NASA Student Launch 2017

Flight Readiness Review Presentation

UNIVERSITY OF SOUTH FLORIDA

SOCIETY OF AERONAUTICS AND ROCKETRY

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Final Launch Vehicle Dimensions

Property	Quantity
Diameter (in)	6
Length (in)	145
Projected unloaded weight (lb)	39.7
Projected loaded weight (lb)	47.5

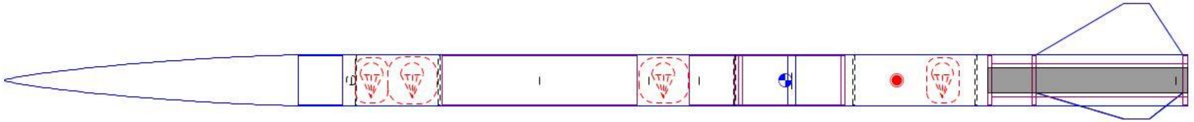


Figure 1: Overview drawing of launch vehicle assembly

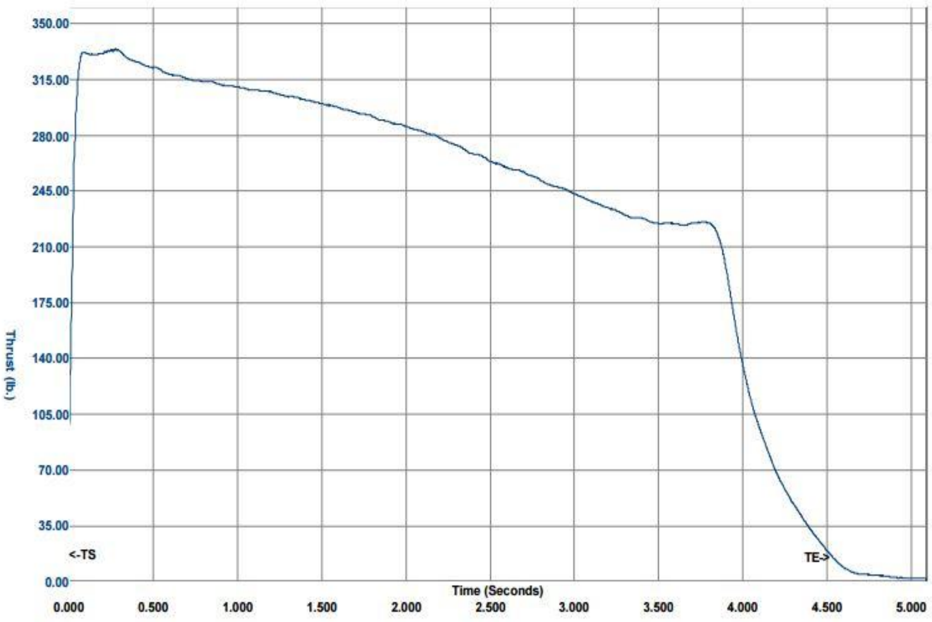
Key Design Features

- Cesaroni L1115 motor
- Four sections
  - Three foot nose cone, five foot body tube, altimeter bay, four foot drogue section
- Recovery
  - One parachute for nose cone, one parachute and one drogue for booster and main body together, one parachute for landing module
- Piston System
  - A piston system is used just below the main parachute to prevent gases from going around the parachutes and improve the probability of successful ejection.
- Landing Module
  - Vehicle designated to land vertical upon touchdown through the use of its spring loaded landing gear, GPS, and vision systems
- Vision System
  - A Raspberry Pi 3b computer module with a VideoCore IV 300Mhz GPU, paired with a oCam 5mp USB 3.0 Camera. An Atmega328p will control 2 servos and calculate the angle and direction the camera needs to face for optimal target identification.

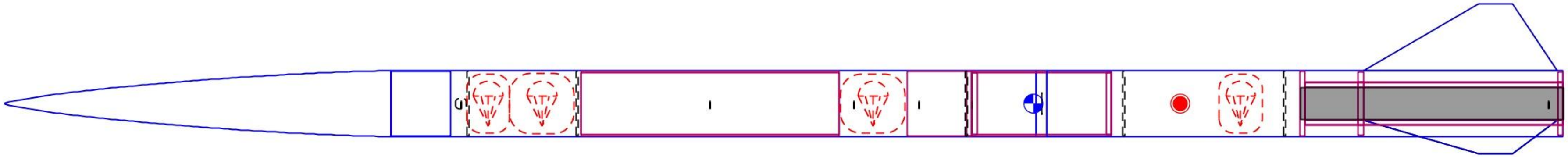
Final Motor Selection

L1115

- Total Impulse:5015 Ns
- Burn Time: 4.5 s
- Diameter 75 mm
- Length: 621 mm
- Propellant Weight: 2394 g



Rocket Flight Stability



Section	Value
Center of Gravity	90.861 in
Center of Pressure	109 in
Stability	3.04 calipers

Thrust-to-Weight Ratio and Rail Exit Velocity

Section	Value
Thrust-to-weight Ratio	5.29
Rail Exit Velocity	58.3 ft/s

Mass Statement and Mass Margin

Section	Weight (lbs)
Nose Cone	4.00
Landing module	7.98
Main Airframe	15.00
Booster	12.69

Recovery Overview

Parachute Name	Parachute Size
Nose Cone parachute	Recon Recovery 50”
Landing Module parachute	Recon Recovery 60”
Main Body parachute	SkyAngle X-Large
Drogue parachute	Recon Recovery 30”

The Drogue parachute: Attached to shockcord that is then attached to a U-Bolt.
The Nose Cone parachute: Directly attached to the nosecone.
The Landing Module parachutes: Directly attached to U-bolt on the landing module.

Kinetic Energy Analysis (at key phases of the mission, especially landing)

- Parachutes were chosen to have appropriate descent velocity and kinetic energy on landing

Section	Descent Velocity with L Cert-3 (ft/s)	Kinetic Energy with L Cert-3 (ft-lbf)
Nosecone	11.33	5.98
Upper Section with Lander	11.33	32.89
Altimeter Bay	11.33	11.96
Booster Section	11.33	28.90

Drift Analysis

- Time to apogee - 19.7 seconds

Wind Speed (MPH)	Drift (ft)
0	0
5	610.589
10	1,221.178
15	1,831.767
20	2442.356

Testing Plan

Type of Test	Reason
Ground Test	To ensure that there was enough black powder to successfully eject the components out of the main airframe.
Sub Scale Launch	To ensure that the rocket could successfully reach the wanted point of apogee and also successfully eject the landing module and land it safely.
Full Scale Launch	To ensure that the rocket could reach an apogee of 5,280 feet and successfully eject the landing module and allow it to determine the designated tarp while landing upright, safely.

Full Scale Test Flight Review

Predicted Flight Data	
Max Altitude: 5,731 ft	Max Velocity: 613 ft/sec
Velocity off the Rod: 58.3 ft/sec	

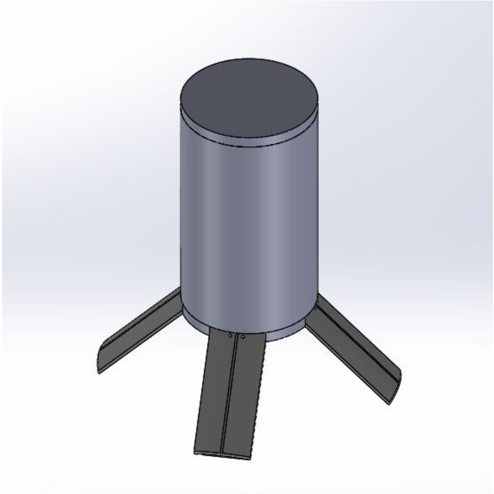
Actual Flight Summary			
Max Altitude: 3,574 ft	Max Velocity: 425 ft/sec	Ascent time: 15.73 sec	Descent Time: 80.48sec
Drogue Rate: 120 ft/sec		Main Rate: 21 ft/sec	

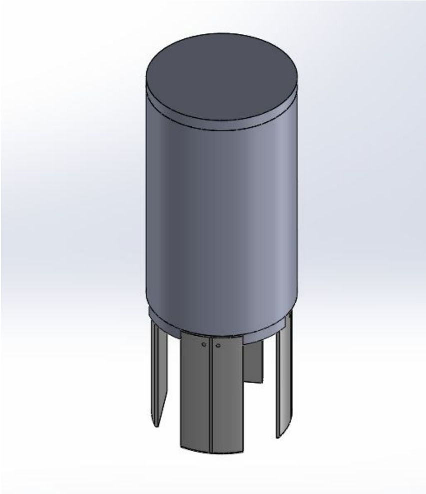
Recovery System Performance

Component	Status	Solution
Piston	Contained gasses and was able to successfully eject components in the main airframe.	N/A
Main Parachute	Successfully ejected and opened fully.	N/A
Nose Cone with Parachute	Successfully ejected but the nomex protector slid up the shroud lines and prevented the parachute from opening	All nomex protectors will be secured below the point where the shroud lines are sewn together
Landing Module with Parachute	Successfully ejected and opened fully	N/A

Final Payload Design Overview

- Implements Two Separate Systems
  - Landing Gear: cylindrical spring loaded legs
  - Electronics Bay: Raspberry Pi 3b based Vision System and Atmega328p based Camera Aiming System





Landing Gear

Design Criteria
- Compact
- Simple
- Strong

Objectives
- Land vertically
- Prevent tipping
- Handle high stresses associated with landing

Final Design
- Spring loaded cylindrical legs
- Extension Springs

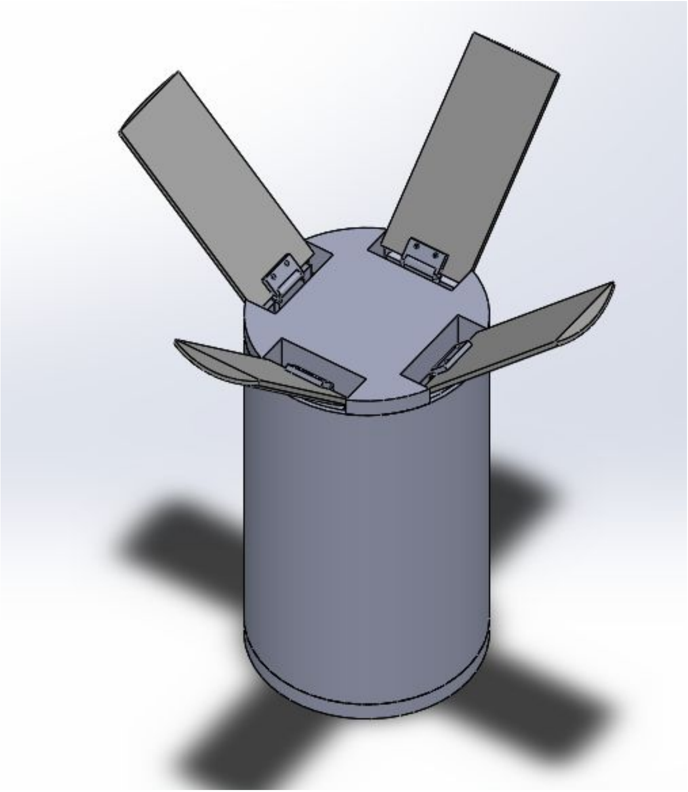


Figure 5: Landing Gear System Bottom View

Final Landing Module Dimensions

Dimension	Value
Length (inches)	24.44
Diameter (inches)	Outside: 6.00 Inside: 5.75
Weight (lbs)	7.98

Payload Integration

- Landing Module Deployment
  - Prior to deployment, the landing module sits inside the rocket, which maintains dimensional constraints on the spring loaded landing gear. Upon deployment, the landing module will be forced out of the rocket due to explosive charges, allowing the landing gear to deploy.

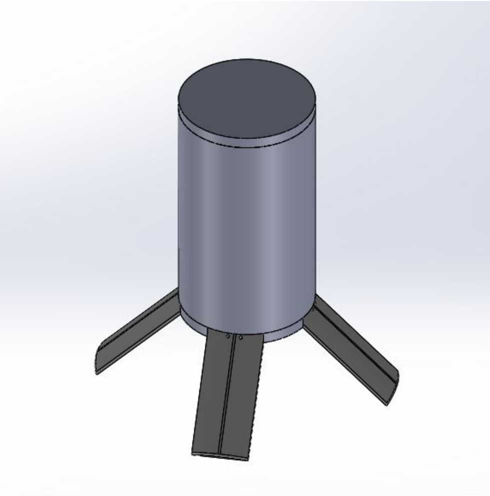


Figure X: Pre-deployment

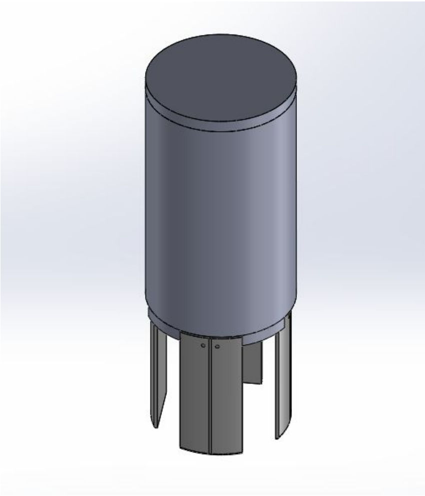
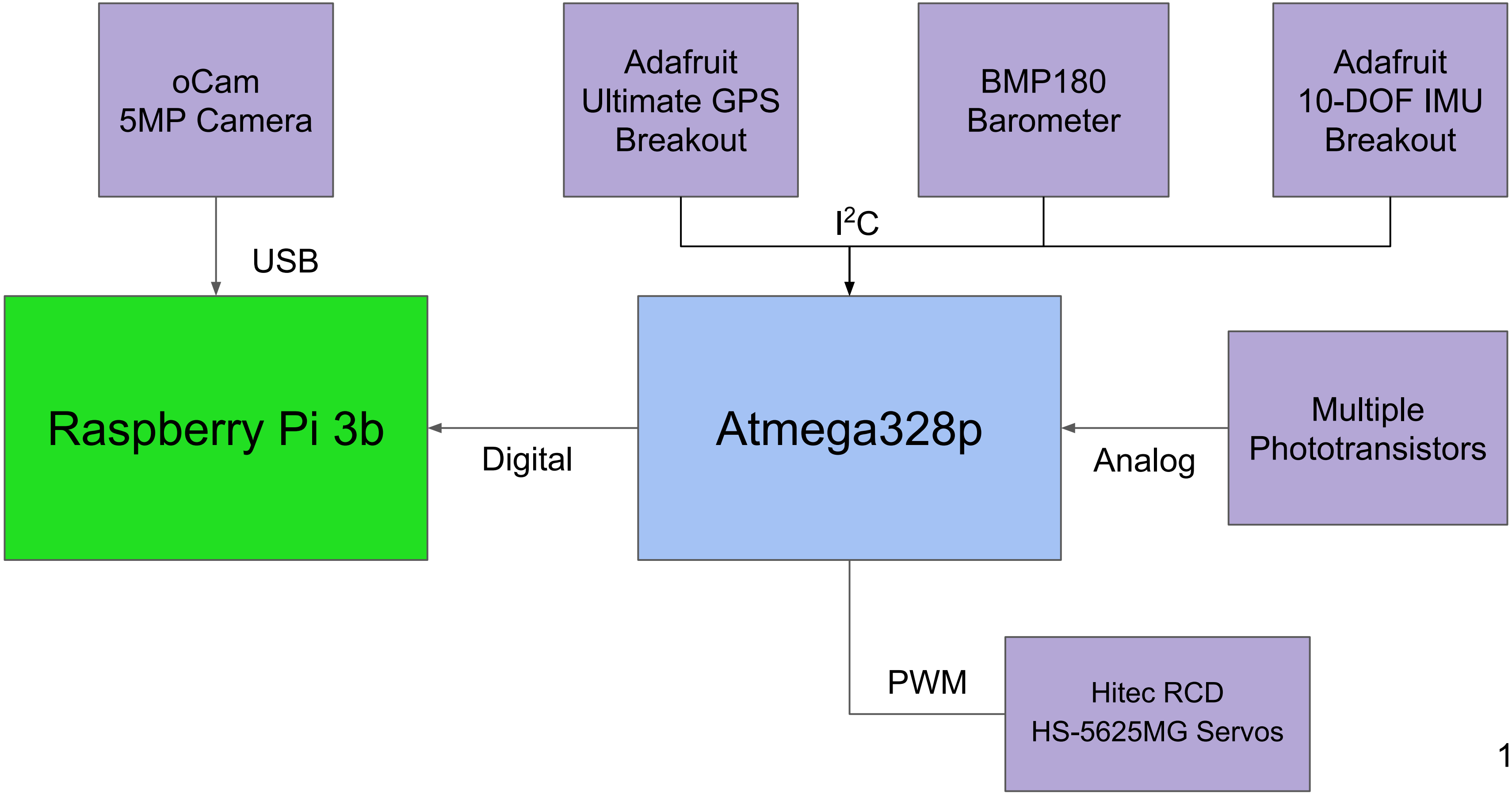


Figure X: Post-deployment

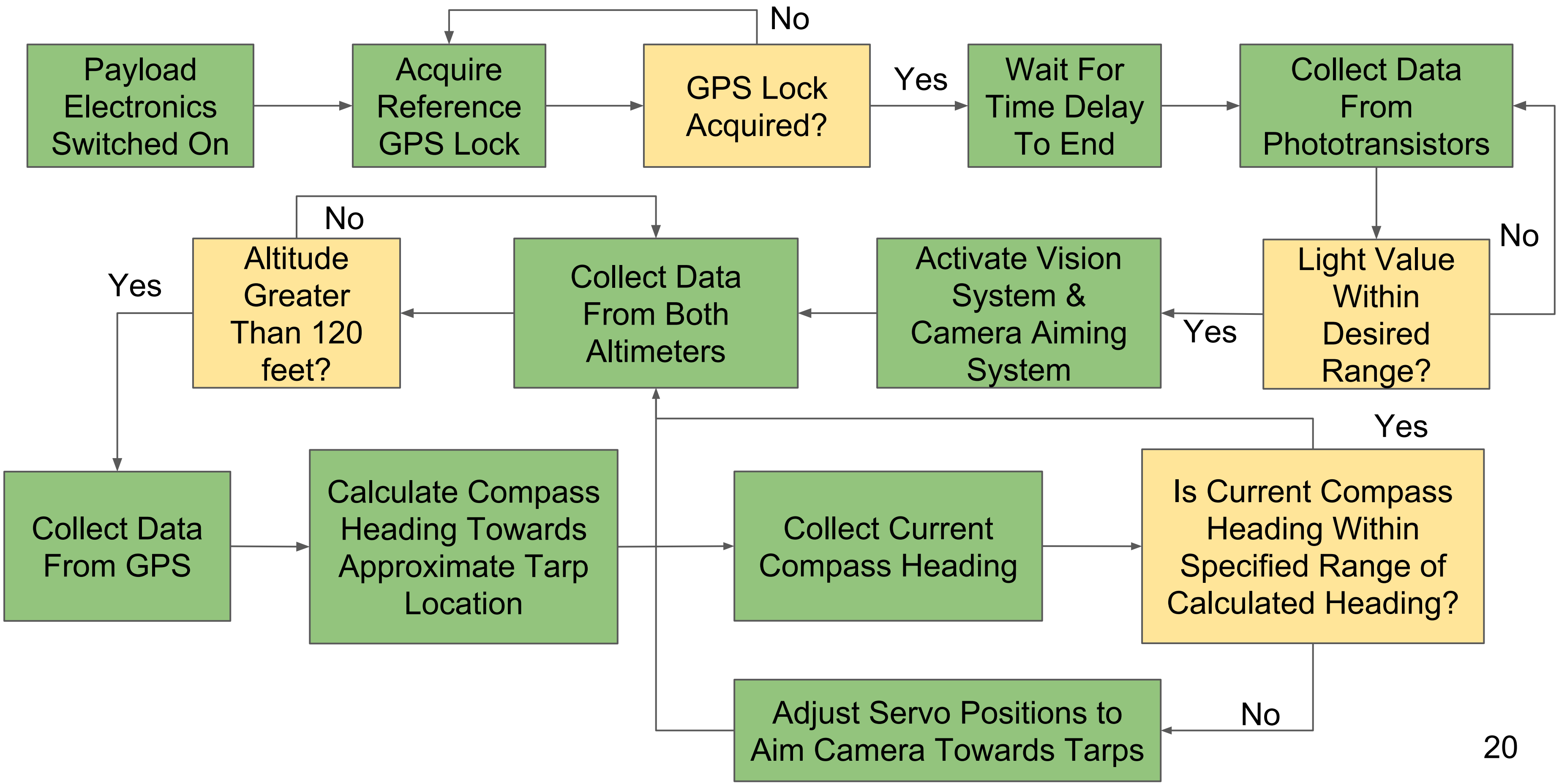
Payload Interfaces

- Loading of the Landing Module
  - The landing module is tucked inside the second stage directly under the nose cone. Dimensional constraints inhibit the landing gear from deploying until the module is removed from the rocket itself.
- Interaction During Flight
  - Deployment of the landing module does not occur until an altitude of 1000 feet on descent. At this altitude, a detonation will force it out of the rocket and all systems will deploy to meet flight objectives. Prior to this, the rocket will simply be inactive in its respective stage.

Payload Electronics Wiring Block Diagram



Steering Control System Flowchart



Status of Requirements Verification

Requirement	Method of Meeting Requirement	Verification
Data from the camera system shall be analyzed in real time by a custom designed onboard software package that shall identify and differentiate between the three targets.	An onboard computer *(Raspberry Pi 3b)* housed in the electronics bay of the landing module will process the captured images in real time. The computer will run a custom python program utilizing the OpenCV computer vision library to differentiate between the three targets.	For verification, review data captured and analyzed by system once recovered after launch.
The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour.	Power consumption calculations will be assessed and an appropriately rated battery will be selected to ensure the electronics system remains in nominal condition. Onboard sensors will keep the main processing computer in a low power mode until specific task are requested.	Computer System with onboard real time clock will log elapsed time of events from the moment it's turned on until the end of the flight.

Status of Requirements Verification

Requirement	Method of Meeting Requirement	Verification
Section housing the cameras shall land upright and provide proof of a successful controlled landing.	An upright landing of the landing module will be made possible by using a landing gear system that will absorb the impact force of the overall system on touchdown and land on any terrain.	Angle of rocket upon landing will be captured and stored within onboard software for later verification.
The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	The launch vehicle will be designed to separate into 4 separate sections. Each section with its own recovery parachute to ensure the rocket body stays intact. The motor can be replaced within 1-2 hours after the casing has cooled. The landing module can be reset quickly by changing out or charging the battery, and relocking the motor arms in their upright positions.	Proper launch procedures and proper handling of the launch vehicles and its components will be followed. All vehicle preparations and launches will be overseen by a certified TRA member.

Status of Requirements Verification

Requirement	Method of Meeting Requirement	Verification
Launch the rocket 5,280 feet	The rocket will be built with a motor designed to get the vehicle to 5,280 feet at apogee.	Subscale and full scale testing to date indicate altitudes below the target. However, weight reduction plans are being implemented.
The vehicle shall carry one barometric altimeter for recording the official altitude used in determining the altitude award winner.	The altimeter in the electronics bay will be able to record the altitude of the rocket throughout the whole flight.	NSL Inspection as well as inspected and approved by the safety officer.
The launch vehicle shall be designed to be recoverable and reusable.	The launch vehicle will contain parachutes on every separate or tethered part of the rocket that will be released at apogee and an altitude that will allow it time to open up properly and safely.	Subscale and full scale test launch showed that all components were successfully recovered and components sustained no damage.

Status of Requirements Verification

Requirement	Method of Meeting Requirement	Verification
The launch vehicle shall be capable of being prepared for flight at the launch site within four hours, from the time the Federal Aviation Administration flight waiver opens.	There will be Final Assembly and Launch Procedure checklist that will ensure that the launch vehicle will be safely prepared and ready to launch within the four hours.	During full scale launch testing, assembly and preparation was complete within one hour.
The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.	The motor that was chosen for the rocket will allow the rocket to achieve a minimum of 52 fps at rail exit.	Full scale testing indicates that the velocity when leaving the rail meets this requirement.
All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day.	SOAR launched the full-scale rocket on February 18, 2017.	Evidence of full-scale testing as well as NSL inspection.

Status of Requirements Verification

Requirement	Method of Meeting Requirement	Verification
The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude.	The launch vehicle is designed to deploy the drogue parachute at apogee and the main parachute at an altitude that is lower than apogee	During full scale launch testing, the drogue parachute successfully deployed at apogee, and the main and other parachutes ejected at 1000 ft.
Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.	A ground ejection test for the drogue and main parachute will be completed prior to initial subscale and full-scale launches.	Ground ejections tests were successfully competed on February 18th.
At landing, each independent sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf	The correct and appropriate parachute size will be chosen in order to slow the launch vehicle down enough to ensure a kinetic energy of less than 75 ft-lb. Multiple tests will be simulated.	Subscale and full scale testing show that the kinetic energy remains within these limits.

Safety

- Risk adjustments and updates from full scale test launch

Recovery	Rocket descends too quickly.	Parachute is improperly sized.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2E	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	2E	The website http://descentratecalculator.onlinetesting.net/ was used to calculate theoretical descent values. Full scale testing resulted in no damage to rocket components.
Recovery	Rocket descends too slowly.	Parachute is improperly sized.	The rocket will drift farther than intended, potentially facing damaging environmental obstacles.	3E	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	3E	The website http://descentratecalculator.onlinetesting.net/ was used to calculate theoretical descent values. Full scale testing resulted in no damage to rocket components.

Safety

- Risk adjustments and updates from full scale test launch

Recovery	Lines in parachutes become tangled during deployment.	Parachute becomes unstable or does not open. Parachute cord becomes caught in landing device.	The rocket has a potential to become ballistic, resulting in damage to the rocket upon impact.	1E	A piston recovery system will be utilized to ensure that parachutes are deployed with enough force to ensure separation. Nomex protection cloths will be used between parachutes to avoid entaglement. Ground testing will be performed to ensure that the packing method will prevent tangling during deployment prior to test flights.	1E	Ground and full scale launch tests verified that the nomex protection cloths prevented parachutes from becoming entagled with one another or with launch vehicle components. Use Launch Vehicle Assembly and Parachute Folding checklists when assembling launch vehicle.

Safety

- Risk adjustments and updates from full scale test launch

Stability	Mass increase during construction.	Unplanned addition of components or building materials.	Launch vehicle does not fly to correct altitude. All sections land with high kinetic energy. Possible minor damage to rocket body and/or fins.	2C	Record will be maintaned of mass changes. Launch vehicle simulations will be repeated for each mass change. Additional launch vehicle simulations will be performed at plus 5% of caclulated mass. Subscale and full scale launches will be performed with accurate mass.	3E	During full scale test launch, launch vehicle did not reach planned altitude. Weight reduction of lander is planned. New open rocket simulation indicates 5260 feet at apogee.
Stability	Internal bulkheads fail during flight.	Forces encountered are greater than the bulkheads can support.	Internal components supported by the bulkheads will no longer be secure. Parachutes attached to bulkheads will be ineffective.	2E	The bulkheads have been designed to withstand the force from takeoff with an acceptable factor of safety. Additional epoxy will be applied to ensure security and carbon fiber shreds will be added where appropriate. Electrical components will be mounted using fasteners that will not shear under the forces seen during the course of the flight. Full scale testing will be conducted and bulkheads inspected after each flight.	2E	During post-flight, it was noted that the two sections of lander bulkead became separated. This was analyzed and determined to be caused by the ground testing impact with the ground and to be due to the significant weight used for the simulated lander. Despite the damage, the lander remained intact during the full scale launch and recovery.

Safety

- Risk adjustments and updates from full scale test launch

Stability	Piston system becomes jammed.	Temperature variations cause contraction/expansion between piston and launch vehicle frame. Dirt or residue collects inside airframe.	Lander fails to land separately. Potential for nosecone section to fail to separate properly. Parachutes do not deploy properly.	2D	Fittings will be tested prior to launch to ensure that no components are sticking together. Inside of launch vehicle frame and surface of piston will be thoroughly cleaned after every test launch. In the event that the rocket does become ballistic, all individuals at the launch field will be notified immediately.	2E	During ground testing, it was found that during launch the piston and the landing module may have become slightly distorted or accumulated debris that caused excessive friction with the launch vehicle body. Post flight Inspection checklist updated to include fit check and cleaning/sanding of components as necessary. During full scale test flight, piston and landing module ejected successfully.

Safety

- Risk adjustments and updates from full scale test launch

Environmental	Rain.	N/A	Unable to launch. Damage electrical components and systems in the rocket.	3C	When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system. Have a plan to place electrical components in water tight bags. Have a location prepared to store the entire rocket to prevent water damage. Electronics on the ground station are all stored in water tight control boxes to seal out any moisture.	3E	During full scale test launch, the assembled rocket experienced approximately 40 minutes of heavy rain. All components were inspected for water damage prior to launch attempt. Launch was successful with no damage due to water incursion. In addition, all tools and ground station equipment was similarly intact and functional.

Project Plan - Current Budget

Budget Item	Projected Cost	Amount Spent	Remaining Budget
Rocket	$3,000	$1,207.40	$1,792.60
Payload	$2,000	$1,486.40	$513.63
Travel	$2,857.08	N/A	N/A

Current budget overview for project duration

Project Plan - Timeline

Main tasks completed between CDR and FRR presentations:

- Full-scale rocket fabrication, ground testing, and launch
- Educational Outreach Requirement (Engineering Expo)
- Revision to the Landing Module design

Questions?