Preliminary Design Review

Tuskegee University

USLI 2009

Summary of Preliminary Design Review Report

Team Summary

School Name	Tuskegee University
Location	Tuskegee, Alabama
Mentors	Eldon Triggs, Aerospace Science Eng. Arbin Ebrahim, Electrical Engineering

Launch Vehicle Summary

Size	L = 120 inches, D = 4.75 inches
Motor Choice	RMS 75/3840 with L850W-p
Recovery System	Parachute (2 x 90.0 inch diameter)

Payload Summary

Transmitter/Receiver	900 MHz TX-900G (Ozark Aerospace) with associated receiver gound station.
Altimeter(s)	1. ARTS2 barometric/accelerometer 2. Perfectflite MINIALT/WD
GPS	Garmin Module (part of TX-900G package)
Sensors	1. Carbon Monoxide module (USB package) 2. Temp/Humidity/Dew Point module (USB package)
Power	Li-polymer battery (11.2 volt)

The sensors will be packaged so that they will be able to download via a single USB cable mounted into the structure of the payload section. The GPS data, altitude, and wind speed will be sent via 900MHz wireless communications to a ground station to verify altitude and final location. The sensors will take measurements of the atmospheric Carbon Monoxide levels, atmospheric temperature, dew point, and humidity to detect level of moisture/water vapor. This will assist in determining the viability of colonization of other planets.

Changes made since Proposal

1. Changes made to Vehicle Criteria

   The vehicle has changed in overall size and thrust requirements. The initial sizing for the launch vehicle was 1270 mm to 1350 mm. The current length is 3048.0 mm (120 inches, 10 feet). The diameter was initially planned for 120 mm and is still planned to be the same. The length was increased drastically due to CG and CP calculations based on the payload achieving the target altitude of 5280 feet. The initial calculations made the rocket very unstable and ultimately un-flyable. The plan for dual parachutes is still in use at this point.

2. Changes made to Payload Criteria

   At this point, no changes have been made to the payload items. All items presented in the proposal are part of the current plan.

3. Changes made to Activity Plan

   The following changes have been made to the Activity Plan:

   a. Water tunnel testing moved from Nov 15-20 to Jan 6-12 due to PIV equipment issues

   b. Electrical testing has been completed on the GPS/Transmitter/Receiver but has not been completed on the Sensors for CO/Temp because they have not been delivered yet.

   c. Rocket body build has been postponed from Dec 1-31 to Dec 15-Jan 15 because the mandrels have not been finished.

Team Members

Brandon W. Student Team Project Manager
- Chris C. Student Team Project Asst. Manager
- Darrian D. Electrical/Science Team Lead
  - Adrian G. Electrical/Science team member
- James D. Mechanical Department Team Lead
- Lumumba O. Structures Team Lead
  - Raquel F. Structures team member
  - Angelo A. Structures team member
  - Chris H. Structures team member

Vehicle Criteria

1. Mission Statement
   - The mission of the TULIP rocket is to carry a scientific payload to a target altitude of 5,280 feet (1.609 kilometers). The structure must be strong enough to withstand the forces of launch, protect the payload, and ensure stable trajectory and recovery for future missions. The design should be such that the rocket is stable enough to provide true trajectory, but not excessively stable so that the rocket turns into the wind and flies horizontal prior to apogee.
   - The scientific payload will look at the surface temperature, humidity, dew point, and Carbon Monoxide levels in the atmosphere as well as wind speed from apogee to landing. These are some of the primary items that would be looked at on distant planets to give us a good indication of the inhabitability. Our design is to make the systems rugged but inexpensive and easy to retrieve the data once collected.
2. Requirements
   a. *The vehicle shall carry a scientific payload. Time critical payloads are discouraged.* The items listed above describe the science package for the flight. All of the sensors will have an average battery life of 24 hours. The package will also have solar cells to aid in power requirements.
   b. *The vehicle shall be developed so that it delivers the science payload to a specific altitude of 5,280 feet above ground level (AGL). The team whose rocket and payload comes the closest (plus or minus) to this altitude scores the most points for this category.* The vehicle will be constructed with lightweight yet strong materials and the motor will be of sufficient thrust to accelerate the rocket and allow it to coast to approximately 5280 feet.
   c. *The vehicle shall carry a Perfect Flight MAWD or ALT15 altimeter for recording of the official altitude used in the competition scoring. Teams may have additional altimeters to control vehicle electronics and payload experiments.* As stated above, the vehicle will be equipped with the necessary module for altitude readings.

d. *The launch vehicle and science payload shall be designed to be recoverable and reusable.* Special care will be taken with the design of the payload module to give great protection to the scientific package. The parachute will be designed such that the entire rocket and payload descend at a rate no greater than 4.5 meters per second.

e. *Separation at apogee will be allowed, but not advised. Separating at apogee increases the risk of drifting outside of the recovery area. Exception: separating at apogee to deploy a drogue parachute. Dual deployment and shear pins are encouraged.* Deployment of parachute will be designed such that the minimal amount of drift is allowed. A single parachute will be used to prevent entanglement and possible parachute failure.

f. *Preparation of the vehicle and payload on launch day shall not exceed 4 hours. At the end of the four-hour preparation period, the team must be prepared to launch. Otherwise, the teams will not be allowed to launch.* The vehicle will be designed such that the parts will assemble and be prepared for flight in less than 30 minutes. Testing should reveal potential problems and allow for those to be remedied prior to launch date. All parts that need accessing just before flight will be open and accessible in the payload area.

g. *Data from the science payload shall be collected, analyzed, and reported by the team following the scientific method.* All of the data collected will be able to be downloaded via USB cable to a laptop and analyzed in a minimal amount of time. Use of commercial programs where applicable will be used and custom programs will be written to handle the remaining data.

h. *A tracking device shall be placed on the vehicle allowing the rocket and payload to be recovered after launch.* An audible beeper plus real-time GPS tracking data will be used to track the descent and locate the landing site of the rocket.

i. *Only Commercially-available, NAR-approved motors (this also covers motors tested by the TRA and CAR, as all three motor-testing organizations accept each other's certifications) shall be used.* As stated before, the team's BATFE certified consultant, Chris Short will handle the purchase, storage, and transportation of all motors. All motors will be ordered through him and are all commercially available.

j. *Each team shall be responsible for providing their launch equipment if possible, especially if using hybrid motors. The Huntsville Area Rocketry Association (HARA) has launch assets (controller, pads) that can be used for APCP rocket launches and has limited hybrid capability.* At this point, no hybrid motors are part of the trade studies and are not part of the consideration process. The team will use conventional APCP motors.

k. *All teams, including hybrid motor teams, must launch their full scale rocket prior to launch day, as a test. The purpose is to test the vehicle structural and recovery systems. A sub-scale motor could be used for the flight tests.* Tests will be conducted as soon as plausible in the Dec-Jan timeframe. They will be launched at the Samson, AL site to verify structural stability, flight characteristics, and apogee altitude.

l. *The following items should not be used in building the rocket:*
   a. *No flashbulbs. The recovery system must use commercially available*
   b. *Low-current electric matches.*
   c. *No forward canards*
   d. *No Mach-Busters*
   e. *No forward firing motors or rear ejection parachute designs* At this point, none of these items are included in the area of possibility and will be avoided completely.

m. *The maximum amount teams may spend on the rocket and payload is $5000 total.* The construction costs will be below this number. See attached budget.

3. Mission Success Criteria: This will be broken down into three separate areas, Mission Success (Complete), Mission Success (Partial), and Mission Failure.
   a. Mission Success (Complete) for vehicle
      i. Completion of flight profile includes:
      ii. Ignition
      iii. Launch and successful separation from launch rail.
      iv. Flight to apogee of approximately 5,280 AGL
      v. Successful deployment of main and lower stage parachutes
      vi. Descent rate of <12 ft/sec for electronics section, descent of <20 ft/sec for lower motor section.
      vii. Maintain structural integrity and be able to refuel, repack parachutes, and prepare to fly within 30 minutes.

b. Mission Success (Complete) for payload
    i. Maintain continuous downlink of altitude/GPS data from ascent to retrieval
    ii. Full function of all onboard sensors and collection of data during entire flight profile.
    iii. Able to download all data to appropriate computers
    iv. Maintain structural integrity of all sensors and preserve ability to return to flight within 30 minutes.

c. Mission Success (Partial) for vehicle
    i. Achieve parabolic flight, but not to assigned altitude
    ii. Successful retrieval and maintain partial serviceability such that vehicle will return to flight after some repair
    iii. Controlled descent keeping electronics/scientific section intact.

d. Mission Success (Partial) for payload
    i. Transmit during >50% of flight
    ii. Download a minimum of 3 of 4 parameters and flight hardware reusable

e. Mission Failure (complete) for vehicle
    i. Failure to launch
    ii. Failure to reach 1,000 feet AGL altitude
    iii. Failure of main/lower stage parachutes to deploy
    iv. Structure too badly damaged to return to flight

f. Mission Failure (complete) for payload
    i. Failure to transmit data for more than 50% of the flight
    ii. Failure of batteries to prove power during entire flight
    iii. Failure of sensors to record data on more than 3 of 4 parameters

Major Milestone Schedule

Event	September	October	November	December	January	February	March	April
Initial Teleconference	12th							
Proposal Due		8th						
USLI Workshop		10th-11th						
Electrical study	15th through	31st						
Fiberglass testing		20th through	30th					
Water tunnel test				15th - 20th				
Electrical test			15		15			
PDR Due				5th				
Rocket body build				1st-31st				
CDR Due					22nd			
CDR presentations					2th through	6th		
Test flights						7th		
Flight Readiness Rev.							18th	
Flight Read. Present.							25th thru	3rd
Launch								15th thru 19th

Vehicle Systems Overview

The following systems are needed for full function of the vehicle throughout the entire flight envelope.

A. Altimeter system for pyros.
B. Pyro systems to ensure proper separation of the desired sections for parachute deployment.
C. Shock cord to provide load attenuation.
D. Parachutes designed to provide proper descent rate.
E. Proper fin design to provide enough stability for flight, but not too much stability to cause wind-vaning.

The following section will deal with the trade studies for materials in regards to the overall construction of the vehicle.

1. Trade studies for Vehicle structure material

Material	Tensile Strength (MPa)	Modulus of Elasticty (GPa)	Cost	Ease of Machinability
(Kevlar/Twaral)	500	75	Medium	Medium
Nylon 6,6	85	3.5	Medium	High
Syalon 101	450	288	High	Low
Zircalon 5	500	205	High	Low
Fiberglass	250	80	Low	High
Carbon Fiber	1100	70	Medium	High

Note: Ease of machinability: High denotes that the material is easily machinable

2. Normalization of Values

Normalization of values

Material	1	2	3
Tensile Strength	<100	<200	>300
Modulus of Elasticty	<5 GPa	<50 GPa	<100 GPa
Cost	High	Medium	Low
Ease of machinability	Low	Medium	High

3. Weighting of items

Weighting factors

Material	1	Reason
Tensile Strength	1	Majority of flight profile will be in compression and will be augmented with stiffeners as needed
Modulus of Elasticty	2	Need a stiff material but not as critical
Cost	3	Very important due to budget constraints
Ease of machinability	2	Minimal equipment on hand to machine parts

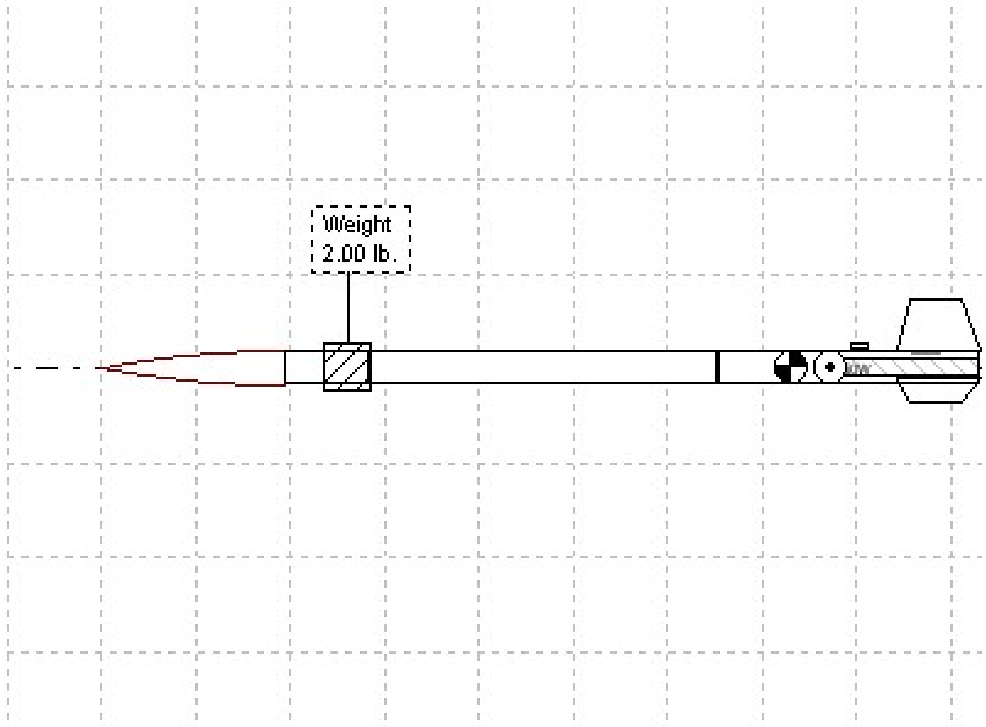
4. Final values and selection

Final Values

Material	Tensile Strength (MPa)	Modulus of Elasticty (GPa)	Cost	Ease of Machinability	SUMS
(Kevlar/Twaral)	3	3	5	4	15
Nylon 6,6	1	1	5	6	13
Syalon 101	3	3	3	2	11
Zircalon 5	3	3	3	2	11
Fiberglass	2	3	9	6	20
Carbon Fiber	3	3	5	6	17

Using this method the team selected fiberglass as the primary vehicle construction material. In high strength areas carbon fiber will be used instead, but because of the pre-preg material on hand and the need for vacuum/autoclave facilities, they will be used only in some areas. These areas include the science payload structure, nosecone, and fins.

Vehicle Design Overview



Version 1 of Flight Vehicle

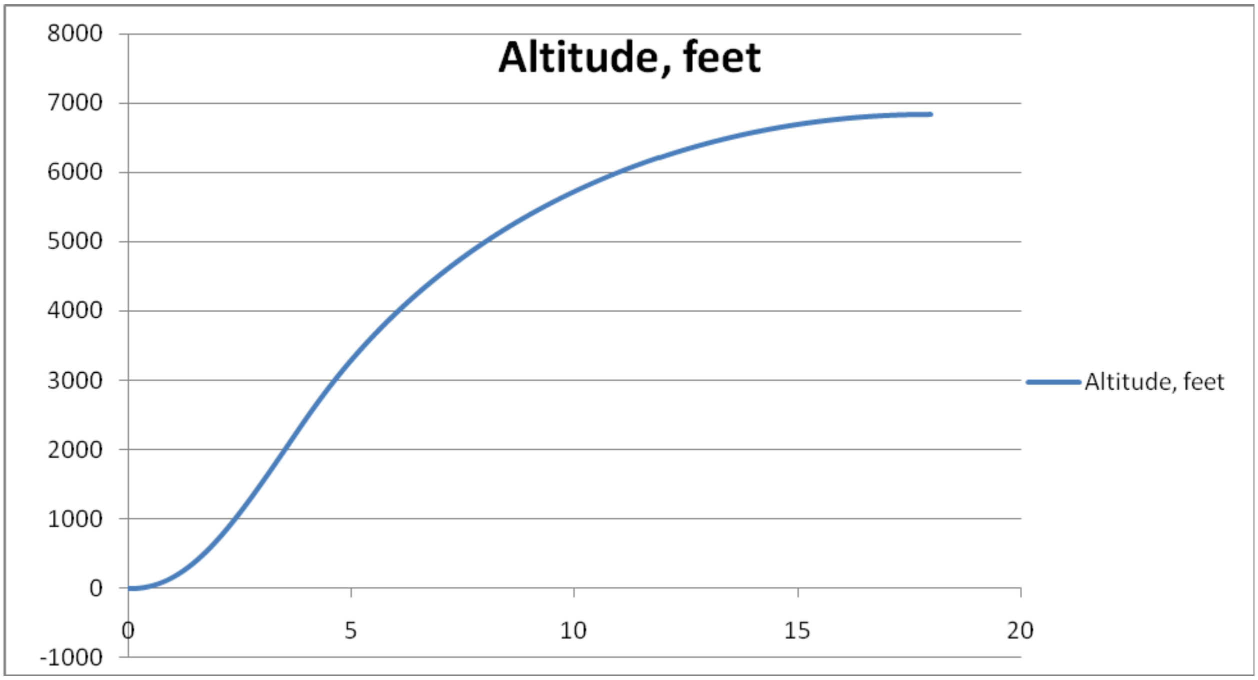
The overall length is 11.25 feet. The calculated cd-value is 0.75 and the lift-off weight is 23.31 pounds. The calculated Center of Gravity (CG) is 8.85 feet from the nose and the Center of Pressure (CP) is 9.25 feet from the nose. This gives the rocket a stability of 1.01 calibers.

Recovery Subsystem

Initial sizing of the parachute for a single parachute is a diameter of 14.57 feet with a 12 panel design. We will use this as a basis to design two separate parachutes so that the aft section with the motor will descend more rapidly and the electronics section will descend at a rate not to exceed 10 feet/sec. The initial calculations given by SpaceCad v. 4 provided the initial parachute sizing and will be used for the two-parachute model. Testing will begin over December to determine the amount and type of ejection charge. Use of either black powder or smokeless power is expected. All hazmat/safety procedures will be followed in regards to the explosive materials.

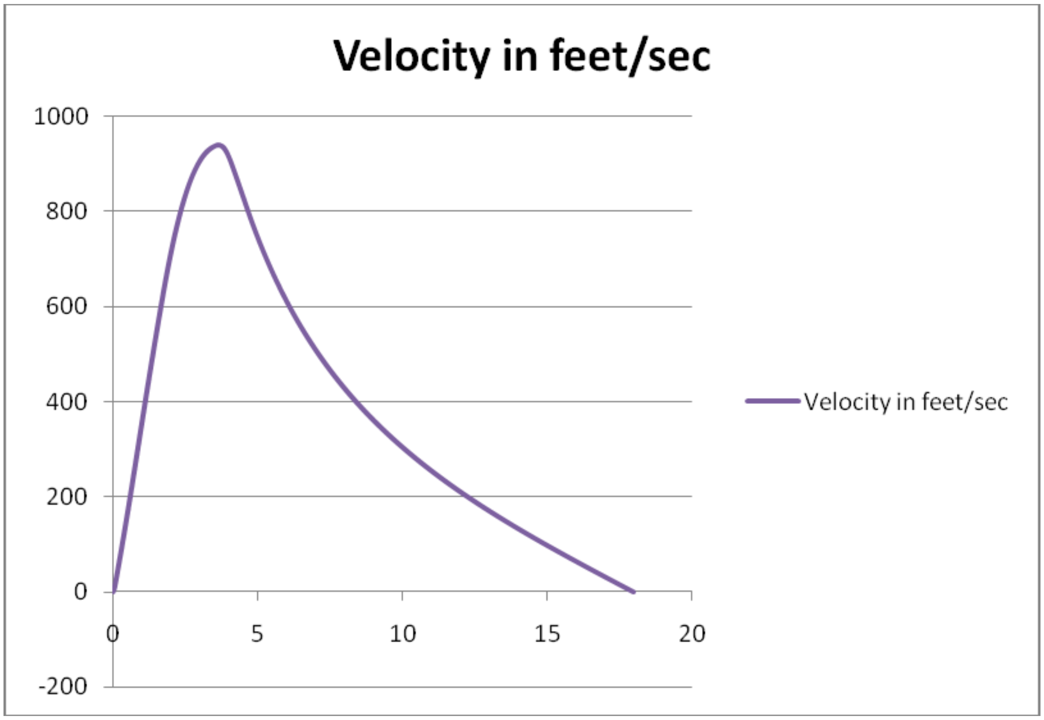
Mission Performance Predictions

The following charts are the calculated values from SpaceCAD version 4.0. This model will give students the basis to start hand calculations as well as basic Theory of Column predictions on fuselage thickness, CP calculations from the Barrowman report, as well as physical calculations for the CG before/after the sections are built.

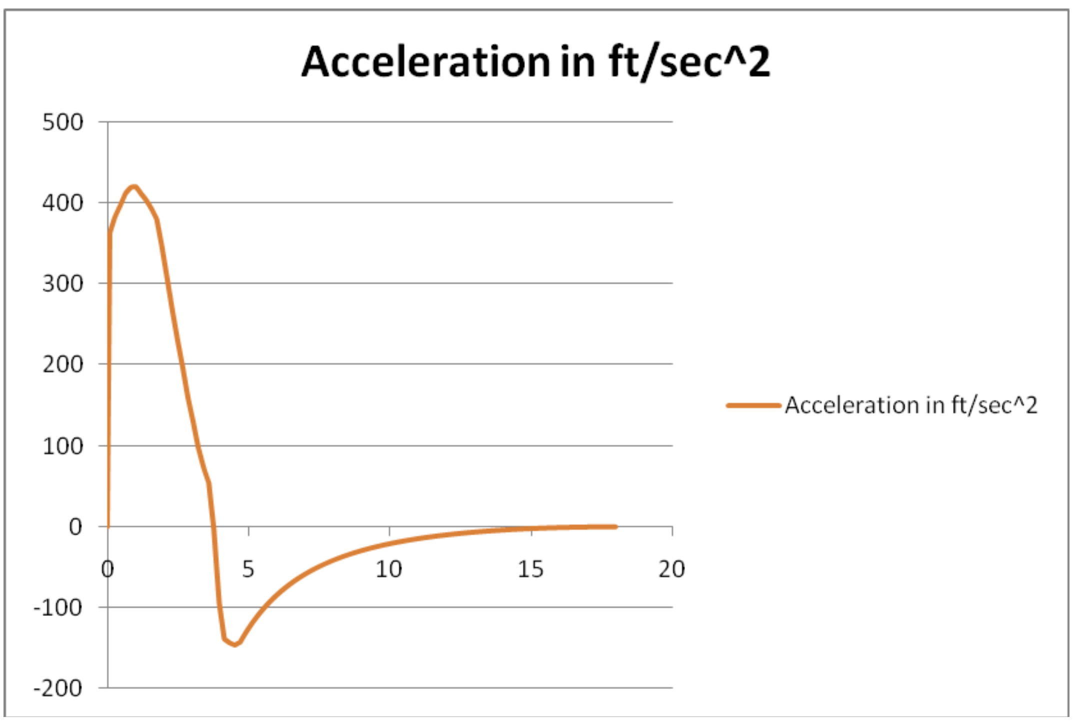


The altitude is in excess of the 5,280 feet target, but previous competitors have consistently come in under the target altitude so this team will allow for shortcomings in fuel/motor burn rate/pressure. This will be tested prior to launch to verify and any adjustments will be made in the mass of the rocket to ensure the target altitude is met. The section aft of the electronics package will be used as the variable section. This will be lengthened / shortened to adjust the CG/CP to provide stable flight.

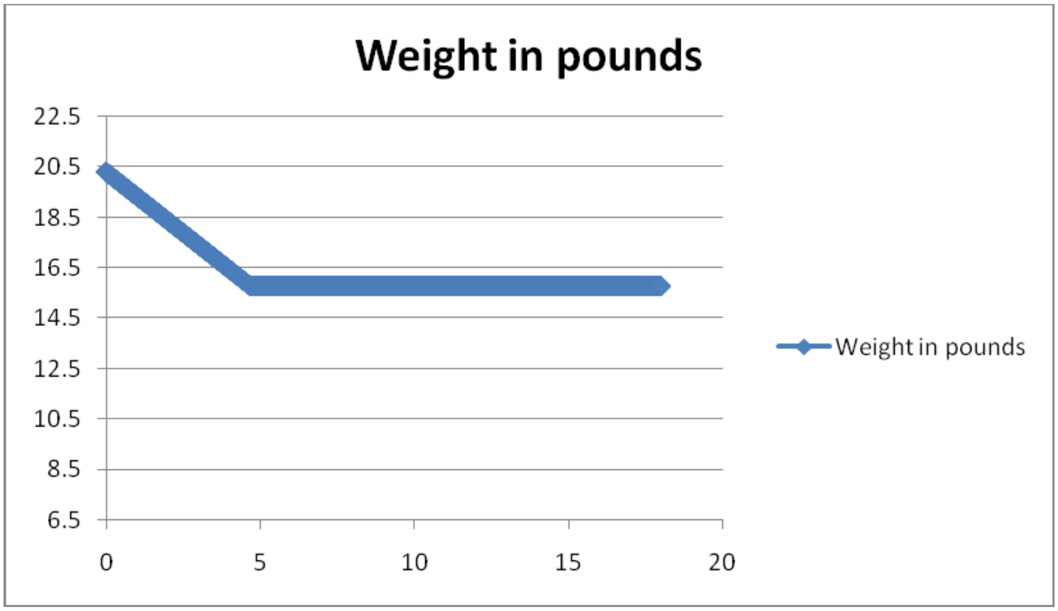
The next graphs show the initial calculations for the velocity and acceleration based on the initial sizing of the rocket. These calculations were also performed in SpaceCAD v.4 and will be verified through testing and hand calculations. These are simply the first iteration of calculations. The initial calculations for motor mass were also provided so that the students would have a better final mass to calculate the needed area of the parachutes.



Velocity in feet/sec
1000
800
600
400
200
0
-200
0
5
10
15
20
Velocity in feet/sec



Acceleration in ft/sec^2
500
400
300
200
100
0
-100
-200
0
5
10
15
20
Acceleration in ft/sec^2



Payload Integration

The payload will be situations such that the mass will as close to the bottom of the payload section as possible. This will assist in the CG determination and give the science team guidance on placement of sensors. The payload section will have suitable static ports drilled in the body to provide needed atmospheric access for both the barometric altimeters as well as the scientific sensors. Any solar panels will be placed in the skin of the section. All switches must be accessible from the outside to ease assembly and activation/deactivation of all power supplies and sensors.

Launch Operation Procedures

All launches will be held at NAR/TRA sanctioned sites. The launch rail will be provided and the overall length will be determined by the final length of the rocket. The minimum length is at least twice the length of the rocket, such that the overall length of the rail will be close to 25 feet in length. The assembly of the vehicle prior to launch will have the following sections:

a. Fuselage

b. Motor

c. Avionics/Science Package

The motor will be assembled before arrival at launch site. The fuselage will be assembled before arrival at launch site. The only parts that will need to be assembled on site is the parachute to shock cord, shock cord to aft end, shock end to nose cone and avionics package. The science package will be enclosed in the fiberglass structure such that the switch will be accessible from the outside. Time to assemble will require a maximum of 30 minutes. The rail lugs will be compatible with the rail constructed. All safety precautions and guidelines will be followed in accordance with the NAR/TRA, BATFE, and NPFA regulations.

Safety and Environment (Vehicle)

The advisor safety officer for the team is Eldon Triggs and the student safety officer is Brandon Williams. The following list encompasses the possible failure modes of the vehicle.

1. Vehicle instability:
    - Vehicle going off-nominal flight path. There is no destruct mechanism for the vehicle, therefore is no possible way to destroy the vehicle before impact. Stability must be maintained through proper design.
2. Parachute failure to deploy
    - Spotters will maintain visual sighting of vehicle during ascent, apogee, and descent. Verification of vehicle location will be maintained at all times.
    - If vehicle does not deploy parachutes, the safety officers will notify the participants immediately of parachute failure and give location of vehicle descent location.
    - The ascent phase of the vehicle will be such that the vehicle moves away from any participants and all participants will be a sufficient distance to avoid injury.
3. Motor failure
    - If the motor fails to ignite, on-site procedures will be followed regarding the Fail-to-fire. Personnel will approach only after a sufficient time has elapsed to verify that the motor is not “cooking off” and fire unexpectedly.
    - A backup engine will be available for flight.

The following MSDS sheets and files are on hand to give students and faculty the necessary information regarding hazardous materials:

1. Ammonium Perchlorate
2. Kester solder
3. Bondo® Fiberglass resin
4. Owens-Corning Fiberglass fabric
5. Krylon® spray paint
6. Title 14, Part 101, Subpart C
7. NFPA 1127, Code for High Power Rocketry

The actual sheets are not included in this document in order to reduce overall length, but are available upon request.

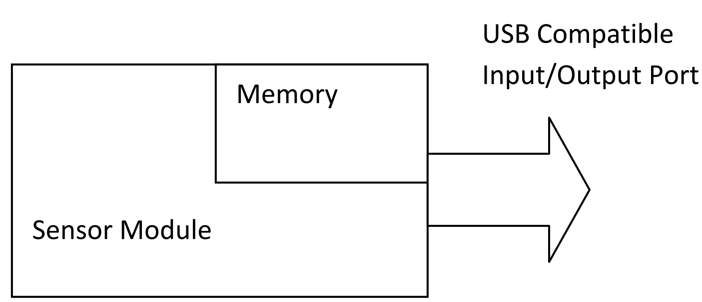
Payload Criteria

Payload

Item	Function
EL-USB-2-LCD	Humidity, Temperature and Dew Point Data Logger
EL-USB-CO	Carbon Monoxide Data Logger
MiniAlt/WD	dual logging event altimeter
standard serial RS-232 format adapter	PC connect data transfer kits for Altimeter
ARTS TX-900G	Altitude, GPS and Wind speed Telemetry transmitter
ARTS RX-900	Receiver for your Telemetry System
Standard Alkaline 9V battery	Altimeter Power supply

Carbon monoxide, Temperature, Humidity and Dew point sensors

The EL-USB-2-LCD and EL-USB-CO sensors have been chosen due to their low weight (0.3lbs each), easy use of usage, and programming. These sensors have inbuilt non volatile memory for storing the measured data and an internal lithium battery.



Altitude, GPS and Wind speed Transmitter and Receiver

Safety and Environment (Payload)

The safety officers will be the same mentioned in the vehicle section. The failure modes mention on page 7 will have the following mitigation plan:

1. Battery
    a. The potential problems with the lithium-polymer battery pack include fire and contact with skin.
    b. The battery will be charged in a Nomex sock with proper charging techniques in a safe area.
2. Motor
    a. The motor has the potential to catch fire and cause large fires.
    b. The motor(s) will be placed in approved containers and transported in accordance with Federal, State, and local laws. The motors will only be handles by NAR Level 2 certified personnel on site and during testing.

The items above are the most hazardous items when the vehicle is not in flight. The MSDS sheets and appropriate NFPA/NAR regulations are posted in a binder and are provided to students and faculty every time work is performed and are kept with the equipment as it is transported to/from launch sites. Equipment is kept on hand to clean up any spill or contamination to keep the environment from being harmed.

Budget

TU-LIP Rocket Construction Est. Budget

Item	Cost each
Fiberglass sheets	$50.00
Resin	$45.00
PVC core mandrel	$51.00
PerfectFlite Altimeter	$100.00
CO detector	$92.00
Temp/Humidity/DP	$82.00
Parachute	$40.00
Bolts/Hardware	$50.00
Motors (6 est)	$1,350
Mold Release agent	$50
Wood for molds	$120
Wire	$20
Expendables***	$200
GPS module	$220
PC Board	$400
Total	**$2,870.00**

*** Expendables include batteries, soldier, paint, etc.

On the following page is a breakdown of the actual funding as presented to the Alabama Space Grant Consortium (ASGC) for fund matching.

Tuskegee University

Cost Estimate for 1 year USLI Competition

Funding Agencies: Alabama Space Grant Consortium, Tuskegee University, External Sources

1. PI Salary /Fringe

Faculty Advisor/PI	Months	Time & Effort	Annual Salary	Fringe	Overhead	Total
Eldon Triggs, Instructor Aerospace Science Eng.	10	10%	$ 42,000.00	$ 756.00	$ 1,974.00	$ 6,930.00

2. Travel/Lodging/Transportation

Competition Time

Item	Number	Cost each	Provider	Days/Nights	Rooms	Total
Lodging	6	$82.00	Beville Conf.	4	4	$1,312.00
Per Diem for food	6	$40.00	Tuskegee	4	n/a	$240.00
Van rental	1	$346.14	Enterprise			$346.14
Fuel		$200.00				$200.00
Total						$2,098.14

3. Travel/Lodging/Transportation

Testing

Item	Number	Cost each	Provider	Days/Nights	Rooms	Total
Lodging (2 trips)	4	$62.00	Holiday Inn	4	4	$992.00
Per Diem for food	4	$30.00	Tuskegee	4	n/a	$120.00
Van rental	2	$149.00	Enterprise			$298.00
Fuel		$300.00				$300.00
Total						$1,710.00

4. Rocket/Payload Construction

Item	Number	Cost each	Provider	Total
Cost for construction items	1	$2,870.00	various	$2,870.00
Ground station (estimated)	1	$300.00	various	$300.00

ASGC 9/1/2008-7/30/2009	Tuskegee Cost Share 9/1/2008-7/30/2009	External Funding 9/1/2008-7/30/2009	Project Total 9/1/2008-7/30/2009
$1,312	$7,366	$992	
$240		$120	
$346		$298	
$200		$300	
$2,098		$1,710	
$2,870			
$300			
$7,366	**$7,366**	**$3,420**	**$14,732**

Timeline

The timeline is given on Page 8

Outreach summary

The students are planning a seminar with Booker T. Washington High School in Tuskegee and will work to encourage students to stay in STEM areas. There are at least one seminar planned for March.

Conclusion

At this time, the schedule of events in the timeline is mostly on schedule, the deliverables will arrive in late December or early January.