USLI Post Launch Assessment Review 2016-2017

Project Odyssey

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Vehicle and Payload Experiment Criteria

1: Team Summary

Team – LionTech Rocket Labs (LTRL)

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2: Motor Used

The motor selected for the competition was an Aerotech L1170 motor, which uses an ammonium perchlorate composite fuel. This gave our launch vehicle a predicted apogee of 4876 ft, a thrust-to-weight ratio of 6.39, and a stability off the rail of 2.94 calipers. This motor selection was not our primary choice of motor, as the primary motor was unavailable to purchase through our usual suppliers due to an unexpected shortfall in the manufacturer's inventory.

3: Payload Summary

The payload submitted by LTRL this year for competition was FOPS (Fragile Object Protection System). FOPS utilized non-Newtonian fluid, cotton, and foam to protect the clay pigeons during flight. The clay pigeons were separated from the liquid in a plastic bag lined with foam and cotton. The second payload that was not submitted for the competition was Kiwi, which is an autonomous gyrocopter that would be guided to a GPS coordinate specified by the ground team.

4. Vehicle Summary

The launch vehicle is 147 in. in length including fins, and has an airframe diameter of 6.079 in. With the motor included, the center of gravity is located 94.25 in. from the tip of the nose cone and the center of pressure is located at 118 in from the tip of the nose cone. The mass without the motor is 516 oz. and with the motor is 692 oz. The cross-sectional area is 38.92 in. squared.

Figure 1: Three-view of launch vehicle.

The launch vehicle's airframe is constructed of Blue tube 2.0 and an acrylic section for the fragile object payload. The vehicle also featured a 3D printed transition coupler to accommodate the change in diameter from the acrylic to the Blue tube. The fins were made of 3/16 in. fiberglass and were held in place using bolts and nuts to the 3D printed fin brackets. The launch vehicle also utilized additive manufacturing for a camera cover. This camera solely recorded down-body footage of the flight. The nose cone was a fiberglass von Karman design which was determined from research was the most aerodynamic design.

The launch vehicle used a dual deployment event recovery system in which the rocket separated at two points and deployed its parachutes. The drogue parachute was deployed at apogee while the main parachute deployed at 700ft AGL which reduced the kinetic energy at landing to safe levels. The parachutes used were 12" Classic Elliptical and a 72" Iris Ultra parachute from FruityChutes for the drogue and the main respectively. The avionics system is comprised of two completely redundant independent systems that ensured the safe descent and landing of the rocket. The recovery of the rocket was successful and all charges deployed as expected.

5. Data analysis & results of vehicle

Upon retrieval of the launch vehicle, the structural components were analyzed and any deformation or damage sustained after flight was noted. There was slight zippering on one end of the Blue tube where a preexisting crack was located. In addition, there was slight separation of the fin bracket and the body tube: this was likely due to the fact that the rocket impacted on the fins at landing. For next year, experimentation with shear pin mating of the fins and fin brackets will be explored. This is so that this landing will not damage the brackets, but rather shear from the brackets and be easily replaced. The launch vehicle achieved an apogee of 4691 ft, which was the predicted apogee considering the excess mass discovered late in the construction process.

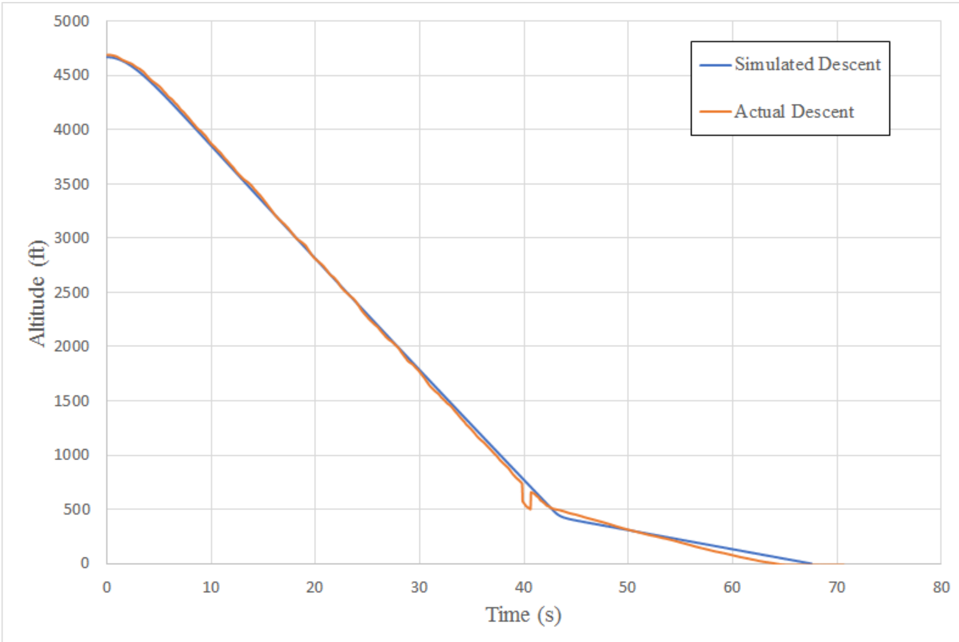

Figure 2: Altitude v. Time of descent of rocket

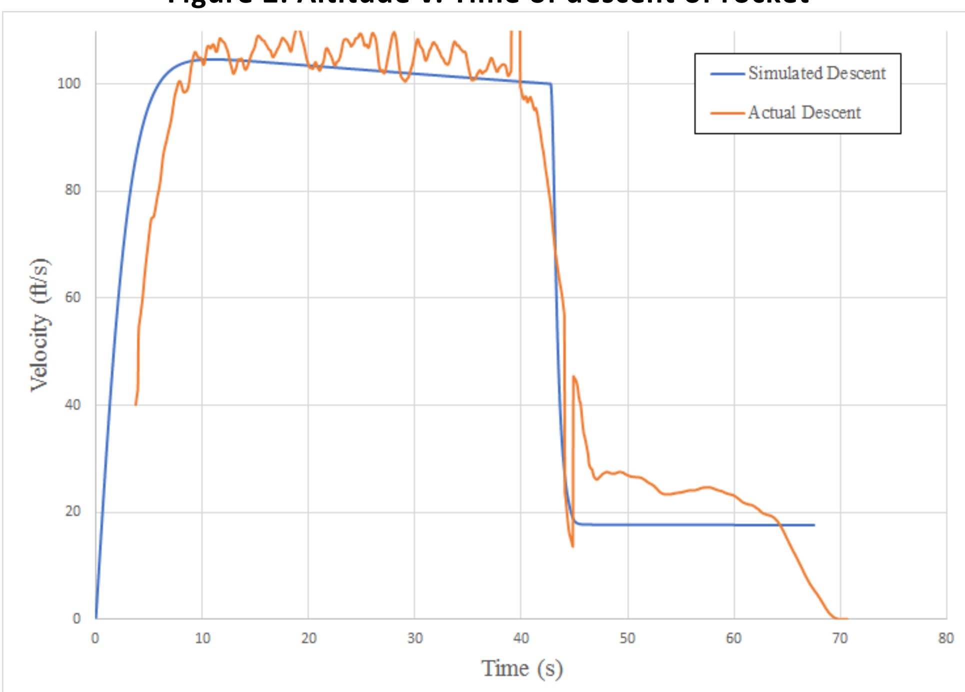

Figure 3: Velocity v. Time of Rocket During Descent

As the graphs show, the actual data and the simulated data are very similar. The simulated flight data was able to be so accurate because the program was fine-tuned after the practice full-scale launches. As a result, the estimated time of descent was within a few seconds of the actual time. For the program, the main thing that had to be tuned was the drag of the body of the rocket at various points during descent. This allowed us to be able to ensure that the drift and kinetic energy were within the expected limits. While the actual flight data shows that the velocity under the main parachute was slightly higher than the predicted model, the velocity right before landing was only a couple of miles per hour faster which means that the kinetic energy of each part was within the kinetic energy limits. This is especially guaranteed by the fact that the 84” parachute allowed for some variation in landing velocity because each part was expected to land well within the limit.

6. Payload Summary

The purpose of FOPS is to protect any fragile objects that fit within a 3’’ diameter and 6’’ tall cylinder. A 1 inch layer of non-Newtonian fluid was poured into the bottom of the payload bay. A 1 gallon re-sealable plastic bag was then put into the payload bay. Foam was then used to line the circumference of the bag to prevent accidental contact with the walls. Cotton was also placed inside the bag to provide additional cushioning, and another layer of non-Newtonian fluid was poured on top. The specimens (clay pigeons) were placed inside the plastic bag, and the individual clay pigeons were separated with cotton to prevent accidental contact during flight.

7. Payload Data Analysis and Results:

FOPS worked as designed and the clay pigeons were retrieved intact from the payload bay shown in Figure 4.

Figure 4: The 5 clay pigeons after flight

8. Scientific Value

This year, LTRL experimented with several major applications of additive manufacturing. The decision to utilize PLA plastic as the fin bracket material was made. This was to allow for easily replaceable fins. PLA was chosen over ABS plastic due to concerns of ABS warping during printing and producing uneven layers or geometric tolerances. Similar to the fin brackets, a PLA transition coupler that served as a critical structural component was fabricated. Several printing settings were experimented with throughout the part's design and prototyping iterations. This has led to a better understanding of the correlations between infill and shell thickness with impact and shear resistance.

This rocket serves as a proof of concept that semi-liquid payloads can be used in future rocket launches without being detrimental to the stability of the rocket. Second, FOPS proves that it is possible to protect sensitive components during launch without an overly complicated payload. This system will be useful if delicate components (such as electronics or sensitive scientific experiments) need to be launched in the future.

This year, the avionics bay was 3-D printed. LTRL decided to 3-D print the avionics bay because it would be significantly smaller and lighter than building one out of fiberglass. With the new AV bay and coupler, most of the set up occurred the day before launch. This allowed for quick assembly on launch day which was important because there were time sensitive components of the rocket. The avionics bay maintained structural integrity throughout the flight and the 3-D printed coupler that held the faraday cage protected the avionics electronics. This year was the first year that a 3-D printed bay and coupler was used and due to its success, it will most likely be used in the future.

The parachutes to use this year were determined by modeling the flight using a MATLAB program. The program has been instrumental in choosing the parachutes for various rockets this year, including the subscale rocket. The success criteria for the recovery system are that the kinetic energy of the largest component must be less than 75 ft-lbs and the drift distance in 20 mph winds must be less than 2500 ft. The parachutes chosen for the rocket were selected to meet the aforementioned criteria. These parachute sizes were selected using the Recovery Descent Profile Calculator (RDPC), a MATLAB code generated by the recovery to make decent predictions and select parachute sizes. RDPC uses a force balance integration method to calculate a descent profile. At each time step, the altitude and velocity are used to find the force of drag the parachutes are exerting on the rocket system. This drag force and the force of gravity are then summed to get a net force, from which the acceleration can be calculated. This acceleration is used to find a velocity at the next time step, after which the process continues until the rocket hits the ground.

9. Visual Data Observed

A slight wobble was noticed immediately after ignition and rail separation. This didn't last long, as the rocket stabilized shortly. This was likely caused by imperfect fit of the couplers and the body tube. In addition, the launch rail was at a slight angle which could have caused the non-Newtonian fluid to gather towards one side of the acrylic airframe section. This mass imbalance could have also contributed to the slight wobbling of the launch vehicle after rail separation.

During descent, both of the parachutes ejected as expected. The drogue parachute deployed at apogee and there were two puffs of smoke signifying that both ejection charges deployed. This was a good sign that both altimeters were fully functioning. Then at 700 ft, the main parachute deployed and again, both ejection charges deployed. The main parachute expected fully and without tangling which allowed the rocket to land safely. At the recovery site, the rocket was intact and there were no live charges. Upon inspection, the parachutes showed no signs of damage which is due to the fact that they were fully protected by the nomex blankets. The avionics bay was unharmed and could be used for other flights. The entire recovery harness also showed no signs of damage due to the fact that it is made of Kevlar and was connected properly.

10. Lessons Learned

Several lessons were learned throughout the duration of the project. One major lesson was the importance of verification when estimating masses of components. This lesson was learned when the manufacturer of Blue Tube 2.0 airframe section listed a weight that was lower than what was eventually measured in-house with the received product. This inconsistency with mass, when gone unnoticed for a significant portion of the project, complicated simulations and other component selections that had already been established based on the data. In addition, several other parameters, such as stability and motor selection, are sensitive to mass and mass distribution and the process for determining both could have been streamlined by verifying the mass of each component before the launch vehicle design is finalized. One mitigation to help prevent issues like this in the future would be to compile a running list or spreadsheet with the measured mass of every component being considered for the launch vehicle design in the early stages of the project. This would result in a more streamlined process with less confusion and miscommunication between subsystems.

Another lesson to be learned is to establish means for testing materials early in the rocket design process. Testing properties such as material strength of the airframe can help solve issues seen with zippering during parachute deployment and fracturing of 3D printed components. By finding the limits of the materials that are worked with, more informed decisions on general launch vehicle design can be made. This would result in a more efficient process, manifesting itself in a superior product in a shorter amount of time.

The Avionics and Recovery subsystem learned several lessons during the construction and launches of Aeolus. There was an emphasis on streamlining the launch day process which meant that having checklists was very important. Robust checklists ensured that everything was assembled properly and allowed the team to have confidence in the equipment. In the event of any malfunctions, A&R learned the importance of spare parts. On launch day in Alabama, one of the e-matches had to be replaced because the wire came loose of the connector. This was a quick fix because there were spare e-matches attached to connectors. This experience solidified the importance of having spare parts on launch day.

When working on the FOPS and Kiwi payloads, time management was difficult for the team. Electronics problems were the primary reason for being behind schedule. In the future, more time will be allotted to electronics troubleshooting. Another lesson learned was to have better integration between the Structures subsystem and the Payload subsystem. Lack of communication caused issues with time management and integration of the payload into the rocket.

The Propulsion learned that we should always confirm if suppliers have adequate stocks of a potential motor before final motor selection. Also, testing the various motors we use for the subscale and full scale rockets would have helped with more accurately calculating important flight characteristics such as velocity and stability off the launch rail, burnout timing and velocity, burn profile, and apogee.

11. Summary of Overall Experience

Participating in the USLI competition was a very valuable experience. The A&R subsystem developed a new avionics bay and coupler that allowed for quick assembly on launch day. This system will most likely be used in the future because it was so successful. Additionally, the MATLAB code that was developed and refined throughout the year proved to be very accurate. This will also be used in the future because it facilitates the choice of parachutes and gives a model for the descent of the rocket. Developing the avionics bay and coupler and the MATLAB code advanced the quality and accuracy of the rockets LTRL makes.

The overall experience was incredible rewarding and fulfilling for all members involved. Many members had not had any prior experience in the field of rocketry before partaking in this competition. Learning about the rocket and its challenges was incredibly educational for members interested in group engineering work. The challenges faced throughout the year such as integration between subsystems, unexpected mass issues, and fracturing problems with 3D printed parts are issues that any engineer will encounter throughout their career. It is valuable to have experience with rocketry and the unique challenges that it brings, as these challenges are typically not found in a classroom.