NASA University Student Launch

University of Alabama in Huntsville 2013-2014

Flight Readiness Review Addendum

April 28, 2014

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Contents

Figures

1 Prometheus As Built

The actual build of the rocket will be detailed with screenshots and descriptions of the different parts of the rocket as it was flown for the full-scale flight.

1.1 Overview

The entire rocket constructed and ready to fly can be seen in Figure 1-1. Its overall length from nose tip to the bottom of the main body tube is 120 inches long. It is 4.59 inches in diameter with a 4.5 in inside diameter.

Figure 1-1: Prometheus

1.2 Nosecone Assembly

The nosecone assembly can be seen in its closed flight ready form in Figure 1-2 and with its components spread out in Figure 1-3.

Figure 1-2: Nosecone

Figure 1-3: Nosecone Assembly

Weight-equivalent ballast was flown inside the nosecone for the payload that will fly there to record acceleration, rotation, and the pressure from the pitot probe. The nosecone coupler is held in tension by the threaded rod that runs from the bulk plate inside the coupler to the pitot probe in the very tip of the nosecone. The payload is secured to this threaded rod inside the nosecone above the coupler. The coupler is 3D sintered glass reinforced nylon with carbon fiber reinforcement along the inside of the transition section.

1.3 Recovery Bay

The recovery bay is a 4.5 in inner diameter tube that makes up the longest section of the rocket. The recovery system as discussed in CRW's main FRR document fits into this section along with the LHDS. See FRR for details concerning the recovery system seem in Figure 1-4.

Figure 1-4: Recovery Bay

The bulk plate that sits on top of the middle coupler holds the charge wells and the recovery system is attached at this point as seen in Figure 1-5.

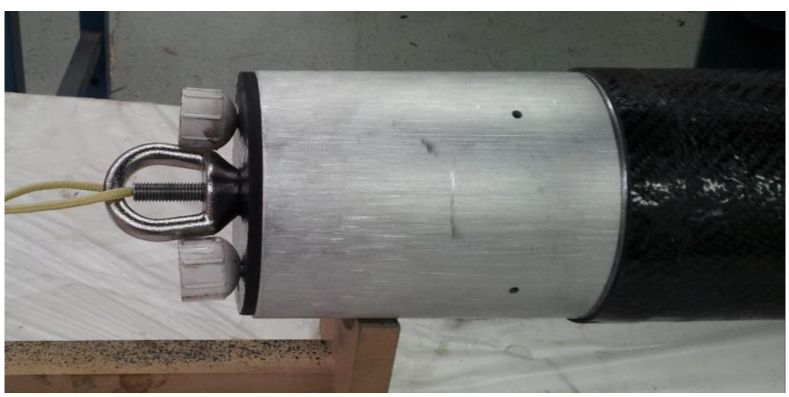

Figure 1-5: Mid Coupler

This rod is the same rod that retains the motor case. It runs from the bulk plate down through the payload bay to the fin can. The slip joint at this Mid Coupler never separates during flight and is mechanically fastened. Its purpose is to allow for the charge wells to be easily accessed. It is aluminum tube .125 in thick with body tube epoxied to the outside to prevent the coupler from moving.

1.4 Payload Bay

The payload bay is below the recovery bay and houses the payload panels as well as the altimeters for the recovery system. The main payload rod runs from above the payload bay down through the payloads into the fin can as seen in Figure 1-6. The payloads are secured to the rod.

Figure 1-6: Payload Bay

1.5 Fin Can

The fin can houses the motor case and allows the fins to be attached to the lower end of the rocket. The fin can and the payload bay are joined by a couple that allows easier access to both the payloads and the top of the motor case. This coupler is also aluminum tube with a piece of body tube adhered on to fix the coupler in place. The coupler is short because the entire coupler is held in tension using the payload rod. Both the primary and backup motor cases can also be seen in Figure 1-7. The Backup motor case and backup payload rod can be seen in the figure attached to the system.

Figure 1-7: Fin Can and Motor Cases

1.6 Lower Assembly (Payload + Fin Can)

The lower assembly contains both the payload bay as well as the fin can. Both sections were shown separately above. An overview showing the connections between the two can be seen in Figure 1-8. The motor cases seen are both the case for the M4770 and the backup K1499 motor case. The threaded rod used was for the backup motor and can be seen connected to the rod. The M4770 case is shown to demonstrate that a shortened payload shaft is used with the larger motor.

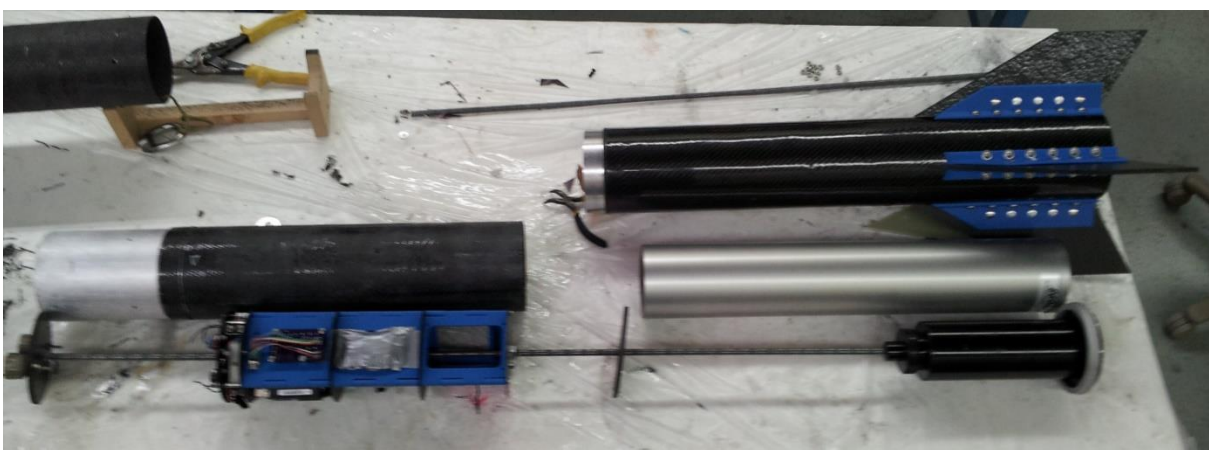

Figure 1-8: Entire Lower Assembly

1.7 Questions from FRR

There were questions during the FRR regarding the use of peanut oil and the possible allergic reactions that could occur to personnel on the ground, were it to be aerosolized. The CRW team intends to use refined peanut oil for the dielectrophoresis experiment, which has been found not to cause a reaction in allergic individuals by the FDA as it contains only minute quantities of the protein that causes the allergic reaction. ("Approaches to Establish Thresholds for Major Food Allergens and for Gluten in Food." *Approaches to Establish Thresholds for Major Allergens and for Gluten in*. U.S Food and Drug Administration, Mar. 2006. Web. 28 Apr. 2014.)

2 Full-scale Flight

The CRW Team has successfully met all of the requirements listed in section 1.11 of the Statement of Work, requiring a full-scale launch.

2.1 Motor Choice

The backup motor, an Aerotech K1499, was flown to test the rocket in its as built configuration in satisfaction of the requirement for a full-scale launch per 1.11 of the Statement of Work.

2.2 Static Stability

Using a measured CG of the flight configuration at 80 inches measured from the nose and a predicted CP position of 93.6 inches from the nose, Prometheus has a static margin of 2.96 calibers on the launch pad. During flight the static margin will increase to 4.41 calibers. Using analytical approximations for center of mass, it is approximated that with the planned primary motor, CTI M4770, the static margin will be 1.2 calibers at launch. Figure 2-1 contains the thought process and math.

Represents Launch April 26, 2014

$M_o := 23.8lb \quad CG := 80in \quad CP := 93.6in$

Estimate Mass center location of K1499 motor

$M_{k1499} := 1.741kg = 3.838 \cdot lb \qquad CG_{k1499} := 120in - \frac{26cm}{2} = 114.882 \cdot in$

Estimated Mass Center Location of M4770 Motor

$M_{M4770} := 6.503kg = 14.337 \cdot lb \qquad CG_{M4770} := 120in - \frac{54.8cm}{2} = 109.213 \cdot in$

COM With M4770

$$CG_1 := \frac{M_o \cdot CG - M_{k1499} \cdot CG_{k1499} + M_{M4770} \cdot CG_{M4770}}{M_o - M_{k1499} + M_{M4770}} = 88.307 \cdot in$$

Diameter

$D := 4.595in$

Calibers

$$SM_o := \frac{CP - CG}{D} = 2.96$$ Static Margin with K1499

$$SM_1 := \frac{CP - CG_1}{D} = 1.152$$ Static Margin with M4770

Static Margin After Burnout with Full Scale Motor

Launch Mass

$M_1 := M_o - M_{k1499} + M_{M4770} = 34.298 lb$

Burnout

$$CG_{burnout} := \frac{CG_1 \cdot M_1 - M_{M4770} \cdot CG_{M4770}}{\left(M_o - M_{k1499} + M_{M4770}\right) - M_{M4770}} = 73.293 \cdot in$$

Calibers

$$SM_{BO} := \frac{CP - CG_{burnout}}{D} = 4.419$$

Figure 2-1: Static Margin and CG

2.3 Flight Analysis

On April 26th, a completed assembly of *Prometheus* with mass simulators was launched at Bragg Farms in Toney, AL. *Prometheus* reached a max altitude of 1680 feet and successfully deployed the recovery systems with timed events. Just after apogee, the drogue was released with the recovery stack and the assembly drifted to 1000 feet where the event trigger released the tender descenders and the main chute deployed successfully.

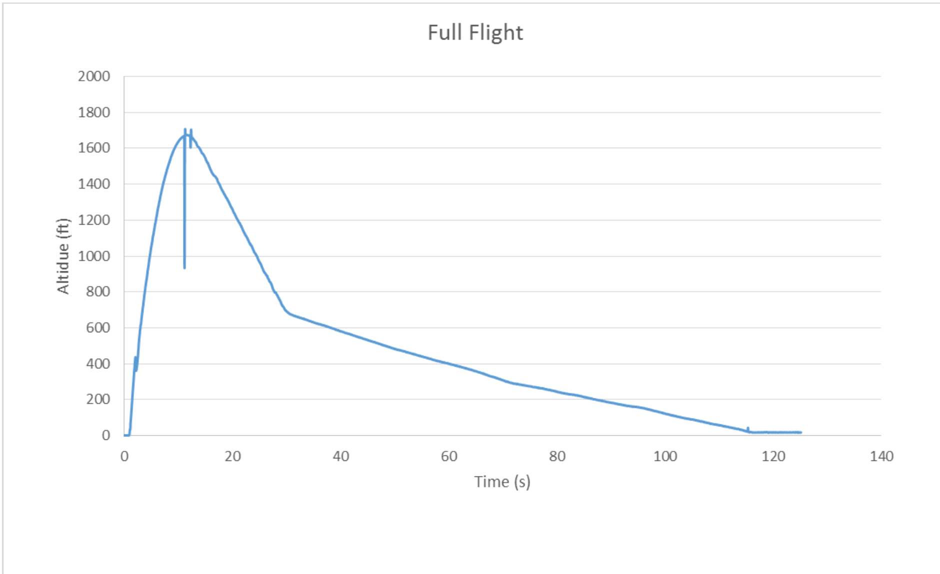

Figure 2-2: Flight Trajectory

Using Perfect Flight Stratologgers, the altitude is record via atmospheric pressure. In Figure 2-2, apogee occurred at 11.5 seconds and the drogue allows the vehicle to descend until 600 feet where the main fully inflates and arrests the rate to just under 7 ft/s. Figure 2-3 is the fully deployed configuration of the recovery system on descent.

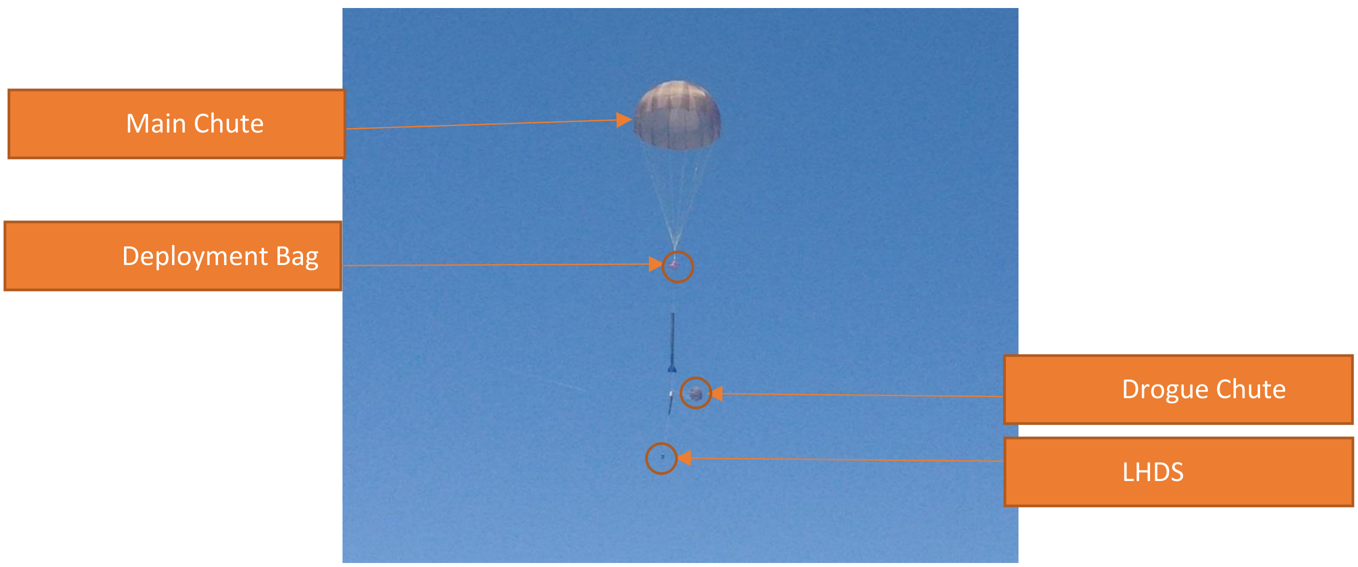

Figure 2-3: Main Chute Deployed

3 Launch Procedures

In order to ensure a safe and ultimately successful flight for Prometheus, a detailed launch procedure was developed to encompass all aspects of vehicle preparation and flight readiness.

NASA University Student Launch Initiative

University of Alabama in Huntsville 2013-2014

Launch Operation Procedures

April 26, 2014

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

Propulsion Research Center, Huntsville, AL 35805, 256.701.4665

SECTION I. DECLARATIONS

1. **Objective**

This SOP establishes the proper procedures for the assembly of Prometheus, being flown by the Charger Rocket Works team.

2. **Test Location**

This procedure is to be used for launches conducted at NAR/TRA approved fields in accordance with all state and federal laws regarding high-powered rocketry.

3. **Roles and Responsibilities**

This procedure requires a minimum of 4 Launch Team members. No more than one (1) Safety Monitor, one (1) Test Operator, one (1) person for the payload, and one (1) NAR/TRA certified flier. All other observers must be wearing proper PPEs in order to be present during the vehicle assembly. The roles of the Launch Team members are identified below:

Safety Monitor: Reads procedure, insures proper number of Launch Team members for test, and ensures that all observers are wearing proper PPEs.

Test Operator: Handles loading of black powder into ejection charges and Tender Descenders and ensures that recovery system circuitry is properly constructed.

Payloads: Responsible for ensuring proper function and installation of the avionics packages into the launch vehicle.

NAR/TRA Flier: Responsible for loading motor into motor case and ensuring that motor has been properly secured into launch vehicle. They should also perform a final inspection of the vehicle before approaching the RSO to launch.

4. **Observer Policy**

Observers will be allowed under this procedure provided that sufficient PPEs are available that all observers can be provided with them. All observers must be briefed on the hazards present during the vehicle assembly and the associated emergency procedures, prior to the conduction of the launch operations.

Before operations commence, an observer must be briefed on the potential hazards, including:

- **Explosions**
- **Temperature Burns**
- **Debris**

Additionally, an observer must be provided personal safety equipment and advised of its use as defined in Table 1.

5. Safety Policy

The Test Operator must have First Aid, CPR, and AED training. Additionally, the Test Operator must be an approved Red Team member on the **USLI-SOP-TC-003 R3 Black Powder Ejection System Test SOP.** The NAR/TRA flier must have all appropriate certifications to fly the designated motor class for the launch. Any member of the Launch Team may ask an observer to exit the area if they feel as though that observer is conducting their self in an unsafe manner.

6. Safety Requirements

- Only Launch Team members are allowed to assist in assembling the launch vehicle.
- At least four Launch Team members must be present during the vehicle assembly.
- Protective eyewear must be worn at all times during the vehicle assembly.
- Canisters of black powder must be stored in approved and clearly-labeled containers. Bulk black powder must be contained and away from test operations during testing.
- Only proper installation tools should be used to load the Black Powder Ejection System. All tools should be verified to be in good working order before the test begins.

7. Personal Protective Equipment (PPE)

Launch Team members must wear safety glasses at all times during vehicle assembly. Long pants and closed toed shoes are required.

Table 1 – Personal Safety Equipment

Equipment	Period
Approved eye protection	**All Times**
Closed-toed footwear	**All Times**
Approved hearing protection (Optional)	**Firing Procedures**

8. Weather/ Emergency

Launch Operations will not be conducted during unfavorable weather conditions. Launch Operations may be stopped if high or variable winds are present at the launch site. In the event of a non-weather emergency, launch operations must be halted until the emergency has been properly handled.

9. Procedure Deviations

At any point during the execution of the launch procedures, any team member may call for a stand down of launch operations to discuss any concern related to safety. Additionally, during the execution of the launch procedures any deviation to the procedures outlined in this document must be noted on the procedure and it must be identified on the cover page that deviations were conducted. Revisions to the procedure may be required prior to the next launch. Prior to each test, verify that the procedures do not require modification due to specific launch requirements. In the event that redlines are required during execution, ensure that redlines present no safety, efficiency, or environmental concerns.

10. Materials/ Parts Checklist

Miscellaneous Materials/ Tools		
Check	Quantity	Item
	N/A	Safety Glasses
	N/A	Black Powder
	5	E-matches
	N/A	Long Wire
	N/A	Wire Cutters
	N/A	Table
	1	Volumetric Measuring Device
	N/A	Electrical Tape
	4	Wire Nuts
	N/A	Insulation (Dog Barf)
	N/A	Zip-Ties
	1	Measuring Tape
	N/A	Drill/ Drill Bits

Nosecone/ Recovery Bay		
Check	Quantity	Item
	1	Nosecone Shell
	1	Nosecone Payload
	1	¼"-20 Nosecone Shaft
	1	Nosecone Bulk Plate
	1	Parachutes (Drogue/Main(s))
	2	Tender Descenders

	1	Landing Hazard Detection System (LHDS)
	1	LHDS Battery (New)
	~30 ft.	Shock Chord
	2	D Rings
	1	Pitot Probe
	1	Recovery Bay Body Tube
	4	Rivets
	2	Shear Pins (#1)
	1	¼" Fender Washers
	1	¼"-20 Jam Nuts
	1	¼"-20 Eye Nut
	2	Charge Wells (1/2" PVC Caps)
	3	Pressure Tubes

Payload Bay-Section		
Check	Quantity	Item
	1	CG Payload
	2	9 Volt Batteries
	1	Li-Po Battery (Fully Charged)
	1	Remove Before Flight Pin
	1	3/8"-16 Payload Shaft
	3	3/8"-16 Jam Nuts
	1	3/8"-16 Eye Nut
	3	3/8" Fender Washers
	1	Mid-Section Coupler

Fin Can-Section		
Check	Quantity	Item

	1	Motor Assembly
	1	Fin Can Coupler
	1	Thrust Ring
	1	Thrust Ring Adapter (if needed)
	1	Fin Can Bulk plate

SECTION II. LAUNCH PROCEDURES

For clarification on the parts needed for any step, refer to Appendix A.

PRE-LAUNCH PREPARATION

☐ 1 Ensure all members of the Launch Team are present.

☐ 2 Ensure that every person involved is aware of all steps in the procedure.

☐ 3 At any point during the launch operations, any Launch Team member can call for the launch operations to be stopped for any reason.

☐ 4 Make sure that all personnel, including observers, are wearing the proper PPE.

☐ 5 Ensure that all required materials and parts are present.

PAYLOAD PRE-FLIGHT PREPARATION

☐ 6 Place batteries in designated slots on CG and Nosecone payloads.

☐ 7 Ensure that there are no loose connections or broken solder joints present on any components.

☐ 8 Attach batteries to payload circuits and set aside. (DO NOT ACTIVATE YET.)

RECOVERY SYSTEM PREPARATION

☐ 9 Attach battery and switch leads to altimeters at their respective posts. (DO NOT ATTACH BATTERIES.)

☐ 10 Attach one set of Tender Descender wire leads to the "Main" posts on each of the altimeters (See Figure 1).

☐ 11 Pull on wire leads to ensure they are properly secured to the altimeters.

☐ 12 Perform continuity check of wire leads by placing one multi-meter lead at the end of the wire, and the other multi-meter lead on the altimeter post the wire is attached to.

☐ 13 Thread wire leads through port in recovery bay bulk plate and through mid-section coupler.

Test Operator Only!

- ☐ 14 Insert E-matches for charge wells through recovery bay bulk plate and mid-section coupler and secure to "Drogue" terminals on the two altimeters.
- ☐ 15 Daisy chain main parachute shroud lines and place in deployment burrito.
- ☐ 16 Place a zip-tie tightly around deployment burrito.
- ☐ 17 Insert E-matches into Tender Descenders and secure with electrical tape.
- ☐ 18 Shunt ends of E-match wires.
- ☐ 19 Remove black powder from day box.
- ☐ 20 Measure specified amount of black powder (0.25 grams per unit) to be used in a volumetric measuring device.
- ☐ 21 Record the volume of the black powder: ________________.
- ☐ 22 Insert specified amount of black powder into Tender Descenders.
- ☐ 23 Using D-links, attach Tender Descenders to elastic loops on deployment burrito.
- ☐ 24 Ensure that Tender Descenders are properly tethered to recovery system hardware to prevent their loss after deployment.
- ☐ 25 Cut zip-tie off of deployment burrito.

NOSECONE ASSEMBLY

- ☐ 26 Attach pitot probe to end of threaded rod.
- ☐ 27 Attach pressure tubes to pitot probe.
- ☐ 28 Slide threaded rod through nosecone shell.
- ☐ 29 Attach pressure tubes to nosecone payload.
- ☐ 30 Activate nosecone payload and insert into nosecone shell.
- ☐ 31 Insert nosecone transition piece into nosecone base.
- ☐ 32 Slide nosecone bulk plate on to threaded rod.
- ☐ 33 Place fender washer on to threaded rod and tighten jam nut on to rod to retain pitot probe and payload.
- ☐ 34 Screw eye nut on to threaded rod until tight.

FIN CAN ASSEMBLY

- ☐ 35 Activate CG payload and attach batteries to altimeters.
- ☐ 36 Slide payload bay body tube section over CG payload.
- ☐ 37 Insert fin can coupler into fin can body tube section.

☐ 38 Slide payload shaft through fin can coupler and into fin can body tube section.

☐ 39 Slide recovery bay bulk plate over forward end of payload shaft.

☐ 40 Insert mid-section coupler into payload bay body tube.

☐ 41 Slide 3/8" fender washer over forward end of payload shaft and tighten until recovery system bulk plate is snug against mid-section coupler.

☐ 42 Insert motor assembly into fin can body tube section and screw on to payload shaft. Ensure that payload shaft reaches the bottom of the threads on the motor case.

☐ 43 Tighten 3/8" nut at forward end of payload shaft to proper torque specification.

☐ 44 Insert remove before flight pin into proper port to deactivate altimeters.

FINAL RECOVERY SYSTEM ASSEMBLY

Test Operator Only!

☐ 45 Insert charge well E-matches into charge wells.

☐ 46 Remove black powder from day box.

☐ 47 Measure amount of black powder determined from ground tests in a volumetric measuring device.

☐ 48 Record the volume of the black powder: _______________.

☐ 49 Insert specified amount of black powder into charge wells.

☐ 50 Pack charge wells with wadding material.

☐ 51 Place electrical tape over charge wells to ensure proper compression.

☐ 52 Return black powder to day box.

☐ 53 Slide recovery bay body tube over mid-section coupler and align with rivet holes.

☐ 54 Insert removable rivets to secure recovery bay.

☐ 55 Attach wire leads to Tender Descender E-matches and secure with wire nuts and/or electrical tape.

☐ 56 Place dog barf in recovery bay and insert deployment burrito.

☐ 57 Insert LHDS, ensuring that shock cord passes through notches in LHDS endplates.

☐ 58 Insert drogue into recovery bay.

☐ 59 Insert nosecone and secure with shear pins.

FINAL PRE-FLIGHT VERIFICATIONS

☐ 60 Perform "balance test" to measure CG.

☐ 61 Measure distance between CG and CP given by simulations.

☐ 62 Weigh vehicle to obtain final mass for simulations.

☐ 63 NAR/TRA Flier should perform final check of vehicle to ensure that all joints have a proper fit and no vehicle pieces are loose or otherwise damaged.

☐ 64 Test Conductor, Safety Monitor, Payloads, and NAR/TRA sign below to confirm that flight a go.

______________________	______________________
TEST CONDUCTOR	**SAFETY MONITOR**
______________________	______________________
PAYLOADS	**NAR/TRA FLIER**

☐ 65 Take vehicle to RSO and wait for permission to approach launch rail.

LAUNCH RAIL PREP

☐ 66 Tilt launch rail until it is parallel with the ground and slide launch lugs into rail.

☐ 67 Slide rocket to base of the launch rail before raising it from its horizontal position.

☐ 68 If launch rail is not equipped with stops, place a small block of wood or small stone at launch rail base to prevent vehicle from resting on fins.

☐ 69 Remove flight pins to activate altimeters and payloads.

☐ 70 Ensure that both altimeters reach "ready" state. (Three beeps in quick succession.)

☐ 71 Shunt ends of E-match or igniter leads.

NAR/TRA FLIER

☐ 72 Insert E-match or igniter into motor.

☐ 73 Place plug into motor to secure E-match or igniter into place.

☐ 74 Attach E-match or igniter to ignition circuit.

☐ 75 Confirm that rocket is ready for launch and return to staging area.

IGNITION FAILURE (IF SUCCESSFUL, PROCEED TO STEP # 84)

- ☐ 76 If motor does not successfully light, wait 60 seconds and follow directions of RSO regarding the installation of additional igniters or removal of the rocket from the launch rail.
- ☐ 77 If vehicle must be removed from launch rail, insert flight pins to deactivate altimeters and payload.
- ☐ 78 Disconnect E-match or igniter from ignition circuit.
- ☐ 79 At vehicle staging area, remove rivets at the base of the recovery bay, and separate two halves of vehicle.
- ☐ 80 Pour contents of charge wells into cup and dispose of properly.
- ☐ 81 Remove deployment burrito and disconnect Tender Descender E-matches from wire leads.
- ☐ 82 Remove black powder from Tender Descenders and dispose of properly.
- ☐ 83 If decision is made to attempt another launch, return to beginning of procedure.

POST-FLIGHT

- ☐ 84 If flight is successful, document the vehicle's state upon landing (parts broken, max altitude reached, successful recovery system deployment, take photos).
- ☐ 85 Insert flight pins to deactivate payload and altimeters.
- ☐ 86 Return vehicle to staging area and remove rivets from recovery bay to separate vehicle halves.
- ☐ 87 Dispose of all burned E-matches.
- ☐ 88 Disconnect altimeters and avionics payload.
- ☐ 89 If desired, download data from avionics payload before performing any subsequent flights.
- ☐ 90 Once motor case has cooled, unthread from the payload shaft and clean thoroughly.

SECTION III. APPENDIX I: VISUAL REFERENCES

Figure 1: StratoLogger

Figure 2: Mid-Section Coupler/ Recovery Bay Bulk Plate

Figure 3: Recovery System

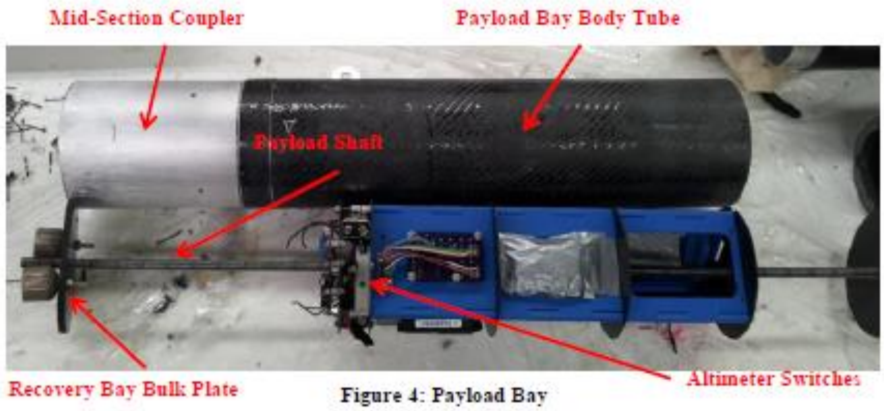

Figure 4: Payload Bay

Figure 5: Fin Can Section

Figure 6: Nosecone Assembly

Figure 7: Prometheus Overview

SECTION IV. HAZARD ANALYSIS

		Hazard Probability				
		Frequent	Likely	Occasional	Seldom	Unlikely
Hazard Severity	Catastrophic	4	4	3	3	2
	Critical	4	3	3	2	1
	Moderate	3	2	2	1	1
	Negligible	2	1	1	1	1

Figure 8: Hazard Analysis Table

Hazard	Severity	Probability	Effect	Mitigations
Explosions	Catastrophic	Unlikely	• Damage to vehicle/equipment. • Injuries due to shrapnel.	• Ensure motor is constructed and installed per manufacturer specs. • Ensure wire leads are shunted during setup. • Use only the required amount of black powder.
Burns	Critical	Seldom	• Burns to skin.	• Ensure motor case has cooled before handling. • Use of heat-resistant gloves when handling spent motor case.

Cuts/ Lacerations	Moderate	Occasional	• Injury to launch team personnel.	• Ensure all cut surfaces on vehicle have been sanded down to remove burrs. • Minimize use of knives or cutting devices during launch procedure.
Inhalation of Black Powder fumes	Moderate	Likely	• Long-term health effects.	• Disassemble vehicle in well-ventilated area. • Use smallest quantity of black powder possible. • Allow vehicle to sit for several minutes before disassembly.
Rail Whip	Critical	Unlikely	• Non-vertical takeoff of vehicle. • Damage to launch rail and/or vehicle. • Increased recovery radius.	• Use rail that is appropriately sized for vehicle mass. • Use the shortest rail possible for proper rail exit velocity. • Ensure rail is securely fashioned to launch pad along its length.
Ignition Circuit Failure	Moderate	Occasional	• Possible loss of payload data. • Loss of flight window if waiver expires. • Project delays.	• Ensure payload can remain active for an extended period of time. • Have vehicle on launch pad well ahead of waiver's end.