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Project Asterales

NASA University Student Launch Initiative

Launch Readiness Review

3 April 2019

Table of Contents

1 Launch Vehicle Overview

1.1 Previous Flight Data

The following table summarizes the recorded and predicted apogees from the previous full scale launches.

Full Scale Apogee Summary					
Flight #	**Date**	**Temp (ºF) / Wind (mph)**	**Weight (lbs)**	**Sensor / Simulation**	**Apogee (ft)**
1	9 Feb 19	31 / SSE 14	35.4	OpenRocket	4,716
				TBS	5,018
				Stratologger	3,974
				Raven	3,917
2	24 Feb19	49 / SSE 6	37.5	OpenRocket	4,712
				TBS	4,701
				Stratologger	3,774
				Raven	3,805
				IMU	3,751
3*	16 Mar 19	60 / SSW 9	37.6	OpenRocket	5,572
				TBS**	4,785
				Stratologger	4,864
				Raven	4,865
				IMU	4,870

*The third full scale launch was completed on an AeroTech L1390 due to availability. The competition motor (AeroTech L1150) was used on the first two flights.

** The team-built simulation includes the use of the active drag system on this flight.

The following figures include the recorded flight profiles from each of the full scale launches. The main parachute did not fully deploy on the first or third flight, as discussed in Section 2.1. Post flight analysis determined the cause of achieving apogees below the predicted values on the first two flights to be a result of motor underperformance.

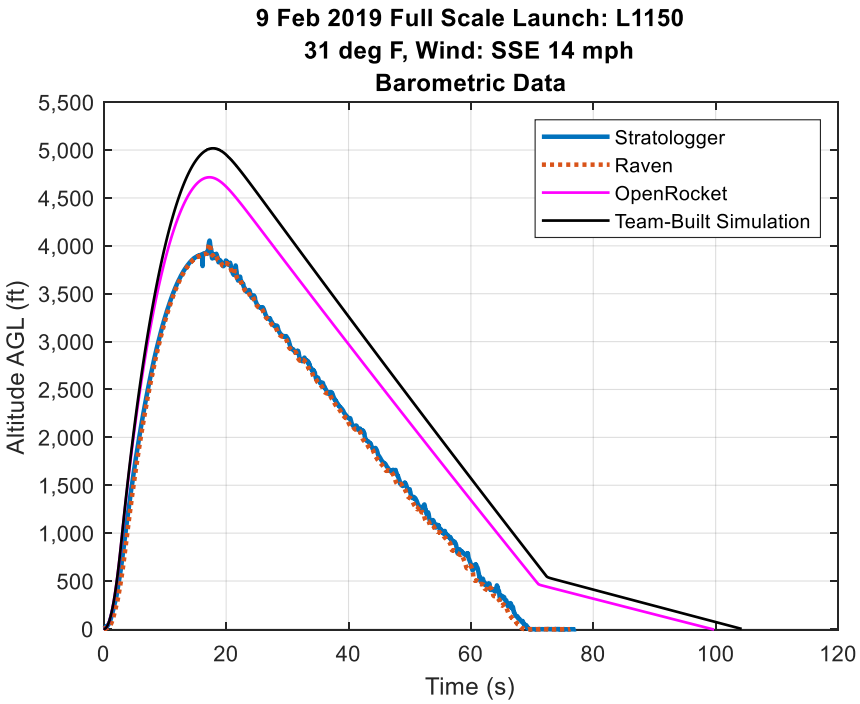

Figure 1: Flight Profile - Full Scale Flight #1

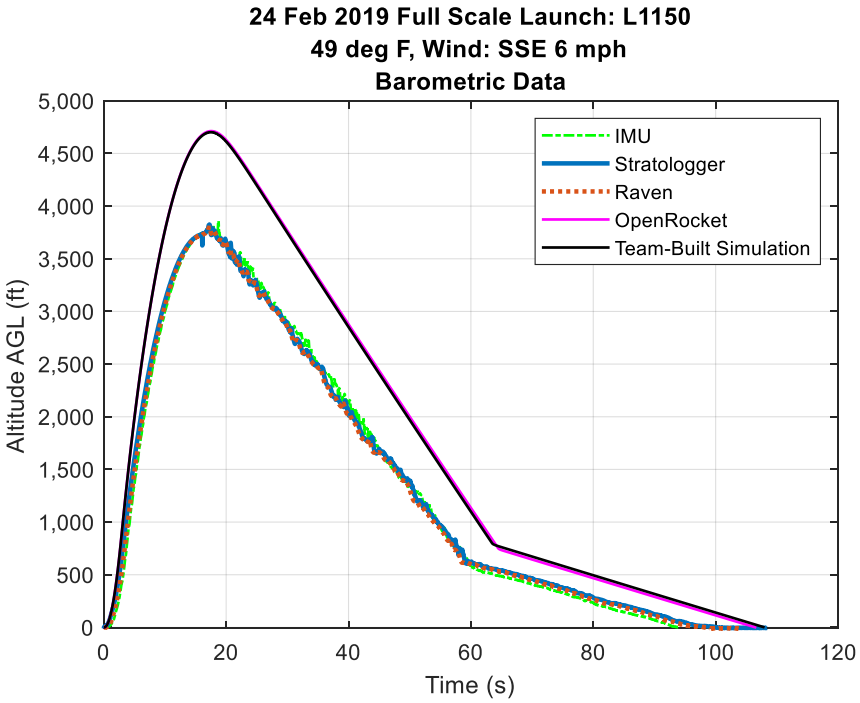

Figure 2: Flight Profile - Vehicle Demonstration Flight

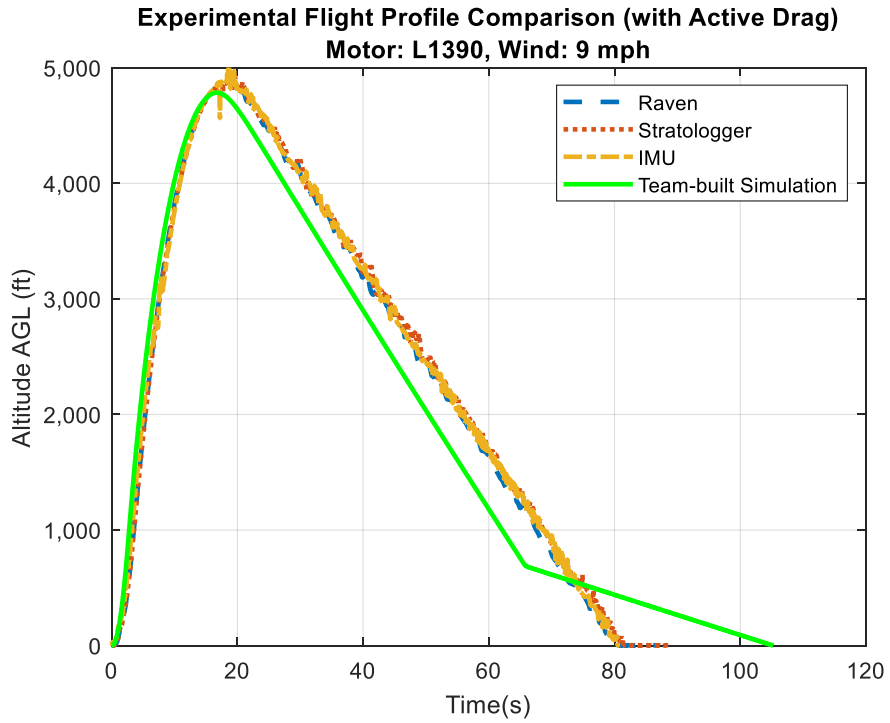

Figure 3: Flight Profile - Payload Demonstration Flight

During the Vehicle Demonstration Flight, the main parachute deployed as designed, yielding a landing velocity of approximately 17.5 ft/s. This corresponded to a maximum landing kinetic energy of approximately 68.8 ft•lb. The change in parachute discussed in Sections 1.3 and 2.1 is predicted to result in a landing velocity of 17 ft/s. With the updated weights of each section, the predicted maximum landing kinetic energy is approximately 62 ft•lb.

1.2 Anomalies and Mitigations

Please see Section 2.1 for a description of the two main parachute anomalies encountered throughout the development and testing process.

1.3 Changes Since Last Flight

Since the Payload Demonstration Flight, the payload bay has been reconstructed to repair damage encountered during said flight. No significant design changes have occurred.

The main parachute has been changed from a 96 inch Fruity Chutes Iris Ultra Compact Parachute to a 12 foot Rocketman Parachutes Parabolic Parachute. The details and rationale for this change are outlined in Section 2.1.

1.4 Flight Simulations

The following figure depicts the predicted flight profile for the launch vehicle in a 10 mph wind with a 5 degree launch angle. The team-built simulation curve includes the use of the active drag system.

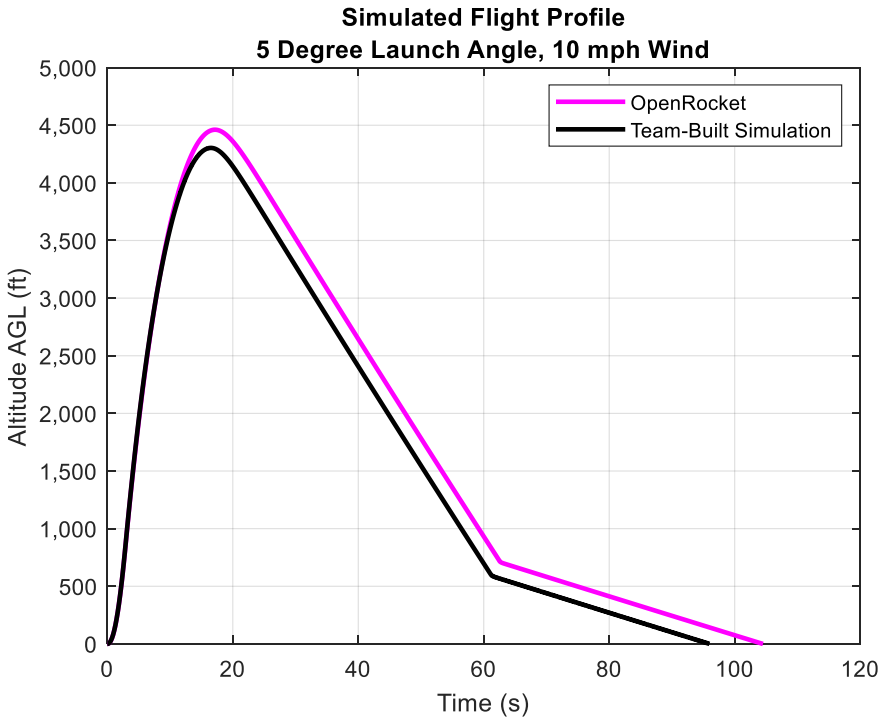

Figure 4: Predicted Flight Profile

The following table summarizes the mission performance predictions for the launch vehicle. The simulations performed using the team-built simulation include the use of the active drag system.

Mission Performance Predictions							
Simulation	**Launch Angle (deg)**	**Wind (mph)**	**Apogee (ft)**	**Rail Exit Velocity (ft/s)**	**Time to Apogee (s)**	**Descent Time (s)**	**Landing Velocity (ft/s)**
OpenRocket	0	0	4,604	70.9	17.4	88.6	16.9
	5	10	4,463	70.9	17.2	87.8	17.0
	10	20	4,103	71.0	16.5	85.5	16.7
TBS	0	0	4,304	70.8	16.5	79.5	16.9
	5	10	4,303	70.4	16.5	79.5	16.9
	10	20	4,301	70.2	16.4	79.5	16.9

The following table includes drift predictions from the team's target apogee of 4,300 feet AGL. The predicted descent time is approximately 81.5 seconds.

Physics Model Drift Predictions from 4,300 feet		
Wind (mph)	**Wind (ft/s)**	**Predicted Drift (ft)**
0	0	0.0
5	7.3	597.7
10	14.7	1195.4
15	22.0	1793.1
20	29.3	2390.8

2 Safety

2.1 Parachute Failure Modes and Effects Analysis

The team has experienced equipment failures involving the main parachute on two test flights of the launch vehicle. The first failure was a result of a main parachute shroud line becoming entangled with its deployment bag after deployment from the launch vehicle. This failure led the team to eliminate the parachute deployment bag from the design and instead make use of parachute protectors. The second flight of the vehicle was successfully completed with the use of these parachute protectors and by following the packing instructions of the manufacturer. On the vehicle's third flight, despite using the same packing procedures as were used on the successful flight, the main parachute's shroud lines became entangled with themselves and did not allow the full inflation of the parachute.

Due to the equipment failures caused by tangling of the parachute shroud lines, the team has developed the following analysis and mitigation of this failure mode.

Failure Mode

Upon the deployment of the main parachute, the shroud lines become tangled and do not allow the full inflation of the parachute.

Cause of Failure

The parachute used when the failures were experienced has numerous shroud lines of varying lengths, resulting in a tendency to tangle when deployed from the launch vehicle.

Effect of Failure

When the main parachute fails to inflate, the launch vehicle impacts the ground with a higher than nominal velocity. This coincides with a greater than anticipated landing kinetic energy. This can result in potential damage to the launch vehicle, launch field, or personnel.

Mitigation

The team has elected to change main parachutes from the 96 inch Iris Ultra Compact made by Fruity Chutes to the 12 ft. parabolic parachute made by Rocketman Parachutes. This new parachute has only four shroud lines as opposed to the 24 total shroud lines on the previous parachute. Additionally, the packing procedure required for the new parachute is far simpler which results in a more consistently packed parachute. The team will continue to use the parachute protector and swivel in an attempt to further reduce the likelihood of this failure mode. Using the current packing method, the Rocketman parachute is stated to pack in the same dimensions as the Iris Ultra Compact parachute. Ejection charge testing will be repeated upon the arrival of the new parachute.

The following table summarizes the Failure Modes and Effects Analysis for this hazard. The risk levels were determined using the methodology discussed in the safety section of the Flight Readiness Review.

Parachute Failure Modes and Effects Analysis							
Mission Phase	**Hazard / Situation**	**Cause**	**Effect**	**Pre-Mitigation Risk Level (R) / Assessment**	**Mitigation**	**Post-Mitigation Risk Level (R) / Assessment**	**Verification**
Descent	Main parachute does not fully inflate	Tangling of shroud lines	Vehicle impacts ground with a high kinetic energy resulting in potential damage to equipment, personnel, or environment.	3B (Moderate)	A new parachute has been selected with far fewer shroud lines and simpler packing procedures greatly reducing the probability of parachute tangling. A parachute protector and swivel will continue to be utilized.	5B (Low)	This change is documented in Section 1.4.1. The ability of the new parachute to satisfy all descent requirements is detailed in Section 2.1.

2.2 Launch Concerns and Operation Procedures

2.2.1 *Launch Preparation and Procedure*

The following steps must be completed in preparation for a launch. The safety officer is responsible for overseeing launch preparation, though the verification of multiple team members is required for the completion of a step. The safety officer will hold a pre-launch briefing to review the launch preparation procedures and safety requirements. The pre-launch briefing shall be held at least one week prior to launch. The team shall only proceed with the launch once all steps in the process have been verified.

- **Prior to Travelling to Launch site**
    1. Prepare Nose Cone Assembly
        - ☐ Install a new 9-volt battery in nose cone electronics sled battery holder.
        - ☐ Attach a small test light to the nose cone terminal block.
        - ☐ Turn rotary switch to the "on" position.
        - ☐ Send RC signal to activate nose cone ejection sequence.
            - Troubleshooting: If the test light does not turn on, disconnect power from the circuit and use a multimeter to check wiring for discontinuities. Once the wiring has been repaired (if needed) and the test is successful, move on to the next step.
            - **WARNING: Improper nose cone electrical assembly could result in early nose cone ejection.**
        - ☐ Turn rotary switch to the "off" position.
        - ☐ Disconnect test light from the nose cone terminal block.
        - ☐ Insert nose cone coupler with attached fore bulkhead and electronics into the nose cone and secure with four 6-32 screws.

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    2. Prepare Fore Body Section Assembly
        - ☐ Attach payload bay electronics sled to main parachute bulkhead/coupler by mounting the rotation servo.
        - ☐ Attach payload bay electronics sled to payload housing by mounting the deployment servo.
        - ☐ Install and secure lead screw to the deployment servo.
        - ☐ Insert LiPo battery for payload bay orientation and deployment servos.
        - ☐ Connect the Arduino to a computer and Upload and run the payload sled and UAV installation program.

- ☐ Thread the payload sled's retention arm onto the lead screw and allow for the sled to be driven into the payload housing up to the designated mark before unplugging the servo battery.
- ☐ Position the UAV's retention arm to be threaded onto the lead screw before plugging in the servo battery.
- ☐ Allow the UAV and deployment sled to be driven fully into the payload housing before unplugging the servo battery.
- ☐ Upload the payload orientation and deployment program to the Arduino then disconnect it from the computer
- ☐ Insert 9-volt battery for powering the Arduino.
- ☐ Zip-tie batteries into position.
- ☐ Test functionality of the orientation and deployment system by sending the RC signal to activate the sequence.
    - Troubleshooting: If the orientation and deployment system fails to function or does not function properly, check for obstructions to the system. If no obstructions are found, disconnect power from the circuitry and carefully examine wiring with a multimeter. If necessary, disassemble the system. Once the issue has been diagnosed and repaired, repeat the fore body section assembly list. Once functionality has been confirmed, move on to the next step.
- ☐ Return payload sled to the stowed position and disconnect electrical power from the system.
- ☐ Install payload deployment assembly within the fore section of the launch vehicle.
- ☐ Ensure the fore-mid section coupler is securely attached with four 6-32 screws.

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3. Prepare Mid Body Section Assembly and Avionics Bay
    - ☐ Connect each altimeter (Stratologger and Raven) to a computer and run calibration protocols.
    - ☐ Fully assemble avionics sled electronics.
    - ☐ Check for proper altimeter functionality by attaching small test light to each altimeter's terminal block.
        - Troubleshooting: If altimeter functionality cannot be confirmed, carefully examine wiring with a multimeter. If wiring is correct, and the altimeter still does not function, the altimeter must be replaced. Once proper altimeter functionality has been confirmed, move on to the next step.

- **WARNING: Improper wiring or a faulty altimeter poses extreme risk to personnel, equipment, and environment.**

☐ Insert avionics sled into avionics bay and secure avionics bay bulkheads to the all-thread attached to the sled.

☐ Ensure that attachment points between the mid body section and the avionics bay are properly aligned and clear of obstruction.

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4. Prepare Aft Body Section Assembly and Active Drag System
   ☐ Ensure that the fins are undamaged.
   ☐ Ensure that the epoxy bonds securing the fins, the motor mount tube and the motor bulkhead and centering rings are undamaged.
      - Troubleshooting: If an epoxy bond is damaged or judged to be too weak, mix and apply 30-minute epoxy as needed.
      - **WARNING: Insufficient bonding of fins, bulkheads, or motor mount tube poses severe risk to personnel, equipment, and environment.**

   ☐ Ensure attachment points between avionics bay and aft body section are properly aligned and clear of obstructions.
   ☐ Ensure that the cam rotation path and drag blade extension paths are clear of obstructions.
      - Troubleshooting: If an obstruction is present, disassemble the system as necessary to clear the obstruction.
      - **WARNING: Obstructions to the moving parts of the active drag system can cause severe damage to equipment.**

   ☐ Upload the functionality test program to the active drag system's Arduino Micro control board.
   ☐ Connect electrical power to the system and ensure that the functionality test is completed properly.
      - Troubleshooting: If functionality test is not completed properly, carefully examine wiring and disassemble system as needed to diagnose the issue. Once the system is fully assembled and the functionality test is run successfully, move on to the next step.

   ☐ Disconnect electrical power from the active drag system.
   ☐ Ensure attachment points between the active drag system and the aft body section are properly aligned and clear of obstructions.

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5. Prepare Recovery System Components
   - ☐ Ensure that the drogue parachute and shock cords are undamaged.
   - ☐ Ensure that the main parachute and shock cords are undamaged.
   - ☐ Attach quick links and swivels to their attachment points on the main and drogue parachutes.
   - ☐ Place parachute protectors on their respective shroud lines.
   - ☐ Carefully fold drogue and main parachutes with their shock cords and quick links and secure with tape for transportation.
   - ☐ **PPE: Put on nitrile gloves and ground self before completing.** Using a digital scale or properly marked container, measure appropriate black powder charges for drogue, main, and nose cone ejection.
     - **WARNING: Extreme caution must be used when handling energetic materials. Do not perform task near any source of ignition.**
   - ☐ Place measured black powder charges in plastic capsules and store in a fire-safe box.
   - ☐ Check electric matches for continuity using a multimeter.
     - Troubleshooting: If continuity is not confirmed for an electric match, replace it.

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6. Prepare Motor
   - ☐ Assemble motor exactly as directed in the included instructions.
     - Note: Since no member of the team has level two NRA/TRA certification, this task will primarily be completed by the team mentor with the assistance of the team as necessary. No motor assembly will take place without the direct supervision of the team mentor.
     - **WARNING: Complete this task with extreme caution. Improper motor assembly poses severe risk to personnel, equipment, and environment.**

- ☐ Check motor ignitor for continuity using a multimeter.
  - Troubleshooting: If the continuity of the ignitor is not confirmed, replace it.
- ☐ Store assembled motor and ignitor separately in fire safe containers for transportation to the launch site.

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7. Pack Vehicle and General Supplies
   - ☐ Fill out and verify the full scale vehicle packing list (given below)
   - ☐ Fill out and verify the general launch packing list (given below)
   - ☐ Gather vehicle and general launch items to be transported to the launch site.

- **Upon Arrival at the Launch Site**
  1. Launch Site Inspection and Setup
     - ☐ Ensure that launch site meets all safety requirements in the NAR High Power Rocket Safety Code. If a requirement is not satisfied, abort the launch.
     - ☐ Check nearest weather station to ensure that the local wind speed is less than 20 mph. If the wind speed exceeds 20 mph, abort the launch.
     - ☐ Assemble folding table and tent.
     - ☐ If necessary, assemble 12’ launch rail in a safe location free from obstructions.
  2. Launch Vehicle Preparation **(Required Verification: 4 team members)**
     - ☐ Ensure that the rotary switches for the avionics bay are turned off.
     - ☐ Verify continuity of e-matches with multimeter.
     - ☐ Repeat this step for all four parachute deployment charges and the nose cone ejection charge: Insert ejection activation wires into terminal blocks and secure with screwdriver. Insert e-match wires into terminal blocks and secure with screwdriver. Funnel pre-measured black powder charge into PVC charge well. Insert the ignition end of the electric match into the charge well. Cover the charge well thoroughly with masking tape ensuring that the electric match remains firmly inside and that no black powder falls out. If necessary, pack the charge well with bits of paper towel to ensure that the e-match remains firmly in contact with the black powder during flight.
       - **WARNING: Extreme caution must be used when handling energetic materials. Do not perform task near any source of ignition.**
     - ☐ Insert the coupler portion of the nose cone assembly into the fore end of the fore body section and secure with four 4-40 nylon shear pins.

- ☐ Insert the avionics bay into its position at the aft end of the mid body section and secure with four 6-32 screws.
- ☐ Install the active drag system in its position in the aft body section and secure with four 6-32 screws.
- ☐ Inspect drogue parachute and shock cord for damage and ensure that no lines are tangled.
- ☐ Inspect main parachute and shock cord for damage and ensure that no lines are tangled.
- ☐ Raise main parachute in the air ensuring that all shroud lines are untangled.
- ☐ Place main parachute on the ground and fold along the gore lines.
- ☐ Fold parachute in half bringing the top of the chute to the shroud lines.
- ☐ Fold shroud lines accordion style on top of folded parachute.
- ☐ Fold the parachute once more around the shroud lines.
- ☐ Attach main parachute quick link to main parachute shock cord.
- ☐ Place folded parachute in parachute protector and wrap protector around the parachute.
- ☐ Secure one main parachute quick link to the U-bolt at the fore end of the avionics bay and the other to the U-bolt at the aft end of the fore body section.
- ☐ Secure one drogue parachute quick link to the U-bolt at the aft end of the avionics bay and the other to the U-bolt on the drogue bulkhead in the aft body section.
- ☐ Place the folded main parachute and shock cord inside the mid body section.
- ☐ Fit the assembled fore section with attached nose cone and coupler onto the mid body section coupler and secure with five M2 nylon shear pins.
- ☐ Power on radio tracker and attach thoroughly to the drogue parachute shock cord using electrical tape.
- ☐ Carefully fold the drogue parachute and shock cord into a bundle inside the drogue parachute protector ensuring that no tangling occurs.
- ☐ Place the folded drogue parachute and shock cord inside the aft body section.
- ☐ Fit the aft body section over the aft end of the avionics bay and secure with five M2 nylon shear pins.
- ☐ Insert the pre-assembled motor into the motor mount tube.
- ☐ Screw on the motor retention cap.
- ☐ Check the motor ignitor for continuity with a digital multimeter. **Do not insert igniter at this point.**
    - **WARNING: Check thoroughly to ensure the motor is properly secured.**

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3. Launch Rail Setup and Launch
    - ☐ Record GPS coordinates of the launch rail.
    - ☐ Record weather conditions and time.
    - ☐ Inspect launch rail to ensure it is on level ground in a safe location and that it has a blast guard.
    - ☐ Using a flat head screwdriver, arm the nose cone ejection rotary switch.
    - ☐ Tilt launch rail and carefully slide the rocket onto the rail ensuring that both rail buttons are secured by the rail.
    - ☐ Using a flat head screwdriver, switch on the two rotary switches within the avionics bay as well as the rotary switch within the active drag system.
    - ☐ Listen for the confirmation beeps from the altimeters (beep beep beep and beep beep boop boop) and from the active drag system (long beep short beep).
        - Troubleshooting: If the confirmation beeps are not heard, remove the vehicle from the launch pad. Diagnose and fix the issue before continuing.
    - ☐ Carefully insert the igniter through the bottom of the motor until the ignition end reaches the top of the motor.
    - ☐ Carefully connect igniter wires to electronic launch system.
    - ☐ Check continuity with launch control system.
    - ☐ Follow the minimum distances table. Move the appropriate distance away from the launch pad and prepare for launch.
4. Payload Mission
    - ☐ Upon successful recovery of the launch vehicle and receiving the approval of the RDO, activate the payload deployment sequence.
    - ☐ Once the payload has been successfully deployed, arm the UAV for flight and complete the payload mission.
5. Post Flight Assessment
    - ☐ Thoroughly inspect the launch vehicle and parachutes. Note any damage or wear.
    - ☐ Turn off switches for altimeters and active drag system.
    - ☐ Record GPS coordinates of landing location.

2.2.2 *Launch Supplies and Packing List*

General Launch Packing List

The following list contains all tools, materials, and personal protective equipment that must be transported to the launch site. The vehicle packing list must also be completed prior to travel to the launch site. **Verification: two team members.**

General Launch Packing List		
Tools/Materials	**Min. Quantity**	**Check box when packed**
Flat-head screwdrivers	2	☐
Philips-head screwdrivers	2	☐
Black Sharpie	1	☐
Metallic Sharpie	1	☐
Tape Measure	1	☐
Hand drill	1	☐
Drill bit set	1	☐
2-56 Tap bit	1	☐
4-40 Tap bit	1	☐
6-32 Tap bit	1	☐
Hex wrench	2	☐
Sandpaper	4 sheets	☐
Wire Brush	1	☐
Wire cutters	2	☐
Wire strippers	2	☐
Needle-nose pliers	2	☐
Channel lock	2	☐
Scissors	1	☐
Digital Multimeter	1	☐
Epoxy resin & hardener (5-minute)	1 bottle of each	☐
Plastic Cups	10	☐
Epoxy Stirring Sticks	10	☐
Electrical tape	1 roll	☐
Zip-ties	50	☐
Grease	1 can	☐
Degreaser	1 bottle	☐
Flashlights	2	☐
Scale	1	☐
LiPo battery charger	1	☐
Extra 9V Batteries	8	☐
Camera/Camera Phone	1	☐
Laptop	1	☐
Altimeter Connection Cables	2	☐

General Launch Packing List		
Tools/Materials	**Min. Quantity**	**Check box when packed**
Personal Protective Equipment	**Min Quantity**	**Check box when packed**
Safety glasses	4 sets	☐
Work gloves	4 pairs	☐
Nitrile gloves	1 box	☐
First Aid Kit	1	☐
Sunscreen	1 bottle	☐
Convenience Items	**Min. Quantity**	**Check box when packed**
Folding table	1	☐
PVC launch vehicle stand	2	☐
Tent	1	☐
Paper towels	1 roll	☐
Bottled Water	16	☐
Disinfectant Wipes	1 box	☐

Team Member Verification

Initials: _____ Date: _____

Initials: _____ Date: _____

Full Scale Vehicle Packing List

The following is a list of all items that must be packed for transport to the launch site relating to the full-scale launch vehicle and its subsystems. Items under the airframe section refer to the fully assembled sections of the vehicle or payload. Fully assembled is defined as all subcomponents being installed and secured. **Required Verification: two team members.**

Full Scale Vehicle Packing List		
Airframe	**Min. Quantity**	**Check box when packed**
Nose Cone Assembly	1	☐
Fore Body Section Assembly	1	☐
Mid Body Section Assembly	1	☐
Avionics Bay	1	☐
Aft Body Section Assembly	1	☐
Motor	1	☐
Motor Casing	1	☐
Igniter	1	☐
Active Drag System Assembly	1	☐
Recovery	**Min. Quantity**	**Check box when packed**
Drogue Parachute	1	☐
Main Parachute	1	☐
Tubular Kevlar Shock Cord	2 x 50’	☐
Quick Links	7	☐
Black Powder	as required	☐
Electric Matches	12	☐
M2 Nylon Shear Pins	40	☐
4-40 Nylon Shear Pins	40	☐
Parachute Protectors	2	☐
Eggfinder GPS Receiver	1	☐
Radio Tracker Receiver	1	☐
Payload	**Min. Quantity**	**Check box when packed**
Payload Vehicle Assembly	1	☐
Batteries	3	☐
FPV Goggles	1	☐
FPV Goggles Battery	1	☐
Circular Antenna	1	☐
Patch Antenna	1	☐

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