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Project Asterales

NASA University Student Launch Initiative

Flight Readiness Review Addendum

25 March 2019

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Nomenclature

AGL – Above Ground Level
APCP – Ammonium Perchlorate Composite Propellant
CAD – Computer Aided Design
CDR – Critical Design Review
CG – Center of Gravity
CP – Center of Pressure
DC – Direct Current
DOF – Degrees-of-Freedom
E-match – Electric Match
ESC – Electronic Speed Controller
ESC – Electronic Speed Control
FAA – Federal Aviation Administration
FAR – Federal Aviation Regulations
FEA – Future Excursion Area
FMEA – Failure Modes and Effects Analysis
FPV – First-Person View
FRR – Flight Readiness Review
GPS – Global Positioning System
ISA – International Standard Atmosphere
LCO – Launch Control Officer
LSWT – Low-Speed Wind Tunnel
MDF – Medium Density Fiberboard
MSDS – Material Safety Data Sheet
MSFC – Marshall Space Flight Center
NFPA – National Fire Protection Association
NAR – National Association of Rocketry
NASA – National Aeronautics and Space Administration
NIAR – National Institute of Aviation Research
OSD – On Screen Display
PDB – Power Distribution Board
PDR – Preliminary Design Review
PLAR – Post Launch Assessment Review
PODS – Payload Orientation and Deployment System
PPE – Personal Protective Equipment
PID – Proportional-Integral-Derivative (with respect to controllers)
PWM – Pulse Width Modulation
R&C's – Requirements and Constraints
RC – Radio Controlled
REM – Risk Evaluation Matrices
RK4 – Fourth Order Runge-Kutta Method
RSO – Range Safety Officer
T/W – Thrust-to-Weight Ratio
TBS – Team-Built Simulation

TPR – Team Derived Payload Requirement
TRR – Team Derived Recovery Requirement
TVR – Team Derived Vehicle Requirement
SLI – Student Launch Initiative
TRA – Tripoli Rocketry Association
TX – Transmitter
UART – Universal Asynchronous Receiver-Transmitter
UAV – Unmanned Aerial Vehicle
WSL – Wichita State Launch
WSU – Wichita State University
VTX – Video Transmitter

1 Summary of Flight Readiness Review Addendum

1.1 Team Summary

University: Wichita State University
Team Name: Wichita State Launch
Project Title: Asterales
Launch Vehicle: M63
Payload Vehicle: M51/Little Blue Stem

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1.2 Purpose of Flight

The purpose of the flight conducted on 16 March 2019 was to serve as the Payload Demonstration Flight.

1.3 Payload Demonstration Flight Summary

Payload Demonstration Flight Summary	
Flight Date	16 March 2019
Flight Location	Argonia, Kansas
Launch Conditions (temperature, wind)	60 ºF, SSW 9 mph
Motor Flown*	AeroTech L1390
Vehicle Launch Weight	37.6 lbs.
Ballast Flown	0 lbs.
Final Payload Flown	Yes
Active Drag System Status	Active
Declared Target Altitude	4,300 ft.
Predicted Altitude (without active drag)**	5,555 ft.
Predicted Altitude (with active drag)**	4,785 ft.
Measured Altitude	4,864 ft.
Off-Nominal Events	Main Parachute Entanglement

*The competition motor shall be an AeroTech L1150 motor.
** Predictions made with TBS using the AeroTech L1390

1.4 Changes Made Since Flight Readiness Review

1.4.1 *Changes to Vehicle Design*

The vehicle has remained relatively unchanged since the submission of the Flight Readiness Review. At the time of submission of the FRR, the payload orientation and deployment system was undergoing final bench testing prior to vehicle integration. Prior to the Payload Demonstration Flight, the system was repeatedly tested upon vehicle integration. This resulted in several small changes to ensure reliable deployment.

The ejection protection bulkhead is now made of two birch plywood bulkheads and is adhered to the payload deployment sled. This change was made after completing ejection charge testing. Before this change was made, the ejection protection bulkhead was capable of becoming stuck within the fore section and thus would not allow the payload orientation and deployment sequence to be completed. Additionally, the bulkhead is no longer threaded on to the lead screw since it is rigidly attached to the deployment sled. This change was made to minimize the possibility of binding on the lead screw. Triangular supports and L-brackets now support the bulkhead.

The orientation servo has been changed from a Hitec D645MW to a Hitec HSR-2645CRH to eliminate the external potentiometer on the original servo.

The cutout in the deployment sled in which the payload is inserted has been enlarged to allow for easier take-off. Blocks to prevent the payload from slipping upon being released from the lead screw have also been added.

Initial predictions suggested 1.5 grams of black powder would be needed to deploy the nose cone. Ejection charge testing has determined 0.75 grams of black powder are sufficient and shall be utilized. This results in the nose cone moving approximately 20 feet from the fore section of the launch vehicle.

Due to a partial failure of the recovery system during the Payload Demonstration Flight, a 12 foot Parabolic Parachute made by Rocketman Parachutes will now be used in place of the 96 in. Iris Ultra Compact Parachute made by Fruity Chutes.

1.4.2 *Changes to Payload Design*

Several changes have been made to the electronics of the payload. The payload no longer utilizes either of the two Tiny's LEDs RealPit VTX switches to control power to the video transmitter and simulated navigational beacon release servo. The Adafruit Trinket M0 control board used for controlling the beacon release servo has also be removed. These components were removed upon the original flight controller experiencing a software failure that does not allow it to be recognized by a computer for programming. The flight controller was replaced with that from the EMAX Magnum 2 F4 Flight Stack, which is an updated model of the original flight stack. Unlike the original flight controller, this second generation flight controller does not include additional UART ports for adding peripheral components.

Due to the lack of available UART ports, the FrSky D8 receiver has been replaced with an FrSky X8R receiver. This change allows the servo to be directly connected to the receiver, eliminating the need for an additional control board. This receiver also allows the use of a Pololu RC Switch. This switch is also directly connected to the receiver and, upon receiving a PWM signal from the RC transmitter, allows the video transmitter to receive power. Having the ability to turn off the video transmitter until needed provides significant battery life improvements.

2 Payload Demonstration Flight Results

2.1 Payload Demonstration Flight Summary

The Payload Demonstration Flight was completed on 16 March 2019 in Argonia, KS in conjunction with Tripoli Kansas #34, also known as Kloudbusters. The temperature was approximately 60 ºF with SSW 9 mph winds. The launch weight of the vehicle was approximately 37.6 lbs and a 12-foot 1515 launch rail was used.

This launch was conducted using an AeroTech L1390 in place of the competition motor (AeroTech L1150). This motor was selected due to its availability and the ability to use the competition day motor casing.

The vehicle performed nominally during ascent and demonstrated strong stability characteristics. The recorded data from the active drag system suggests the system functioned as designed. Without the active drag system, the use of the L1390 was predicted to result in an apogee of 5,555 feet AGL (using the team-built simulation), while the active drag system was set to target the competition altitude of 4,300 feet. The team-built simulation suggested the system could remove approximately 770 feet of excess altitude. The achieved apogee recorded by the official scoring altimeter was 4,864 feet AGL, which corresponds to a reduction of 691 feet from the predicted apogee without the active drag system.

During the recovery sequence, the drogue parachute was successfully deployed at apogee. The main parachute was set to be deployed at 600 feet AGL and was successfully deployed from the interior of the vehicle. Despite following the same packing procedure as was used on the Vehicle Demonstration Flight, the main parachute's shroud lines became entangled and did not allow the main parachute to fully open. Despite the faster than intended ground impact, minimal damage was sustained. Some components within the payload bay required reattachment with adhesive. All necessary repairs have been completed.

The payload was successfully retained throughout the entirety of the flight profile and was found in an undamaged state. The payload deployment sequence was also capable of being completed upon recovery of the vehicle.

Since the payload will be flown by Jonathan Mowrey (Wichita State University's small aircraft and unmanned aerial vehicle's pilot), who was not present, the team did not attempt to fly the payload. The payload was successfully flown by Jonathan the following day.

As a result of the main parachute failing to open, the team will now utilize a 12 foot Parabolic Parachute made by Rocketman Parachutes, in an attempt to ensure successful recovery. This parachute has four shroud lines and has a stated descent velocity of 17 ft/s for a 33 pound rocket, which is approximately the weight of the launch vehicle after burnout. It is worth noting during the Vehicle Demonstration Flight the landing velocity of the vehicle was approximately 17.5 ft/s. The team's mentor has successfully used this variety of parachutes in the past, with descent rates similar to those quoted by the company. A landing velocity of 17 ft/s will ensure the maximum landing kinetic energy of any section of the vehicle is below 75 ft•lb.

2.2 Payload Retention System Summary

2.2.1 *Functional Systems*

The UAV was designed to be retained within the payload housing using a retention arm that is threaded onto the deployment leadscrew, resulting in a fail-safe active retention. The payload retention system functioned as designed, despite the higher than expected landing kinetic energy. The payload was found to still be safely retained on the lead screw during the post flight inspection.

With the exception of the ability to reorient, the payload deployment system was functional upon recovery of the vehicle.

2.2.2 *Hardware and Software Functioning Outside of Nominal Parameters*

All payload retention and deployment hardware and software functioned as designed during the Payload Demonstration Flight and during integration testing.

2.2.3 *Damaged Hardware*

The payload orientation and deployment system suffered minor damage, including the payload housing coupler becoming separated from the rotating bulkhead and one of the track pieces separating from the coupler. This prevented the system from being capable of reorienting the payload housing. Neither component experienced significant structural damage and were reattached with appropriate adhesives.

2.2.4 *Retention System Lessons Learned*

The team is confident the payload will be successfully retained during all future flights due to the payload retention system functioning as designed despite the large landing kinetic energy experienced during the Payload Demonstration Flight.

2.3 Payload Mission Summary

2.3.1 *Payload Mission Sequence Summary*

The payload deployment sequence is shown in graphical form in the following figure.

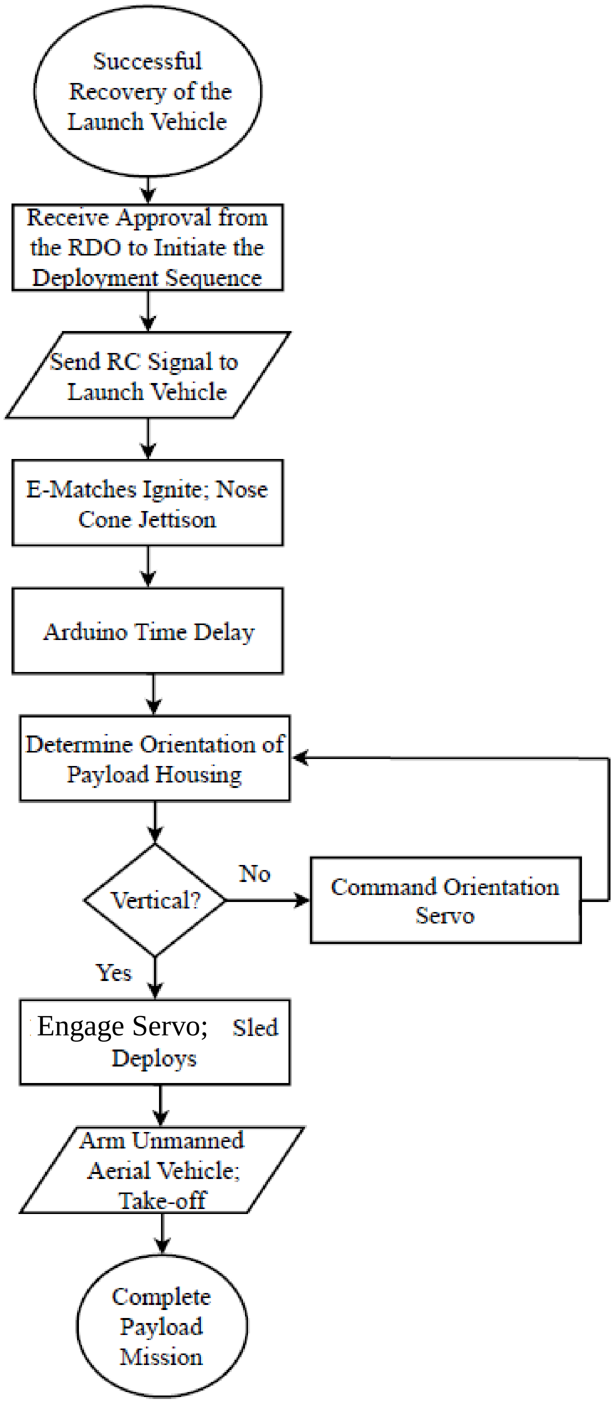

Figure 1: Payload Deployment Sequence

The key elements of the sequence include successful recovery of the vehicle, receiving approval from the Range Deployment Officer, initiating jettison of the nose cone, allowing the system to properly orient and deploy the payload. After deployment, the pilot will arm the payload and take off. The pilot will use first-person view goggles to locate a Future Excursion Area and approach. The payload will then be hovered over the FEA before releasing the simulated navigational beacon. Finally, the pilot will land the payload at a safe distance outside of the FEA.

2.3.2 *Functional Systems*

All components on the unmanned aerial vehicle functioned nominally during the Payload Demonstration Flight. Flight Testing was completed the following day due to the pilot's inability to attend the launch. All flight characteristics were nominal and the simulated navigational beacon release mechanism functioned as designed.

2.3.3 *Hardware and Software Functioning Outside of Nominal Parameters*

All hardware and software functioned within nominal parameters.

2.3.4 *Damaged Hardware*

The payload did not experience any damage.

2.3.5 *Payload Lessons Learned*

The team is confident in the ability of the payload to complete the mission and withstand all expected flight forces.

2.4 Launch Vehicle Flight

2.4.1 *Functional Systems*

The vehicle performed nominally during ascent and the active drag system successfully determined the vehicle was on a path to overshoot the target altitude of 4,300 feet AGL. Accordingly, the system deployed the drag blades.

The recovery system electronics functioned nominally, with all four ejection charges being fired.

2.4.2 *Hardware and Software Functioning Outside of Nominal Parameters*

While both parachutes were successfully deployed from the interior of the vehicle, the main parachute became entangled on its shroud lines and did not fully open. This occurred despite following proper packing procedures which were utilized during the successful Vehicle Demonstration Flight.

2.4.3 *Flight Data*

Figure 2 depicts the simulated flight profile without the use of the active drag system. Figure 3 shows the recorded flight data from both altimeters and the on-board inertial measurement unit as well as the simulated profile with the use of the active drag system from the team-built simulation.

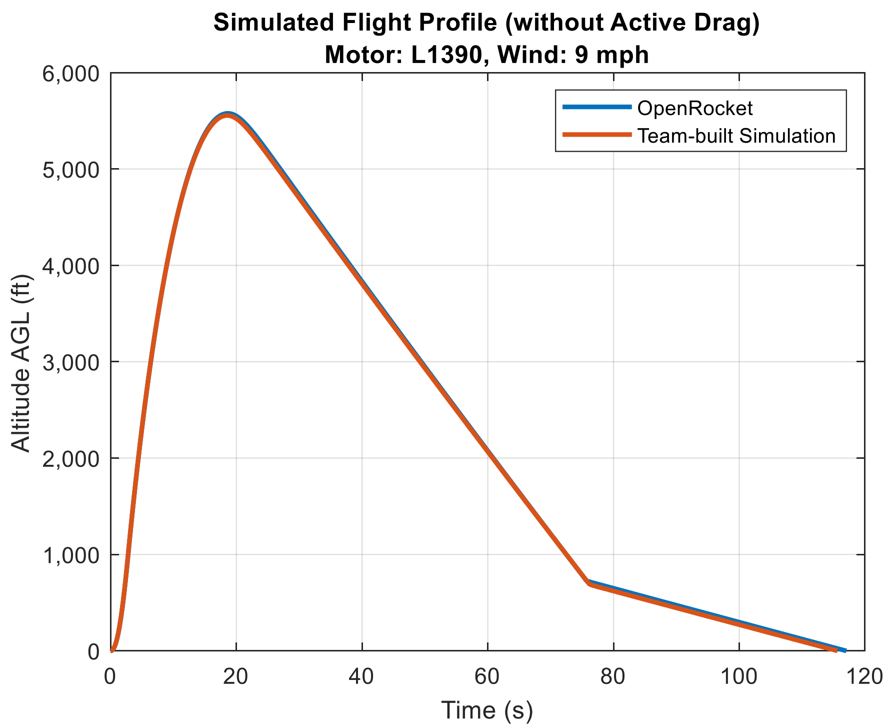

Figure 2: Simulated Payload Demonstration Flight without the Active Drag System

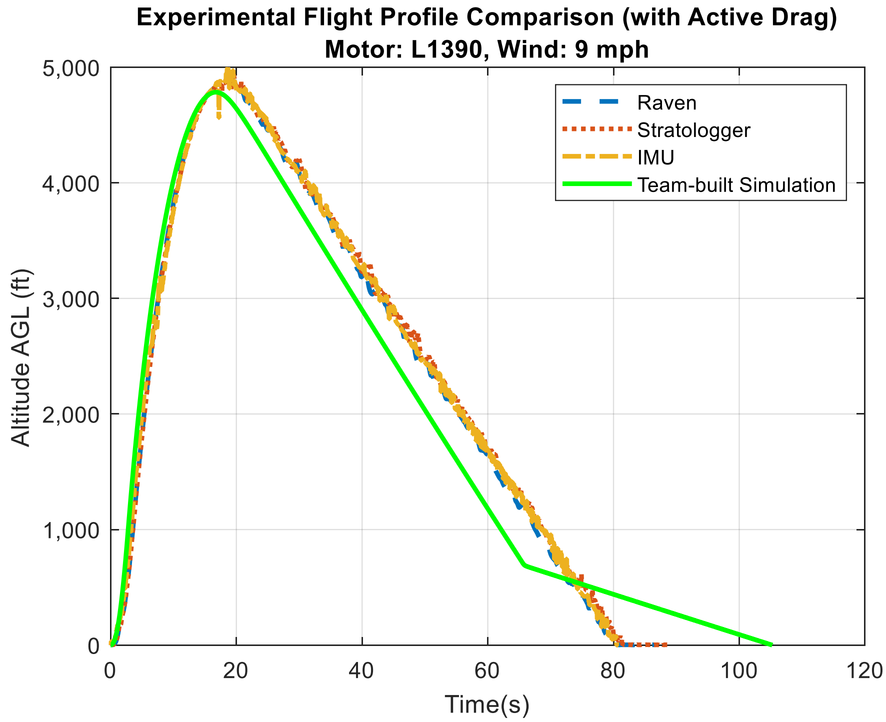

Figure 3: Payload Demonstration Flight Recorded and Simulated Flight Profile with the Active Drag System

The two altimeters and the IMU showed strong agreement in the recorded apogee with the Stratologger CF recording apogee of 4,864 feet, the Raven recording 4,865 feet, and the IMU recording 4,870 feet. The vehicle achieved apogee in approximately 18.2 seconds.

The Raven reported the maximum achieved velocity to be approximately 660 ft/s. OpenRocket predicted a maximum velocity of 669 ft/s. This gives the team confidence that the motor achieved near nominal performance.

The landing velocity of the vehicle was approximately 81 ft/s, which results in a landing kinetic energy of approximately 1,411 ft•lb using the mass of the aft section (0.43 slugs). If the vehicle had landed at 17.5 ft/s, as was done on the vehicle demonstration flight, the maximum expected landing kinetic energy would be 66 ft•lb.

2.4.4 *Hardware and Software Functioning Outside of Nominal Parameters*

The main parachute was the only component that functioned outside of nominal parameters during the Payload Demonstration Flight.

2.4.5 *Damaged Hardware*

The launch vehicle suffered no significant damage. The payload bay was the only section requiring attention, as described in Section 2.2.3.

To address the tangling of the main parachute, the team has ordered a 12-foot Parabolic Parachute made by Rocketman Parachutes. These parachutes have successfully been used by the team's mentor in the past and have four shroud lines. Additionally, the descent rates claimed by Rocketman Parachutes were validated using data from the team's mentor's past experiences.

Accordingly, this parachute is expected to allow the vehicle to land with a velocity of approximately 17 ft/s. The team believes changing to a parachute with many fewer shroud lines and a less complicated packing procedure will ensure successful deployment of the parachute. Additionally, using the current packing method, the 96 in. Iris Ultra Compact packs in an 11 inch length with a 4 inch diameter, while the Rocketman parachute is expected to pack in a shape 11 inches long with a 4 inch diameter. This suggests the new parachute is unlikely to be more difficult to deploy than the current parachute.

2.4.6 *Launch Vehicle Lessons Learned*

The vehicle was capable of being prepared in under 90 minutes and all procedures were followed.

The replacement of the parachute is expected to sufficiently mitigate the risk of the main parachute not opening. A complete hazard analysis is included in Section 3.1.

3 Safety

3.1 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.

3.2 Launch Concerns and Operation Procedures

3.2.1 *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.

     Team member Verification:

     Initials: _____ Date: _____

     Initials: _____ Date: _____

  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.

Team member Verification:

Initials: _____ Date: _____

Initials: _____ Date: _____

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.

Team member Verification:

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Initials: _____ Date: _____

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.

Team member Verification:

Initials: _____ Date: _____

Initials: _____ Date: _____

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.

Team member Verification:

Initials: _____ Date: _____

Initials: _____ Date: _____

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.

Team member Verification:

Initials: _____ Date: _____

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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.**

Team member Verification:

Initials: _____ Date: _____

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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.

3.2.2 *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	☐

Team Member Verification

Initials: _____ Date: _____

Initials: _____ Date: _____