The Pennsylvania State University

LionTech Rocket Labs

2018 - 2019 Solium Project

Post-Launch Assessment Review

Supplemental Mail Room, University Park, PA 16802
April 29th, 2019

Table of Contents

<u>List of Acronyms</u>

A&R	Avionics and Recovery
AGL	Above Ground Level
GPS	Global Positioning System
LTRL	LionTech Rocket Labs
MDRA	Maryland Delaware Rocketry Association
NAR	National Association of Rocketry
NASA	National Aeronautics and Space Administration
PSU	The Pennsylvania State University
STEM	Science Technology Engineering and Mathematics
UPAC	University Park Allocation Committee
USLI	University Student Launch Initiative

List of Tables

List of Figures

1. Summary of Report

1.1 Team Summary

Team Name and Address

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1.2 Vehicle Summary

Vehicle Dimensions

The flight vehicle is designed to carry a rover payload along with the necessary flight systems for telemetry acquisition and a successful recovery. The flight vehicle's target apogee is 5,280 feet. A diameter of 6 inches was chosen to give adequate space for the rover, its retention system, and its deployment system. The length of the flight vehicle is 120 inches to provide enough space for the payload and the necessary avionics and flight systems. On competition launch day, the flight vehicle's dry mass weight was 28.4 lbs while wet mass weight was 39.6 lbs. The launch vehicle launched on a 10-foot tall, 15-15 rail at 5 degrees. A model of the final flight vehicle with internal components visible can be seen below in Figure 1. Figure 2 shows a picture of the fully assembled flight vehicle before the competition launch.

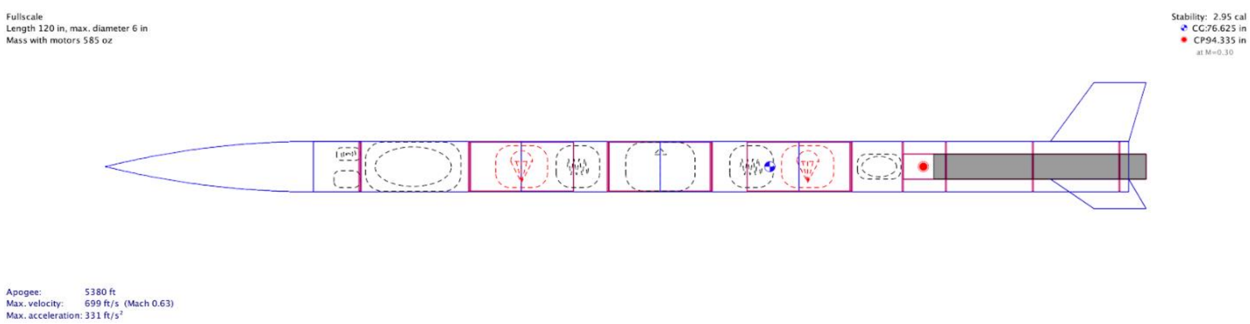

Figure 1. Side view of the fullscale flight vehicle

Figure 2. Fullscale flight vehicle on the pad at the competition launch

Motor Used and Official Target Altitude

The motor selection is based on the mission performance criteria outlined in the 2019 NASA Student Launch Handbook and utilizes OpenRocket to simulate flight characteristics. Through this motor selection process, the Cesaroni L1355 was selected as the vehicle's motor.

Vehicle Description

The launch vehicle's airframe was constructed of wrapped plies of carbon fiber. The vehicle also included a removable door to the avionics bay to ensure easy access in case of technical difficulties. The vehicle utilized an ogive 4:1 nose cone made of fiberglass due to its high strength and low cost. The fins were made of fiberglass and held in place by 3D printed fin brackets with nuts and bolts. The fin brackets were 3D printed so they could be removed in case of structural damage. The 3D printed fin brackets also helped to combat fin flutter and ensure structural integrity. The launch vehicle also included a 3D printed aerodynamic camera cover which aligned the camera to record down-body and protected the camera during flight. The launch vehicle featured three separation points: two for parachute deployment and one for rover deployment. The separation point for drogue parachute is located between the booster and drogue body tube, and the separation point for main parachute is located between the payload body tube and the main body tube. The rover deployed through the nose cone after the separation between the nose cone shoulder and the payload body tube. The motor was retained using three equidistant centering rings epoxied to the motor tube and to the body of the rocket using JB-Weld.

Recovery System

The rocket utilized a dual-deployment parachute recovery system where the primary altimeter deployed the 18” Fruity Chutes Classical Ultra drogue parachute at apogee and deployed the 96” Fruity Chutes Iris Ultra main parachute at 600 feet AGL. The redundant altimeter had a two-second delay for drogue and deployed at 500 feet AGL for main in order to prevent over-pressurization of the body tube. The avionics bay featured a removable avionics board consisting of two independent Stratologger CF altimeters with corresponding independent power sources, switches, initiators, and black powder charge wells. The parachutes were also folded and wrapped within a fire blanket in order to mitigate the potential for tearing or ignition during deployment.

1.3 Payload Summary

Payload Description

This year’s payload competition was to design and build an autonomous rover that is secured in the launch vehicle during flight and deployed after landing. Once the rocket landed, a signal was sent to tell the rover to exit the rocket and drive a minimum of 10 feet. After the minimum distance was reached, the rover had a mechanism to collect a soil sample of at least 10 milliliters.

The payload bay was able to freely rotate within the rocket body and was weighted such that the bay would always be oriented correctly upon rover deployment. The payload bay was also designed to receive a signal from the communications system to detonate a black powder charge which separated the nose cone from the main body tube. The payload bay then unlocked the rover which then freely drove from the payload bay on to the ground. After driving more than the minimum distance of ten feet by powering the motor for 60 seconds, the rover rotated a lever arm with a scoop underneath the rover body. The scoop was supposed to pick up the soil and subsequently seal to the bottom of the rover body. The rover was constrained during flight by two shelves screwed to the inside of the rotating payload bay and locked in place with a rotating solenoid-powered locking key.

2. Competition Launch Results

2.1 Launch Vehicle

Data Analysis and Results

The flight vehicle ascended smoothly and in a controlled manner to 5061 feet which was 219 feet lower than the target altitude of 5280 feet. Figure 3 shows the altitude versus time plot from the primary altimeter. Figure 4 is a picture of the ascent of the vehicle. The discrepancy in the apogee of the flight vehicle is likely due to a miscalculation of the mass of the rocket, specifically the motor. During the fullscale test flight the team weighted the motor at 9.8 lbs which was 1 lb lighter than the mass in the OpenRocket default database. The team used this information to run OpenRocket simulations with 1lb of mass subtracted from the total vehicle mass to offset the apparent extra mass OpenRocket was adding. OpenRocket's database was accurate because the fully assembled motor weighed 10.9 lbs on launch day. The team is looking into more accurate scales and balances for weighing component parts for next year.

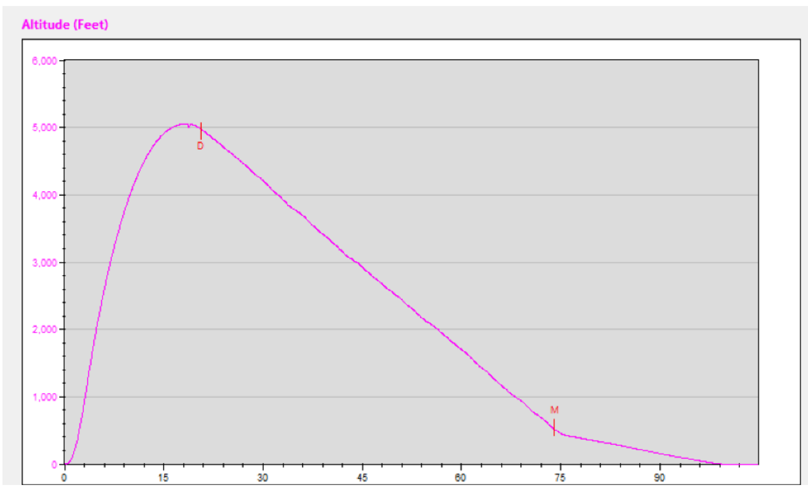

Figure 3. Altitude versus time plot for the competition launch

Figure 4. Ascent of the flight vehicle at the competition launch

Both sections of the rocket separated successfully at the correct altitudes upon firing of the primary altimeter. Both main and drogue parachutes exited the body tubes and deployed as predicted. The flight vehicle descended in the orientation predicted without any of the body tubes colliding or damaging components. The descent of the rocket under main and drogue are shown below in Figure 5.

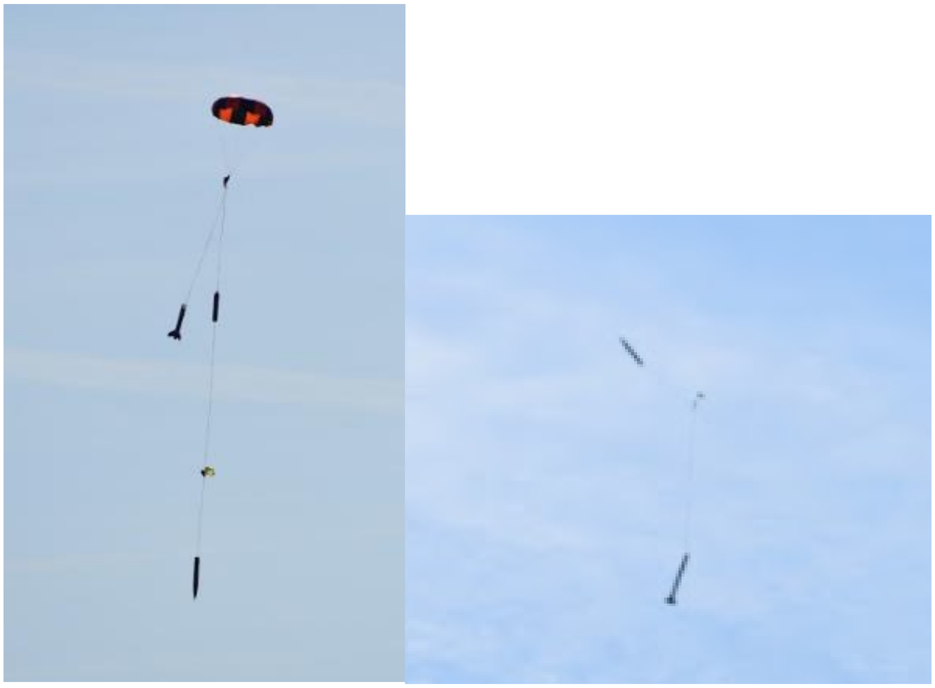

Figure 5. Descent of the rocket under main and drogue

The predicted drift distance was 820 feet with the predicted wind speeds and our actual drift distance on the day of competition launch was approximately 1000 feet, within the acceptable 2500 foot range. However this could not be validated since our GPS did not save the position due to an operational error. This was caused by a step to manually save the data that was not included on the post flight checklist. Figure 6 shows the predicted drift distance and Figure 7 shows the predicted descent of the rocket from apogee. The difference between the predicted and actual drift distances is about 180 feet. This can be accounted for the launch angle being angled away from the crowd a few degrees since our calculations were for a launch straight up. The rocket also may have encountered slightly different winds at altitude that could not be measured from the ground.

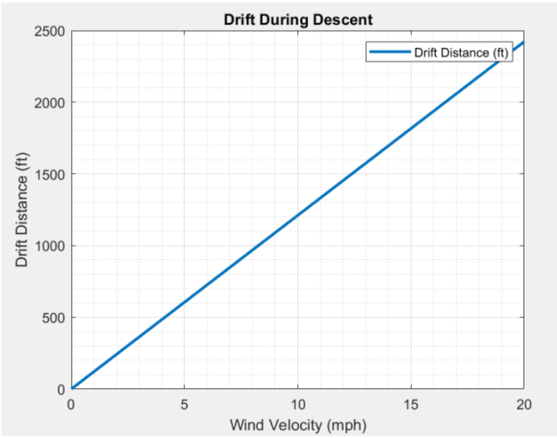

Figure 6. Predicted drift distance of the flight vehicle in varying wind speeds

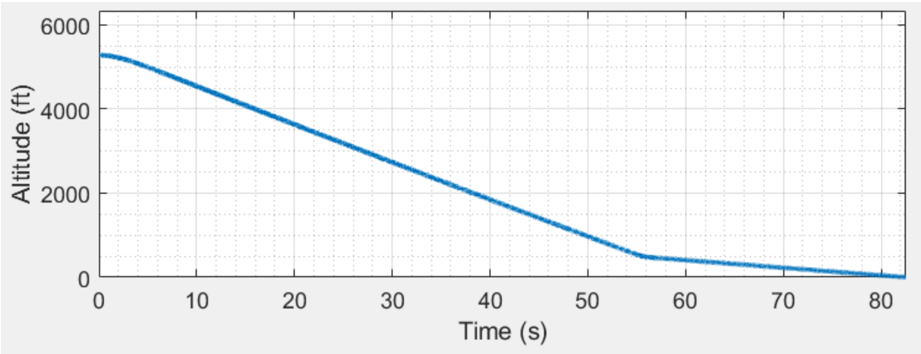

Figure 7. Predicted descent from apogee

The predicted descent velocity for descent under drogue was 87 ft/s, and the actual descent velocity after drogue deployment was 83.8 ft/s. This difference of 4% is likely due to unpredictable winds. This margin of error is a 200% improvement on our results from the fullscale test flight. The descent velocity under main was 19.2 ft/s, while the predicted decent velocity under main was 18.5 ft/s. The predicted descent velocities are shown in Figure 8 and the actual descent plots are seen in Figure 9.

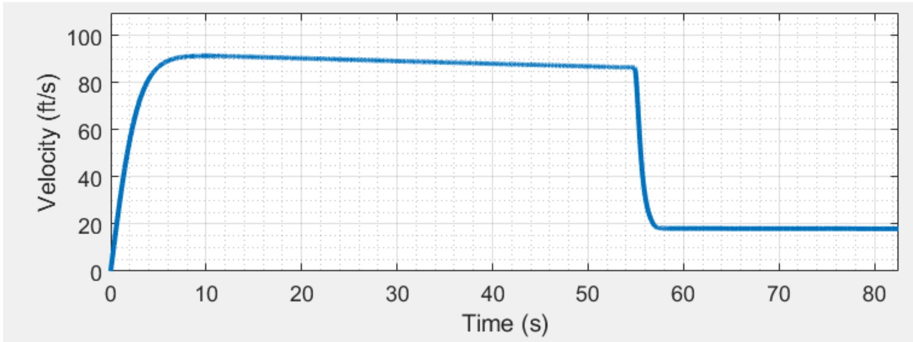

Figure 8. Predicted descent velocities for the competition launch

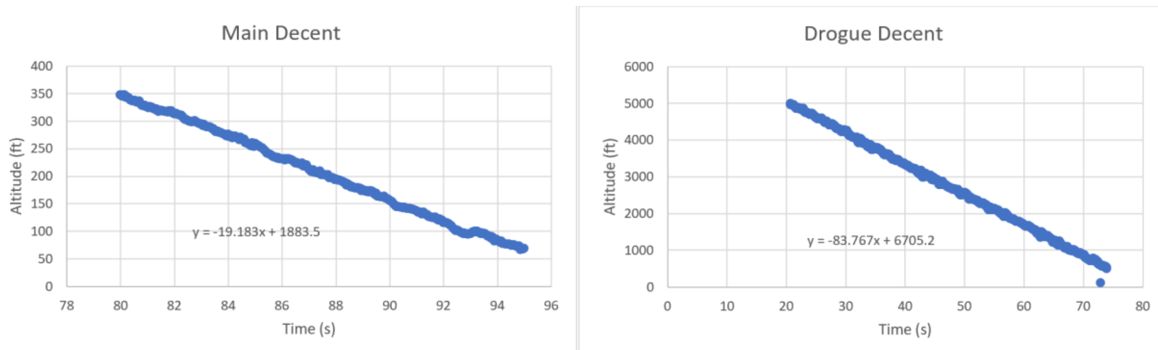

Figure 9. Actual descent plots for the competition launch

Upon retrieval of the launch vehicle, all structural components were analyzed to determine if significant damage had occurred. The carbon fiber body tubes and all other structural components successfully withstood all launch, flight, and impact forces without any visual deformation. Several components were scratched and dirtied from the landing but are in condition to re-fly right away without any maintenance. The fin bracket that cracked on the test flight did not sustain any damage during the competition flight, showing that the team’s fix implemented after the fullscale test flight was successful.

Additionally, there was no damage detected to any of the recovery components. The door to the avionics bay did not prevent the altimeters from accurately measuring air pressure, and it allowed quick access to the avionics bay while the rocket was on the launch pad. Neither the quick links, fire blanket, nor shock cords in main and drogue sustained any damage. The nomex fire blankets protected the parachutes during deployment and ensured they were not damaged when the black powder was ignited. There were no tears in the aluminum foil faraday cage and no unwanted electromagnetic interference was detected. Additionally, no threaded rods or other metal components located inside the avionics bay shorted any electrical components. No cracks were detected in the PLA used to 3D print the avionics bay and the avionics board. The charge wells used to contain the black powder maintained their structural integrity and were not damaged during the ignition of the black powder. There was no black powder found in the avionics bay after launch, which indicates that the putty and tape covering the holes in the bulkheads prevented any blowback upon initiation of the black powder.

2.2 Payload

Data Analysis and Results

The rover was successfully retained during launch and descent by the solenoid locking mechanism. After the rocket had landed, the payload bay was in the correct orientation for the rover to exit the launch vehicle upright. The ground station then successfully sent the signal from the ground station to the rocket to separate the nose cone from the rocket with a black powder charge. The rover exited the vehicle and proceeded to drive for 60 seconds which ended up taking the rover to the minimum of 10 feet from its original starting distance.

Once the rover reached its destination after driving for 60 seconds, the soil sample recovery system failed to recover the soil due to a failure in the electronics that pulled the string for the scooping arm. The reason for this failure was most likely due to a failure in the electronics for the soil sample recovery system.

While not meeting the end mission goal of soil sample recovery, there were multiple successful components to the payload. The rotating payload bay, retention, deployment, and rover driving mechanisms all worked as expected. Further testing and development time would have most likely allowed for the successful operation of the soil sample recovery system as well.

Scientific Value Achieved

While developing and testing a solution to the competition, the payload subsystem determined that an autonomous rover would be useful in rocket launches to drive to a location and obtain information about the landing site. It is vital that the rover is autonomous because LTRL should not need to have access or be within a certain range of the rover for it to function properly. The soil collection mechanism allows the team to gain further information about the surroundings through an analysis of the soil. Importantly, the soil would be protected from contamination in transport because of the air-tight seal on the containment mechanism.

3. Lessons Learned

Most of the lessons learned this year were in the payload subsystem. Although many of the design decisions were decided early on, their full integration into the rover was not entirely thought out. One example of this was the soil containment mechanism. As the payload team went through the design process for the rover, ideas and simple drawings were created of the soil retention system, but issues and bugs arose out of testing the driving aspect. Their solutions changed the overall design, and the soil containment was not modified. It is important to keep the whole design of the rover in view rather than individual modifications and make unnecessary compromises. Beyond the technical lessons in the building and modeling of the payload, our young leadership in the payload team gained experience with retaining new members and delegating responsibilities to general body members.

4. Summary of Overall Experience

Participating in NASA's USLI competition was a valuable experience. All members gained hands-on experience working in an integrative team, constructing a design that the members personally made, and overcoming challenging problems that are not encountered in the classroom.

One of the main goals for the payload subsystem this year was improving testing and integration of the payload by better meeting deadlines and communicating better between subsystems. This was a goal that was achieved but could still be improved upon in future projects.

Overall, more testing was done this year than previous years and this was helpful in the success of the rover retainment, deployment, and driving. This is something that the team hopes to continue to progress in. To better improve this, more test procedures will be written to better organize testing.

Additionally, integration was better improved this year by increasing communication between the payload subsystem and the structures subsystem. The mass of the rover and payload system was approximately 48 oz which was 2 oz under the allowed amount from the structures subsystem. This allowed for the team to more accurately reach the target altitude.

5. STEM Engagement Summary

To keep other people of the community involved, LTRL participated in many outreach events during the school year. Many of these events took place in State College such as the annual STEM engagement event at Bald Eagle High School, and addition outreach was done in team members' hometowns such as Bethel Park High School. At these events LTRL members showed their excitement in their STEM field in hopes to motivate people of all ages to become involved with science and technology. During these events, team members went to elementary schools, middle schools, and high schools to display LTRL's past projects. Team members disassemble rockets to show pieces of the rocket such as the avionics bay, the rover, and where the parachutes go on launch day. For younger students, club members set up a competition for balloon races to explain propulsion. For older students, the team has the engaged students build drinking-straw rockets to show the effectiveness of fins for stability.

All LTRL members interested in traveling to Huntsville, Alabama for the Student Launch competition in April are required to attend at least two outreach events. The public relations/outreach chair was responsible for setting up these events and for making a packing list of supplies that needs to be taken to the event. The team did not bring energetics to any of these events since the team does not hold any demonstration launches.

This year LTRL educated 665 students of varying ages and education levels through all of the outreach events.

6. Final Budget Summary

Table 1 gives the club's inflow for the academic year.

Table 1. Inflow 2018-2019

Donor	Requested Amount
Penn State Aerospace Engineering Department	$2,000.00
Penn State Mechanical Engineering Department	$1,500.00
Club Fundraising	$1,250.00
University Park Allocations Committee	$10,000.00
Engineering Undergraduate Council	$1,000.00
Pennsylvania Space Grant Consortium	$2,000.00
The Boeing Company	$500.00
Northrop Grumman	$200.00
Total	**$18,450.00**

Table 2 gives the summary of the outflow for the 2018-2019 academic year.

Table 2. Outflow 2018-2019

Budget	Cost
Fullscale	$2,031.85
Subscale	$867.69
Travel	$5,509.84
Outreach	$300.00
Miscellaneous Supplies and Equipment	$500.00
Total	**$9,209.38**

Overall, this past year was financially successful. The expenses for fullscale include costs of equipment and materials that were used to build the final launch vehicle. Subscale accounts for costs of the subscale launch. This includes mainly expenses from the airframe and motors since there was reusable equipment from previous years for flight and recovery. Travel accounts for the costs of hotels, rental cars, and fuel for Alabama and fuel reimbursements for the various test launches. The main expenses of the Alabama were the rental cars and the hotels. Outreach expenses include costs of any miscellaneous materials that may have been required for the event.

Without all of the sponsors for LTRL, a successful year would not have been possible. As seen in Table 1, The Penn State Aerospace Engineering Department granted the club $2,000.00. The Penn State Mechanical and Nuclear Engineering Department also agreed to donate $1,500.00. Club fundraising collected $1,250.00 mainly with club dues. The University Park Allocations Committee was the biggest supporter of the club this year with giving $10,000.00. The Pennsylvania Space Grant Consortium gave the club $2,000.00. The Boeing Company donated $500.00 for the club this year. Northrop Grumman gave LTRL a $200.00 stipend.

The sponsors' support was used to fund LTRL to completion of the University Student Launch Initiative. The full scale and subscale rocket were one of our main expenses at $2,899.54 to fund both scales. Travel was the other main expense costing the club $5,509.84. There was $300.00 allocated to outreach and $500.00 given for miscellaneous expenses. The remaining funding will roll over to be used next year.