities in relation to relative humidity
$\boldsymbol{L} = F(\boldsymbol{B})$ Light intensities in relation to location planetary boundary layer
$\boldsymbol{L} = F(\boldsymbol{C})$ Light intensities in relation to atmospheric content

We will attempt to make these other possible correlations as well:

Other Possible Correlations

$\boldsymbol{L} = F(\boldsymbol{G})$ Light intensities in relation to underlying land features
$\boldsymbol{L} = F(\boldsymbol{A})$ Light intensities in relation to altitude
$\boldsymbol{L} = F(\boldsymbol{X})$ Light intensities in relation to position

Relevance of Expected Data and Accuracy/Error Analysis

On-going research consistently proves that atmospheric content alters the intensity of solar radiation. Various studies have shown that sunlight intensity differs 1-2% above and within the planetary boundary layer, and a 10% reduction has been observed under conditions of smog and industrial pollution. Since there is a greater concentration of pollutants close to the upper edge of the boundary layer, we expect there to be less sunlight within the layer than above it.

We expect that the light sensors on the lower half of the spherical module, facing the ground, will receive less light than the light sensors located on top of the module. Since the typical irradiance is 1000-1400 W/m^2, we would expect our data values to be close to this value.

Experiment Process Procedures

Experiment Sequence

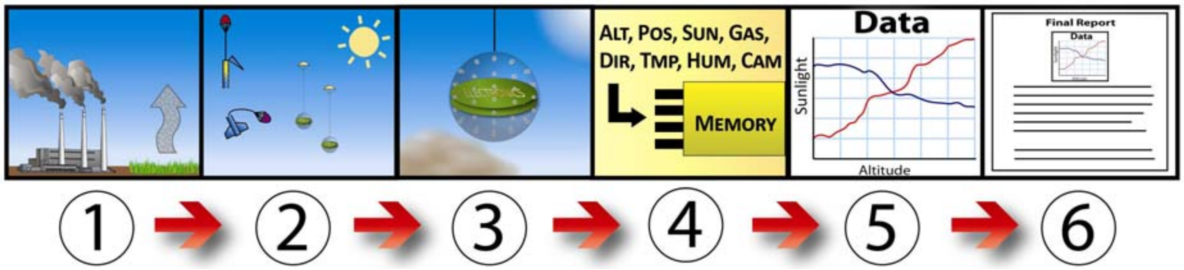

Figure 16: This picture shows our experiment sequence. Pollutants have been released into the air, via industrial and agricultural processes (1). We will launch our rocket, and deploy the probes (2). The probes will descend through the atmosphere, collecting data on the intensity of sunlight, the atmospheric content/conditions, and ground features (3). The altitude, position, sunlight intensity, atmospheric composition, sensor orientation, temperature and humidity data, as well as pictures from the onboard camera, will all be stored in non-volatile memory (5). After flight, the data will be analyzed (5) and placed in our final report (6).

Flight Sequence

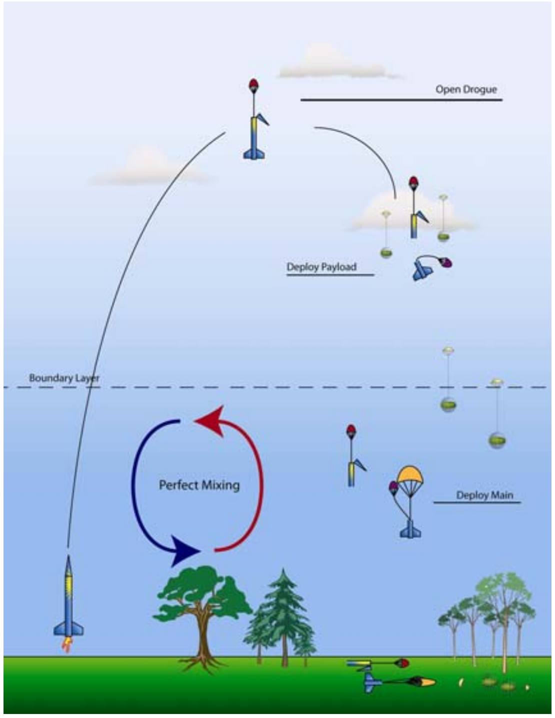

Figure 17: The flight sequence of the payload and vehicle. The common drogue (drogue parachute for the entire vehicle,including the payload section) is deployed at apogee. The rocket then descends to the payload deployment altitude where the payload and booster sections separate from each other and probes Argus-1 and Argus-2 are deployed from the payload section. The booster section deploys the booster drogue parachute and quickly descends to 700ft where the booster main parachute is deployed to slow the booster section to a safe landing speed. The payload section is now light enough to land safely under the common drogue. The probes descends through the atmosphere, collecting data until their landing.

The flight sequence is shown on the previous page. The sampling will be continuous from the payload deployment until the landing of each probe.

A modified dual recovery scheme is utilized. At apogee, the rocket will deploy a drogue parachute large enough for the entire rocket (so called *common drogue*). The entire rocket will descend under this drogue parachute to the payload deployment altitude. At this altitude, the rocket will separate into two sections, the payload compartment and the booster section, deploying the Argus probes in the process. The probes will descend under their own parachutes. The payload compartment will continue to descend under the common drogue parachute, however as the mass has been reduced this parachute will be large enough to slow the payload compartment to a safe landing speed. At payload deployment, the booster section will deploy its own drogue parachute, and at an altitude of 700 feet deploy the main parachute. This will insure the safe and easy recovery of the most valuable, complex, and massive portion of the rocket, including the transition, motor mount, motor casing, and fin assembly.

If weather conditions do not allow for high altitude payload deployment, the flight sequence can be easily modified by reprogramming the flight computer for a lower payload deployment altitude. A compromise on exact sampling range and the danger of the rocket and probes drifting away will be considered and balanced prior to launch. We plan more than one launch during the project duration to maximize our opportunities to collect data.

Safety and Environment

The safety officer for the payload team will be Jacqueline.

Environmental Concerns

With any activity such as rocketry, one can cause damage to the environment. Fumes emitted from the engine of the rocket during the launch can possibly cause air pollution, rockets that aren’t recovered could cause physical harm to animals, and any non-biodegradable material will remain for years. To try to minimize the potential environmental hazards associated with rocketry, we will strictly comply with all state and federal environmental regulations. We will keep track of everything we use to launch our rockets and the rockets themselves to ensure that all parts are recovered. We will use Nomex parachute protection to avoid littering the launch area with flame retardant wadding.

Activity Plan

Budget

Full Scale Vehicle

Nosecone	$20.00
Body	$300.00
Parachutes	$0*
Fins	$50.00
Other Parts	$100.00
Preliminary Flight Motors	$250.00
Final Flight Motors	$0.00**

Scale Model

Parts of Scale Model	$70.00
Scale Model Motors	$60.00

Payload

Altimeters	$0*
Sensors	$0***
Custom Electronics	$350.00

Tracking

Tracking System (beacon only)	$0*

Miscellaneous

Tools, glues, screws, etc.	$150.00

Table 22: Expected project expenses

* Already in possession, **Provided by NASA, SLI Program, *** Donated by Parallax

Travel and Lodging Expenses

Number of travelers: 11 (9 team members, 1 teacher, 1 mentor)

Traveling by plane	11 x $400 (estimated)	$4,400
Ground support vehicle	$400 (gasoline) + $400 (rental)	$800.00
Lodging	5 rooms x 4 nights x $119.00 (estimated)	$2,380.00

Travel/ Lodging Total =$7,580.00

Table 23: Estimated travel expenses

The total estimated travel/lodging expenses for a team of 9 members, a teacher and a mentor are $7,580.00. NASA contributes $1,200.00 and the team will pay the remaining amount of $6,380.00. Therefore each member's personal contributions would be $709.00 ($6,380.00 divided to 9 members).We will explore various possibilities of acquiring the needed funds, either through sponsors, or fundraising.

Timeline

August 2009	
14	Request for Proposal (RFP) goes out to all teams
October 2009	
1	One electronic version of the completed proposal due to NASA
22	Awards Granted. Schools notified of selection
23	SLI teams teleconference
November 2009	
1	PDR work begins
5	Web presence established for each team, NASA media announces new teams
December 2009	
4	Preliminary Design Review (PDR) report due
7	Begin work on scale model
14	Acquire parts and supplies for scale model
21-Jan 3	Winter break
January 2010	
4	Scale Model Completed
5	Purchase parts and supplies for full scale vehicle
13	Scale model test flight
20	Critical Design Review (CDR) due
24	CDR Presentation practice
28-Feb. 5	Critical Design Review presentations (tentative)
February 2010	
8	Payload design finalized, payload construction starts
15	Full scale vehicle completed
22	First test flight of the full scale vehicle
March 2010	
17	Flight Readiness Review presentation slides and CDR report due
15	Second test flight, payload complete
22	Payload test flight
25-Apr. 2	FRR presentations (tentative)
April 2010	
12	Rocket Ready for Launch in Huntsville
14	Travel to Huntsville
15/16	Rocket Fair/hardware and safety check
17-18	Launch weekend
19	Return Home
May 2010	
21	Post-Launch Assessment Review (PLAR) due

Table 24: Timeline

Educational Outreach

This year we plan to do rocketry presentations and/or workshops and demonstrations with local schools and after-school programs. Our school's club, Science for Kids, visits local elementary schools giving science talks and demonstrations to interest children in science. When we participate in this program, we will seek community monetary support or manufacturer's donation to obtain rocketry kits. We will present to around 50 children each time.

We will offer our assistance in organizing and running a Make-It-Take-It session for UW Space Place, a UW outreach center. The session will include rocket building and then launch at our TARC practice launch site, Reddan Soccer Park in Verona. The estimated participation at the activity is about 50 kids, ages 6-10.

Conclusion

The project is on schedule and progresses as expected. The details of the vehicle design are now well defined and we will start the construction of a half scale model on the weekend of December 7, 2009. A design of the payload has been developed and we are already researching electronic components and sensors that will be used during our experiment. The integration issues have been also resolved and there are no conflicts between the needs of the payload and the deployment/recovery subsystem.