CRITICAL DESIGN REVIEW

University of South Florida

Society of Aeronautics and Rocketry

2017-2018

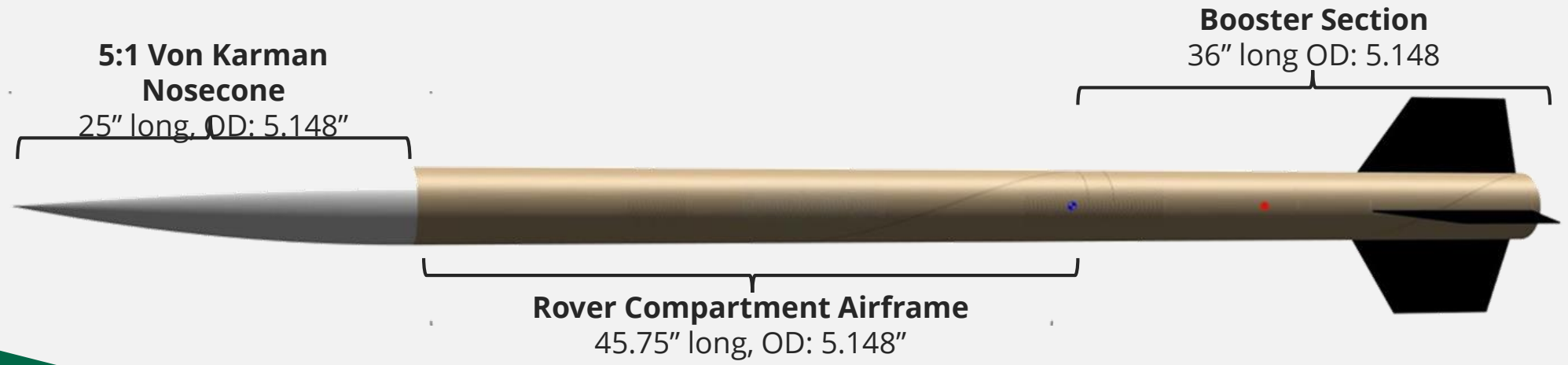
AGENDA

1. Launch Vehicle
2. Recovery
3. Testing
4. Subscale Vehicle
5. Payload
6. Educational Outreach
7. Safety
8. Project Plan

1. LAUNCH VEHICLE

LAUNCH VEHICLE AND PAYLOAD DIMENSIONS

Diameter	5.148 in
Length	111 in
Projected Unloaded Weight	27.2 lbs
Projected Loaded Weight (min ballast)	37.3 lbs
Estimated Max Payload Weight	10 lbs
Estimated Max Payload Length	15 in

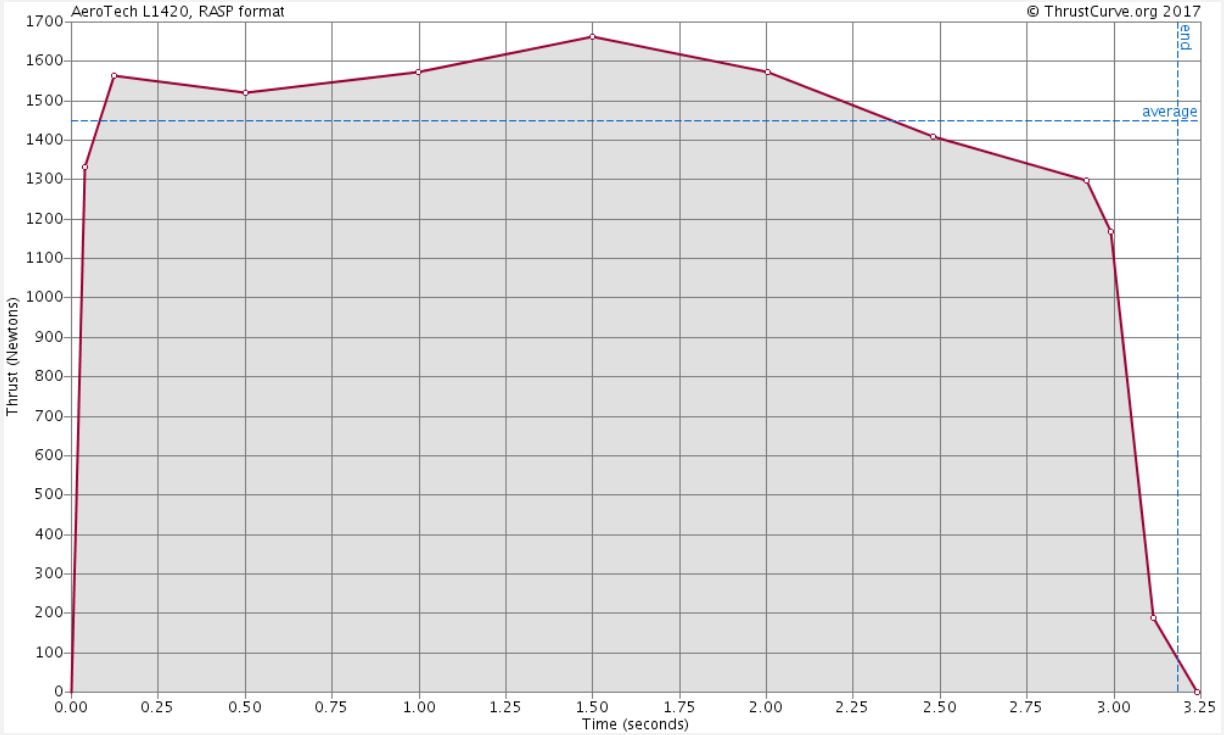


KEY DESIGN FEATURES

- Aerotech L1420 75mm Motor
- Four Sections
  - Nosecone
  - Rover Compartment
  - Main Altimeter Bay
  - Booster Section
- Recovery
  - One parachute for rover compartment and nosecone
  - One parachute and one drogue for Main Altimeter and Booster Section
- Adjustable Ballast System
  - Removable Ballast for Nosecone shoulder to manipulate flight path and apogee to launch day conditions
- Payload
  - Deployable Rover

FINAL MOTOR SELECTION

Aerotech L1420	
Average Thrust	1420 N
Maximum thrust	1814 N
Total Impulse	4603 Ns
Burn Time	3.2 s
Case Info	CTI Pro75-4G



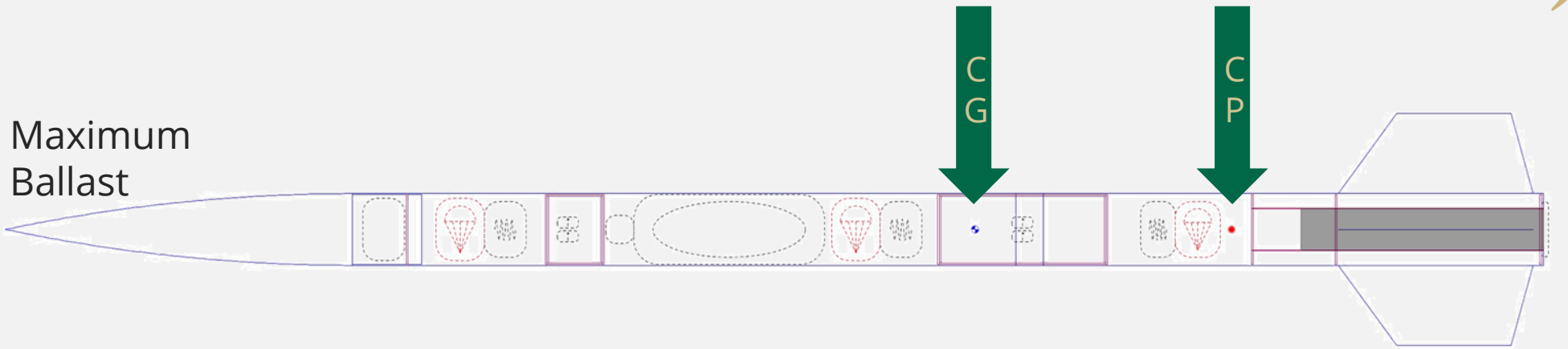
ROCKET FLIGHT STABILITY

- Due to adjustable ballast system the stability has been calculated at minimum and maximum possible weight

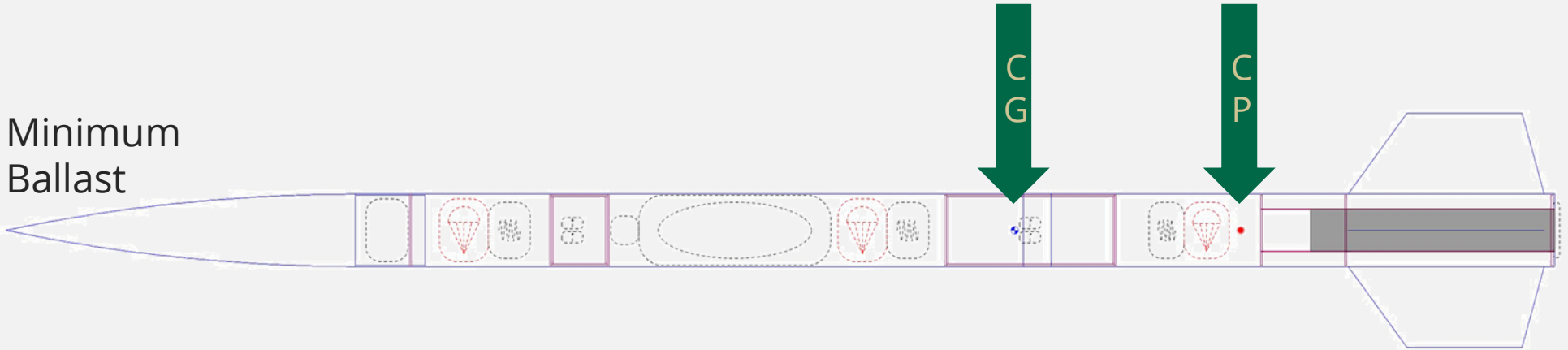
Configuration with Aerotech L1420		
Ballast	Max (2.71 lbs)	Min (.375 lbs)
Center of Pressure	89.308 in	88.308 inches
Center of Gravity	69.488 in	72.143 inches
Calibers	3.66 in	3.14

ROCKET FLIGHT STABILITY

Maximum Ballast



Minimum Ballast



FLIGHT CHARACTERISTICS

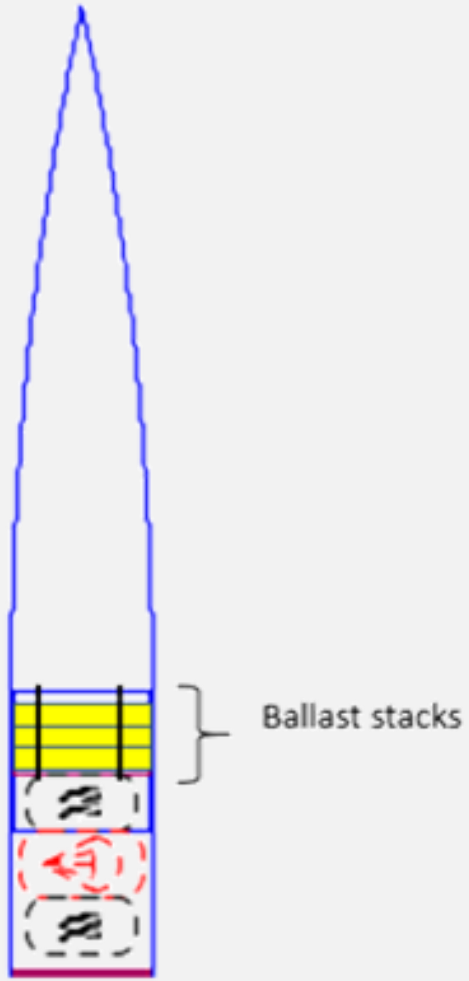
Ballast	Minimum
Projected Apogee	6695 ft
Thrust-to-Weight Ratio	9.12:1
Max Velocity	793 fps
Max Acceleration	298 fps^2
Exit Rail Velocity	67.75 fps
Exit Rail Stability	3.2 cal

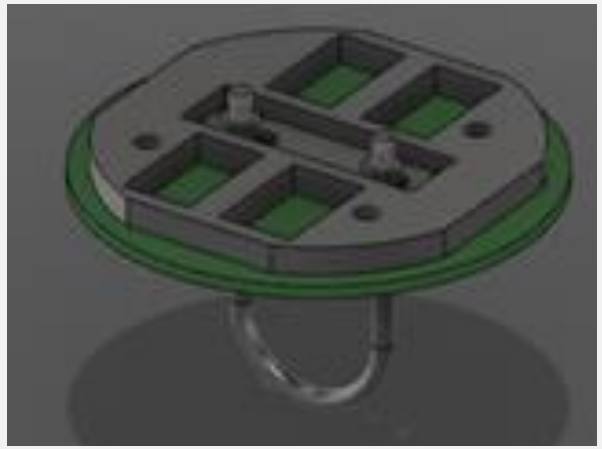
MASS STATEMENT & MASS MARGIN

System Name	Projected Weight (pounds)
Loaded Rocket (motor & max ballast)	37.202
Nosecone (bulkhead & minimum ballast configuration)	2.99
Rover Compartment (airframe, payload altimeter bay & rover)	13.964
Booster Section (airframe, motor mount & recovery equipment)	6.522
Main Altimeter Bay (G12 coupler, bulkheads, altimeters & recovery equipment)	1.824
Parachutes	1.802
Aerotech 75mm L1420 Motor (Total / Propellant)	10.1

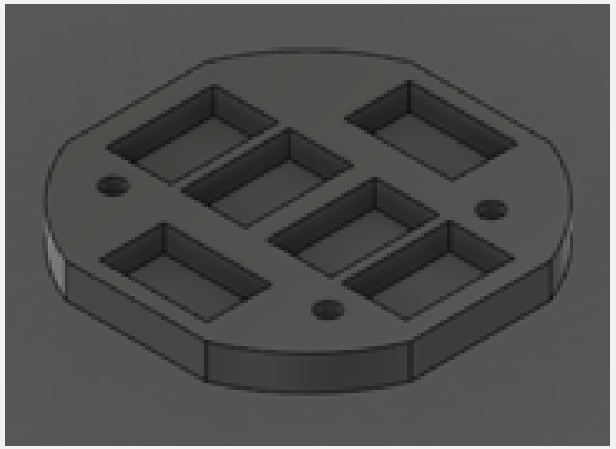
ADJUSTABLE BALLAST SYSTEM

- Loaded in either or both the Nosecone and/or the Main Altimeter Bay
- Layered modular elements
- Dimensions:
  - .4” height
  - Same diameter as launch vehicle
  - Weight range of 1-74 ounces

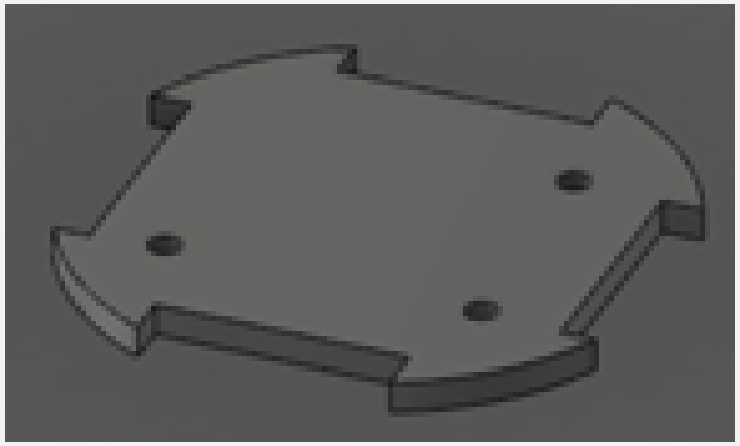




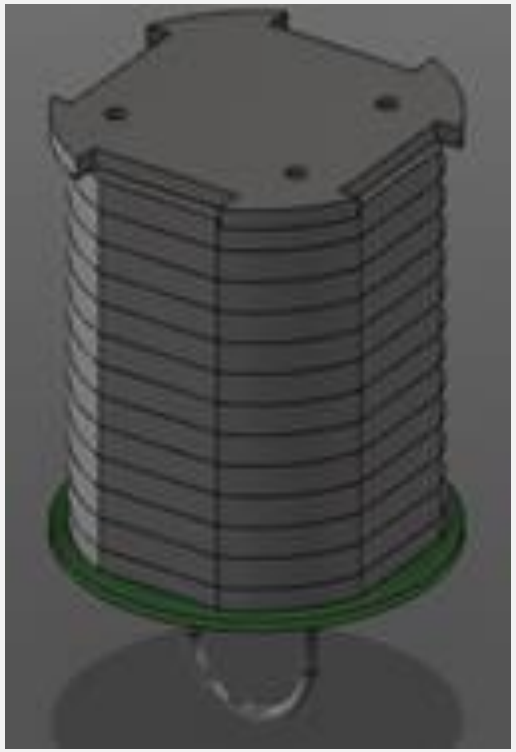
Section 1
4 ounces per layer



Section 2
6 ounces per layer



Section 3
Holds no weights



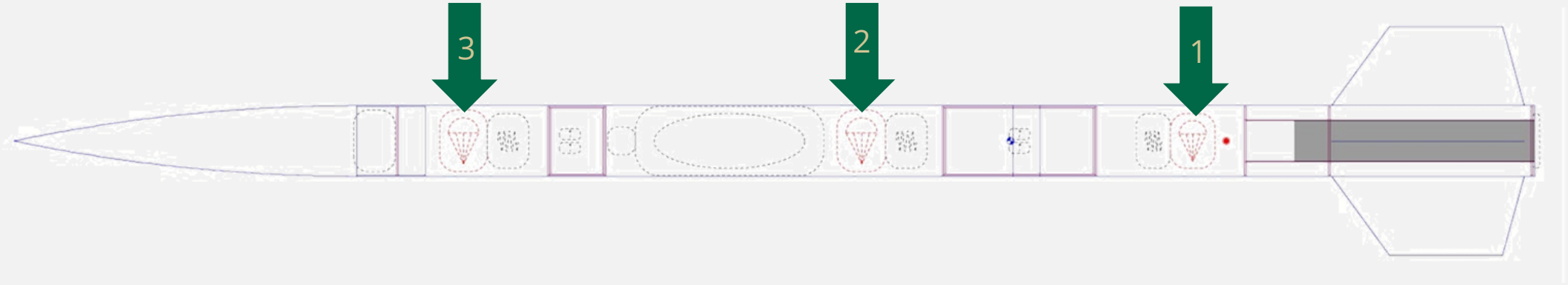
Final Assembly
14 stackable sections

Altitude Predictions with Various Ballast					
Wind Speed (mph)	**Total Ballast Weight (pounds)**	**Projected Apogee (feet)**	**Wind Speed (mph)**	**Total Ballast Weight (pounds)**	**Projected Apogee (feet)**
0	2.4375	5285.9	11	1.4375	5286.7
1	2.3750	5286.8	12	1.3125	5284.8
2	2.3125	5286.5	13	1.1875	5284.6
3	2.2500	5285.3	14	1.0625	5288.2
4	2.1875	5283.8	15	0.9375	5289.0
5	2.0625	5288.0	16	0.8750	5286.4
6	2.0000	5283.9	17	0.7500	5280.0
7	1.8750	5286.0	18	0.6250	5282.6
8	1.8125	5281.5	19	0.5000	5284.4
9	1.6250	5288.8	20	0.3125	5288.9
10	1.5625	5278.8			

2. RECOVERY

RECOVERY OVERVIEW

1. Drogue parachute: Attached to shock cord that is attached to a U-bolt
2. Booster Section parachute: Attached to shock cord that is attached to a U-bolt
3. Rover Compartment parachute: Directly attached to nosecone U-bolt and Payload Altimeter Bay U-bolt



Recovery			
Name	SkyAngle Classic II 60	Fruity Chutes Iris Ultra 36” HP Compact Chute	20 inch SkyAngle Classic II drogue
Deployed at	800 ft	950 ft	Apogee
Material	Zero-porosity 1.9 oz. silicone-coated balloon cloth	Lightweight 1.1oz Mil-spec calendared ripstop nylon	Zero-porosity 1.9 oz. silicone-coated balloon cloth
Surface Area (sq ft)	39.3	12.19	4.4
Drag Coefficient	1.89	2.2	.8
Number of Lines	3	8	3
Line Length (in)	60	36	20
Line Material	3/8” tubular nylon (950 lbs)	1/4" Kevlar and 400# Spectra Nanoline	3/8” tubular nylon (950 lbs)
Attachment Type	Heavy-duty 1,500 lb. size 12/0 nickel-plated swivel	No swivel, plan to purchase and equip a 500# ball bearing swivel	Heavy-duty 1,500 lb. size 12/0 nickel-plated swivel
Descent Rate (fps)	20.5	49.7	133

DRIFT ANALYSIS

- Booster Section and Altimeter
  - Total descent time of 83 seconds
- Nosecone and Rover Compartment
  - Total descent time of 84 seconds

Booster Section and Altimeter		
Wind Speed (mph)	**Wind Speed** (ft./s)	**Drift** (ft.)
0	0	0
5	7.33	608.39
10	14.66	1216.78
15	23.46	1947.18
20	29.33	2434.39

Nosecone and Rover Compartment		
Wind Speed (mph)	**Wind Speed** (ft./s)	**Drift** (ft.)
0	0	0
5	7.33	615.72
10	14.66	1231.44
15	23.46	1970.64
20	29.33	2463.72

KINETIC ENERGY

Kinetic Energy at Key Phases (ft – lbs)				
	Nosecone	Rover Compartment	Main Altimeter Bay	Booster Section
Drogue Deployment	827.59	4154.54	1918.12	603.39
Main #1 Deployment	727.65	3652.87	1686.5	530.53
Main #2 Deployment	114.82	576.41	266.12	83.72
Touchdown	19.44	57.16	45.05	14.17

3. TESTING

Test Plan		
Type of test	**Reason**	**Status**
Subscale Ground Test	To ensure enough black powder is used to successfully eject the components out of the airframe	Completed on 12/16/17
Subscale Launch	To ensure all systems perform as expected and verify that rocket can be recovered and reused	Completed on 12/16/17
Full Scale Ground Test	To ensure enough black powder is used to successfully eject the components out of the airframe	1/20/18
Full Scale Launch 1	To ensure all systems perform as expected and verify that rocket can be recovered and reused and that the rocket can reach apogee of 5,280 feet	1/20/18
Full Scale Launch 2	To test payload deployment system reliability and performance as well as vehicle reliability with equipped rover	2/17/18
Rover Drop Test	Simulate vehicle landing by placing rover in fiberglass tube and testing impact forces at various drop angles and heights	TBD
Mobility Test	Test mobility of rover on various terrain types and slopes	TBD

4. SUBSCALE VEHICLE

SUBSCALE VEHICLE SUMMARY

Components of the subscale model were resized to replicate a 4:5 diameter ratio:

- Launch Vehicle Diameter - 4” wide, 80% width of full scale
- Main Altimeter Bay - 8” long, 80% length of full scale
- Booster Section airframe - 30” long, 83% length of full scale
- Rover Compartment airframe - 39” long, 85% length of full scale
- Nose cone length - 20” long, 80% length of full scale
- Weight of Launch Vehicle - 22.8 lbs, 63% weight of full scale
- Thrust to Weight Ratio - 7.83:1, as close to the thrust to weight ratio of the full scale, which was, at the time of subscale launch, 8.6:1

Launched twice on December 16th 2017 at Varn Ranch

SUBSCALE RECOVERY

Drogue

- Skyangle 30”

Main

- Rover Compartment and Nosecone – SkyAngle Cert 3 Large
- Main Alt Bay and Booster Section – SkyAngle Cert 3 Medium

Altimeter

- Main alt bay – 2 Missile Works RRC3 (at apogee and 1000ft)
- Payload alt bay – 2 Atlus Metrum Easymini (at 1000ft)

SUBSCALE FLIGHT SIMULATION

- Minimal cloud cover
- 4mph winds
- 69.8 degrees Fahrenheit
- .04 psi

Subscale Launch Simulation	
Apogee	3456 ft
Time to Apogee	14.9 s
Max Velocity	505 fps
Max Acceleration	246 fps
Ground Hit Velocity	10.4 fps
Total Flight Time	161 s

SUBSCALE GROUND TEST

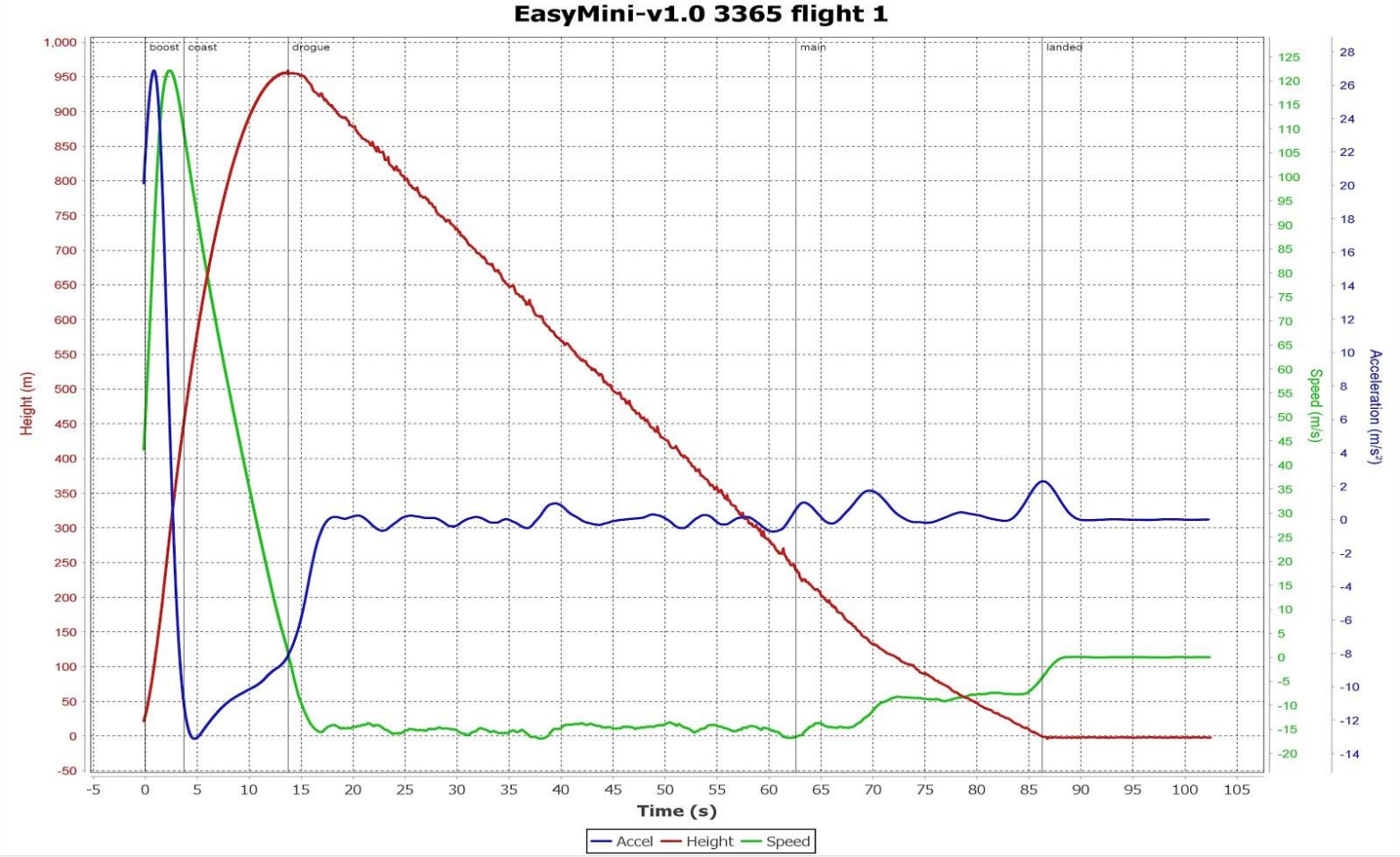
Ground Test for Nosecone Section

Ground Test for Booster Section

LAUNCH #1

Subscale Launch #1 Analysis	
Motor	Cesaroni 4G 54mm K740
Apogee	3146 ft
Time to Apogee	13.7 s
Max Velocity	401 fps
Descent Rate	33 fps
Total Flight Time	86.3 s

LAUNCH #1 ALTIMETER DATA



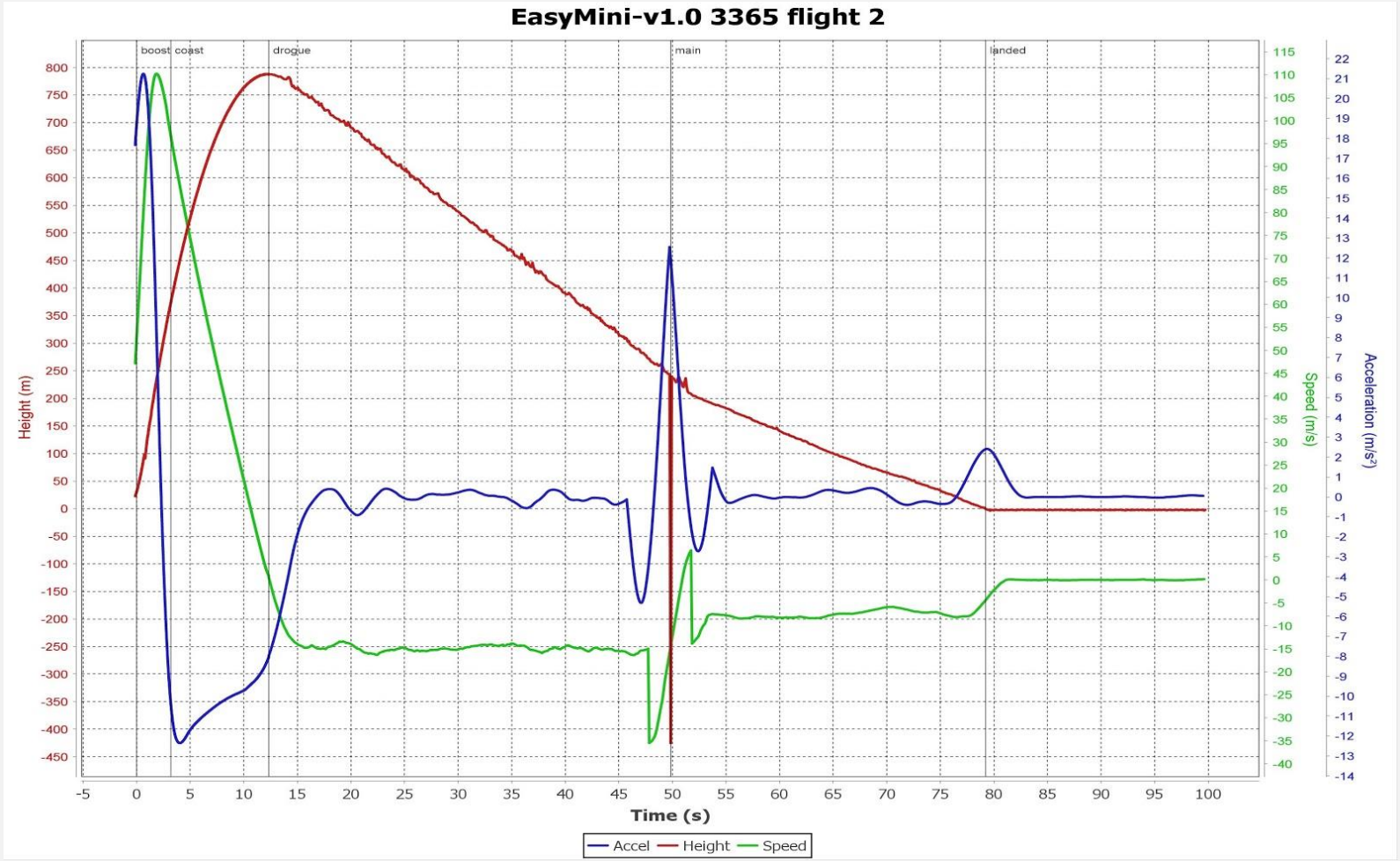
LAUNCH #1 RECOVERY

- Drogue and Rover Compartment Main parachute deployed successfully
- Main Altimeter Bay shear pins (4 x 4-40) did not break completely
- Main Altimeter Bay and Rover Compartment did not separate
- Main parachute for Booster Section and Main Altimeter Bay did not deploy

LAUNCH #2

Subscale Launch #2 Analysis	
Motor	Cesaroni 4G 54mm K940
Apogee	2587 ft
Time to Apogee	12.3 s
Max Velocity	362 fps
Descent Rate	24 fps
Total Flight Time	79.2 s

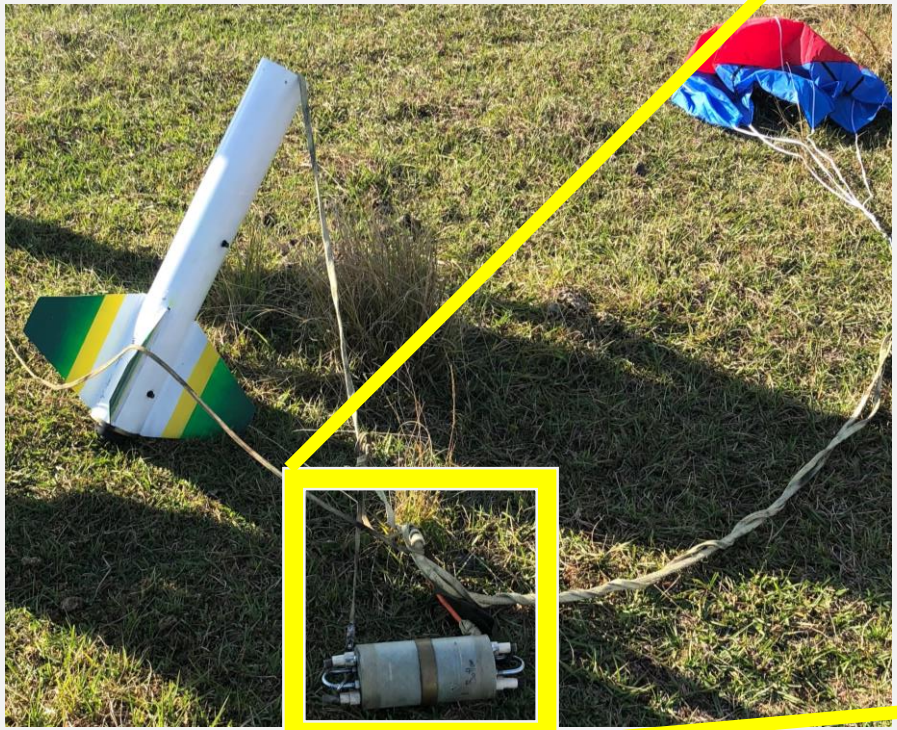
LAUNCH #2 ALTIMETER DATA



LAUNCH #2 RECOVERY

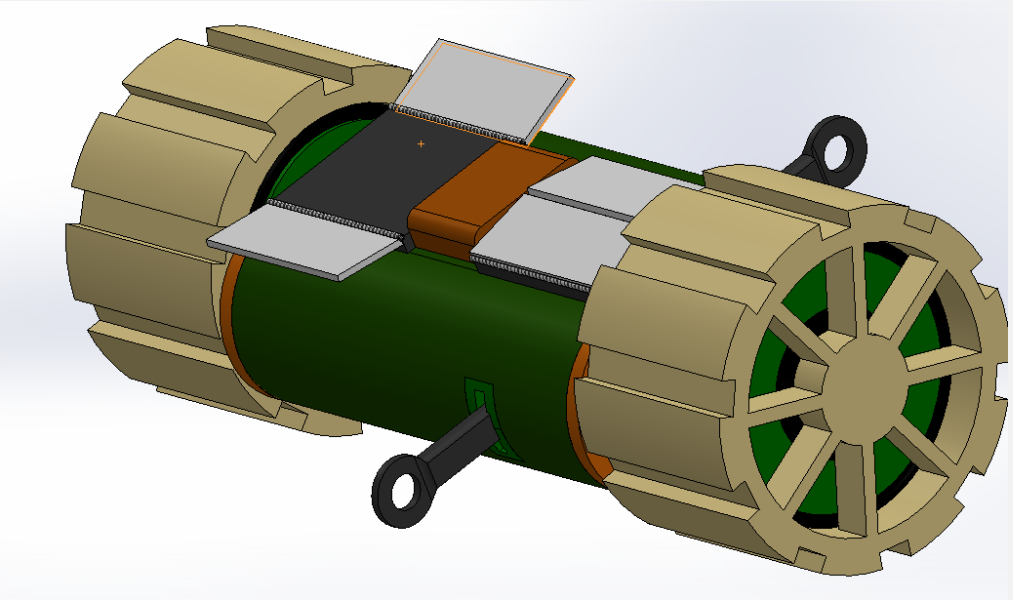
- Drogue and Rover Compartment Main deployed successfully
- Changed Main Altimeter Bay shear pins to 2 x 4-40
- Main Altimeter Bay and Rover Compartment separated
- Shock cord entanglement and overly compact parachute storage prohibited successful deployment for Main Altimeter Bay and Booster Section Main

LAUNCH #2 RECOVERY CONTINUED



5. PAYLOAD

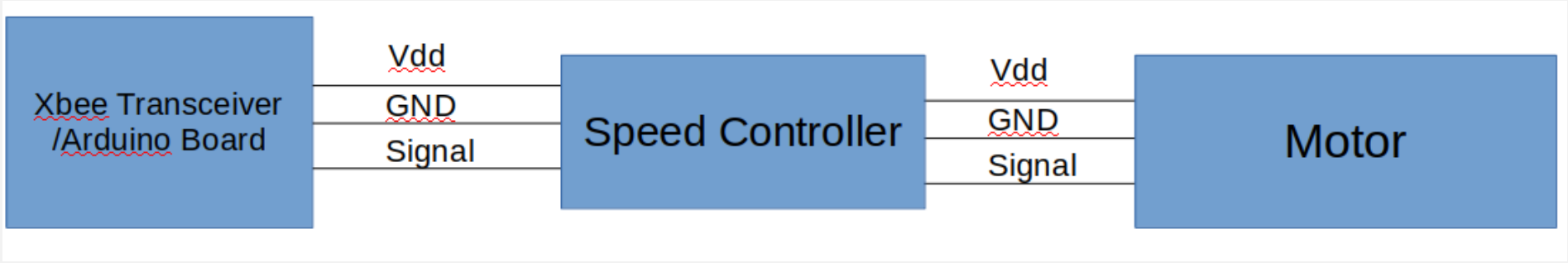
PAYLOAD SUMMARY



Max Weight	10 lbs
Height	4.8 in
Max Length	12 in
Motor	12V Brushed DC
Projected Motor Run Time	53 min
Stall Torque	42 kg-cm

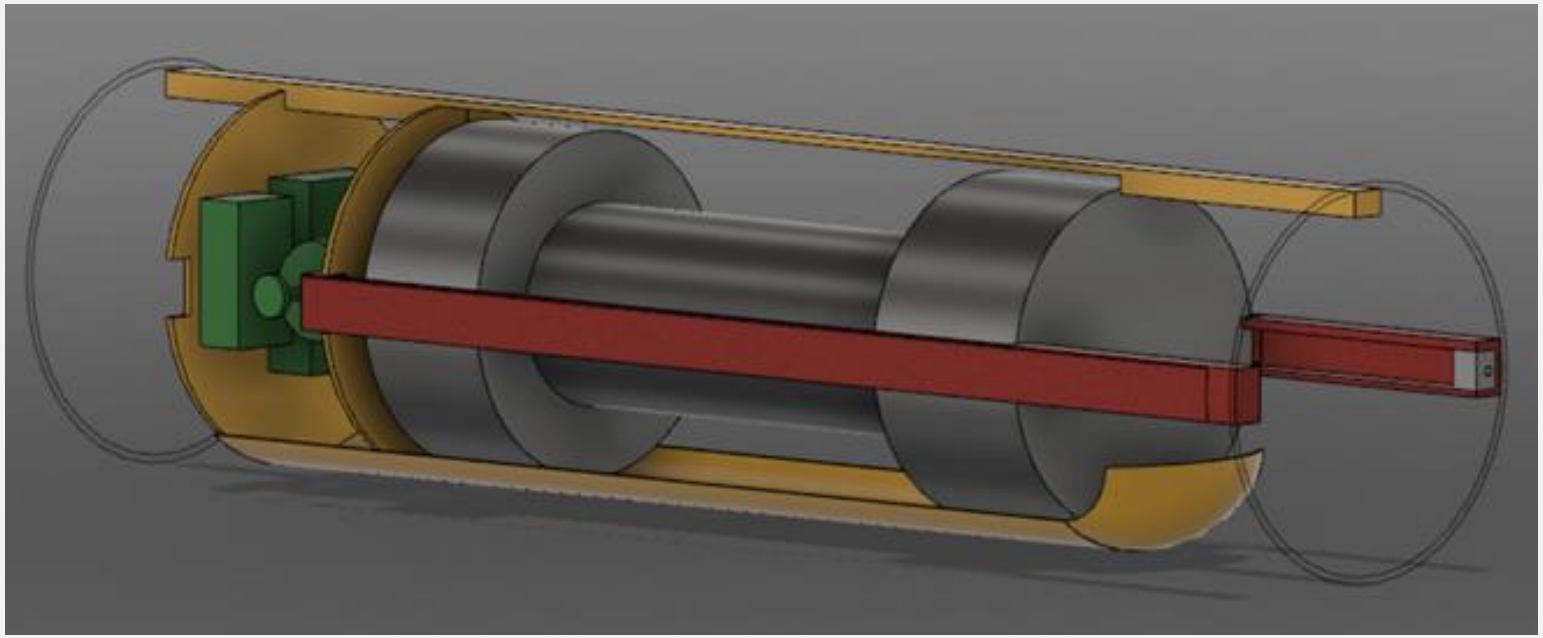
DEPLOYMENT SYSTEM ELECTRONICS

- Two XBee RF transceivers
- Base station
  - One XBee transceiver
  - Computer connected by USB
- Onboard deployment system
  - One XBee transceiver connected to a shield designed to be attached to an Arduino
- Manual switch used for backup activation method



PAYLOAD DEPLOYMENT SYSTEM

- Different design then PDR
- Sled and winch system



PAYLOAD INTERFACES

Loading the Payload

- Situated on a precisely designed sled intended to discourage vertical movement and spinning within the rocket
- Rover and deployment system are located aft the Payload Altimeter Bay

Payload Deployment

- Deployment system will start via a connection from a high gain antenna from a remote laptop to the microcontroller and Arduino inside the system
- Once activated the rover will move in a forward motion to exit open end of Rover Compartment Airframe

6. SAFETY

KEY SAFETY ISSUES

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Parachute deployment failure.	Altimeter failure. Electronics failure. Parachutes snag on shock cord.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Shroud lines and shock cord will be measured for appropriate lengths. Altimeter and electronics check will be conducted with checklist several hours prior to launch. Nomex shields will be secured low on shroud lines to prevent entanglement. Main parachutes will deploy at different altitudes.	2E	Subscale test launch resulted in shroud lines and/or shock cords becoming entangled. Full scale testing will be conducted under new configuration.
Sections fail to separate at apogee or at 1000 feet.	Black powder charges fail or are inadequate. Shear pins stick. Launcher mechanics obstruct separation.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Correct amount of black powder needed for each blast charge will be calculated. Black powder will be measured using scale. Altimeter and electronics check will be conducted with checklist several hours prior to launch. Inside of rocket body will be coated with graphite powder in areas of launcher mechanics. Couplings between components will be sanded to prevent components from sticking together. Fittings will be tested prior to launch to ensure that no components are sticking together. In the event that the rocket does become ballistic, all individuals at the launch field will be notified immediately.	2E	Subscale ground and launch tests verified that the amount of black powder is adequate. However, In subscale test launch, all black powder charges successfully ignited, but full separation of booster main parachute was not achieved. Full scale ground testing will include parachutes in order to better simulate actual launch conditions. Use Launch Vehicle Assembly checklist when assembling launch vehicle.

KEY SAFETY ISSUES

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
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	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. Parachutes will be deployed at different altitudes.	1E	During subscale launch tests parachute lines became entangled. Full scale testing will be conducted under new configuration and settings. Use Launch Vehicle Assembly and Parachute Folding checklists when assembling launch vehicle.
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. Subscale testing resulted in no damage to rocket components.

KEY SAFETY ISSUES

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Parachute does not inflate.	Parachute lines become entangled.	Parachute does not generate enough drag.	2E	Parachute lines will be carefully folded in accordance with checklist. Nomex covers will be secured at lower end of shroud lines.	2E	Subscale test launch showed that the parachute that did deploy successfully opened, verifying that the folding and packing technique with reference to this are appropriate. Use Launch Vehicle Assembly and Parachute Folding checklists when assembling launch vehicle.

KEY SAFETY ISSUES

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
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 subscale test launch, launch vehicle did not reach planned altitude. The team has selected a larger motor for full scale launch. New open rocket simulation indicates more than sufficient height at apogee, which will be altered by the adjustable ballast system.

7. PROJECT PLAN

BUDGET AND FUNDING

Funding	
USF Student Government	$7,500
Total	**$7,500**

Budget	
Rocket Materials	$1,000
Launch Motors	$400
Test Launch Motors	$800
Subscale Materials	$600
Subscale Motor	$350
Payload	$800
Miscellaneous Hardware	$400
Travel	$1,500
Total	**$5,850**

REQUIREMENTS VERIFICATION STATUS

NASA General Requirements	
Complete	14
Awaiting Completion	0

NASA Recovery Requirements	
Complete	12
Awaiting Completion	1

NASA Safety Requirements	
Complete	4
Awaiting Completion	1

NASA Vehicle Requirements	
Complete	18
Awaiting Completion	8

NASA Experiment Requirements	
Complete	2
Awaiting Completion	4

Team Requirements	
Complete	0
Awaiting Completion	9

TIMELINE – PDR TO CDR

- Main tasks completed between PDR and CDR
  - Subscale construction
  - Subscale testing
  - Subscale launch
  - Finalize full scale design
  - Finalize payload deployment system design
  - Prototype rover construction

TIMELINE – CDR TO FRR

- Tasks to complete before the Final Review Report:
  - Full scale construction
  - Full scale testing
  - Full scale launch
  - Rover prototype construction
  - Deployment system fabrication
  - Rover programming
  - Final rover fabrication
  - Rover testing

8. EDUCATIONAL OUTREACH

OUTREACH OVERVIEW

- 10/13 planned events completed
- 3 upcoming events - 1 TBD, 1 in January, 1 in February
- Reached 911 participants

Student Count Table		
	NASA Requirement	Team Requirement
Required Amount	200	1000
Amount needed to reach requirement	0	89
Verification Status	COMPLETE	

QUESTIONS?