Team name – LionTech Rocket Labs
Team Advisor – Dr. Michael Micci (x0c@psu.edu)
Team Lead – Adam Mohammed (aqm5498@psu.edu)
Safety Officer – Amy Maffei (yma723@gmail.com)
Address – 46 Hammond Building, University Park, PA 16802
Mentor – Robert Dehate – NAR L3CC - #75198

Motor Selection:

The motor selected was the L1350-CS produced by Cesaroni. The motor performed about as expected from static testing and allowed for a nominal flight. This motor was changed from the L645-GR because of safety concerns due to mass gain at the time of FRR. Changing motors increased the thrust to weight ratio from 3.73 to 7.55 allowing the rocket to remain stable in flight.

Altitude Reached:

Utilizing the L1350-CS and the data collected on launch day, the rocket reached an apogee of 5045 ft. Wind speed data was collected and entered into a model allowing for an appropriate mass adjustment of the ballast weight in the rocket. Due to the variability of wind, unknown amount of force due to drag from ASP, and a degree of error in the model 5045 ft was achieved instead of 5280 ft.

Brief Payload Descriptions:

The two payloads LTRL submitted in this year’s competition were TAP(Terrain Analysis Package) and ASP(Active Stabilization Package). TAP is a camera-based system which uses color segmentation to determine the location of ground hazards during rocket descent. ASP uses control surfaces on the rocket fins to control the spin of the rocket during ascent.

Vechicle Summary:

In Figure 1 below, a model of LTRL's rocket is shown:

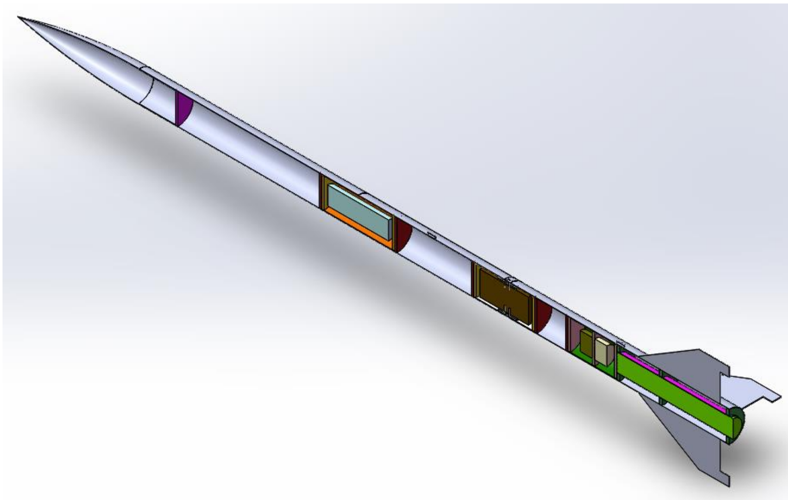

Figure 1: The Rocket Model

Pre-Launch:

High winds on launch day, about 15 mph sustained, caused our rocket simulation stability to drop below the required 2.0 calipers. To ensure a safe and stable flight, a 12 ounce machined aluminum block was installed into the nosecone connecting coupler. The mass was held in place by two 1/8" diameter bolts fastened to the forward bulkhead. With the aluminum block in place, the new stability according to OpenRocket simulations was an acceptable 2.1 calipers off the rail.

Post-Launch:

After recovering the rocket, all damages were assessed. The fin, which was the first point of contact with the ground, was slightly loose. The hinges on the control surface of the same fin also showed signs of damage. After analyzing the video taken of the landing, the booster section was seen swinging downward at the time of impact causing a larger than expected force on the fin. The rest of the structure of the rocket was without damage other than scuffed pant.

Data Analysis & Results of Vehicle:

As can be seen in Figure 2, the rocket reached an apogee of 5045 ft. above ground level (AGL). At apogee, the drogue chute deployed on the secondary charge, as can be seen with the delay in velocity reduction. The rocket successfully descended under drogue until it reached 725 ft. AGL, where the main chute was deployed using its primary charge. The vehicle descended under drogue until it successfully landed in the field, where it was recovered by ground crews.

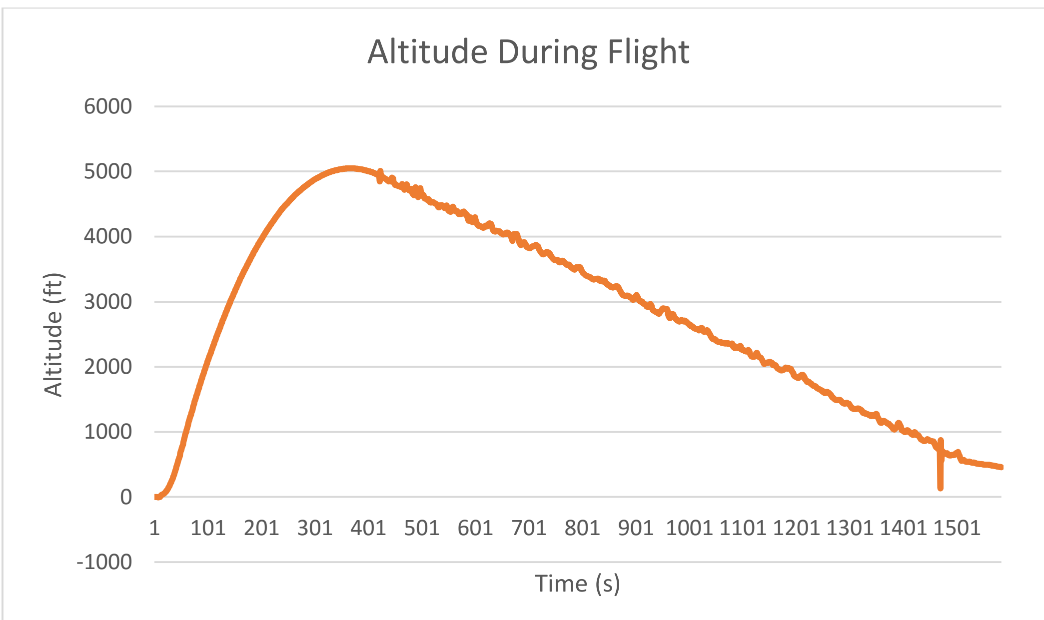

Figure 2: Altitude During Flight

Payload Summary:

Terrain Analysis Package (TAP):

TAP uses a small camera encased in a protective shell that is mounted on the outside of the rocket, facing down-body. Video data is captured using the camera, and stills will be pulled from this video data. Images are then posterized, to reduce the number of colors that TAP must analyze. Colors that constitute a large portion of the image are classified as “background” colors. These background colors are considered to be normal terrain, which do not pose a threat to the rocket upon landing. Colors that are not present in large amounts are considered “object” colors, which designate pixels in which hazardous objects are imaged. Groups of hazardous pixels are then grouped together using blob segmentation. “Hazard” blobs are then analyzed for size, with blobs of a significant size considered landing hazards. Using altimeter and GPS data, each hazard is then given a location. For each image, a list of hazard locations are generated, which is then transmitted via radio to the ground control station.

Unfortunately, the camera used to capture images for TAP broke, which prevented its use during the competition, therefore there was no visual data or result for this payload.

TAP’s objective revolves around the success of the system. TAP will take stills from a constant video feed while in descent, beginning at a height of 700 ft. TAP will analyze those pictures in real time to find landing hazards with a diameter greater than or equal to 5 feet. Using mathematical calculations and a GPS locator, the coordinates of each hazard will be identified. These coordinates will be compiled and transmitted to the ground station.

TAP will have completed its task if it can accurately detect terrain hazards and relay those hazards’ position to the ground control station. Any object that could cause damage to the rocket upon landing constitutes a hazard that must be detected. All data from the TAP must reach the ground control station, and provide an accurate analysis of the landing zone to consider the mission successful.

The software LTRL has constructed will detect any potential landing hazards without issue. At its basis, TAP uses reliable pre-existing computer vision concepts, such as distinguishing color and blob segmentation. TAP relies on the distinction in color between hazardous objects and terrain and safe terrain. The system will divide the colors in the image being analyzed into hazard and non-hazard categories, and classify blobs of hazardous colors meeting a size requirement as hazardous. Ground tests have proven that the method and software for the image analysis is reliable and results have been verified by inspection. During testing during vehicle flight, the Payload team will ensure that TAP can reliably distinguish between regular terrain and hazardous objects or terrain by verifying results through inspection.

The TAP will be ground tested by analyzing photographs of real-life terrain examples. The accuracy of the TAP will be determined by how many terrain hazards it detects, as well as accurately reporting the relative locations of all hazards. Hazards will be considered to be any objects that would cause damage to the structure of the rocket upon landing. Misinterpretations of regular, safe terrain as hazardous will also be considered in assessing the accuracy of TAP. Tests will begin with analyzing plain global imaging pictures of regular fields and plains where no hazards are present. The next series of tests will be of images with distinct terrain hazards. The distinction of hazard from background terrain will be made smaller with each progressive test, until the software has been refined to the point of being able to accurately detect and locate at least 80 percent of obstacles, and not confuse any regular terrain for hazards. Additional tests will be done by running the software in full scale flights.

Data collected from testing will consist of the ratio true hazards detected to actual hazards existing and the ratio of false hazards detected to true hazards detected. This data will show the accuracy of the system and provide a method of comparison between old and updated versions of TAP. The data acquired from the launches of the rocket will show the ability of the TAP to analyze terrain and isolate landing hazards in real time. By determining where ground hazards are present, TAP will demonstrate the ability to analyze terrain with minimal processing power and equipment. While TAP is not expected to distinguish between hazards and non-hazardous terrain with perfect accuracy, TAP is expected to find all hazards, and all terrain features that may be construed as hazards.

Describe the preliminary experiment process procedures - The testing of TAP will be multi-faceted, with each individual segment being tested before testing the combined system.

The battery will undergo testing to determine how long it will provide power for the system. The camera quality will be tested by taking images of objects at various distances while the camera is both stable and moving. The raspberry pi and its software will be tested for speed and accuracy by running test images through the system. The images used for testing will be inspected by team members to identify landing hazards and the team's analysis will be compared to that of the system to verify that TAP works. After each iteration of the tests, the software will be adjusted to more accurately detect hazardous objects. Adjusted variables could include the percentage threshold for a "background" color, the amount of smoothing, and the amount of posterization. The range of the radios and the quality of their transmitted signals will be tested both horizontally and vertically, while the radios are at various orientations relative to each other. TAP as a whole will be tested by mimicking the vertical tests for the radio. The distance between the "on-board" system and ground station will be increased using the uniform floors of a building.

Active Stabilization Package (ASP):

The Active Stabilization Package (ASP) utilizes a 10-Degree of Freedom (IMU) in order to input the rockets current parameters such as speed, roll rate, and altitude into a PID controller. This controller, with the use of 4 independently actuated fins, was designed to hold the rocket at a near constant roll rate for the entirety of the flight. This roll rate is induced in order to increase the stability of the rocket.

As can be seen from the data in Figure 3, the ASP was able to hold the rocket at a near constant roll rate for a majority of the ascent. Unfortunately, 1 of the servos had failed before the flight, so we had to do the flight using only 2 actuated fins in order to keep the rocket symmetrical. So while it was able to hold a constant roll rate, this was below the targeted 4 Hz that we wanted. As well, this was done with the fins at a constant maximum deflection as can be seen in Figure 4. Had the ASP been fully operational, with 4 functioning fins, we believe that it would have been able to maintain the 4 Hz roll rate.

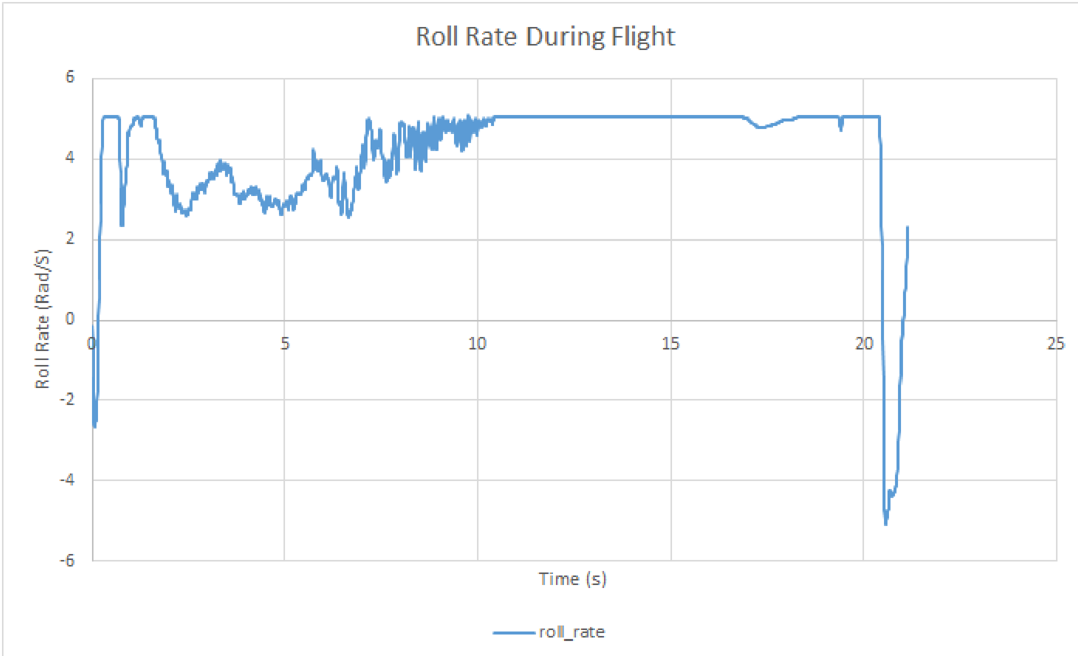

Figure 3: Roll Rate during Flight

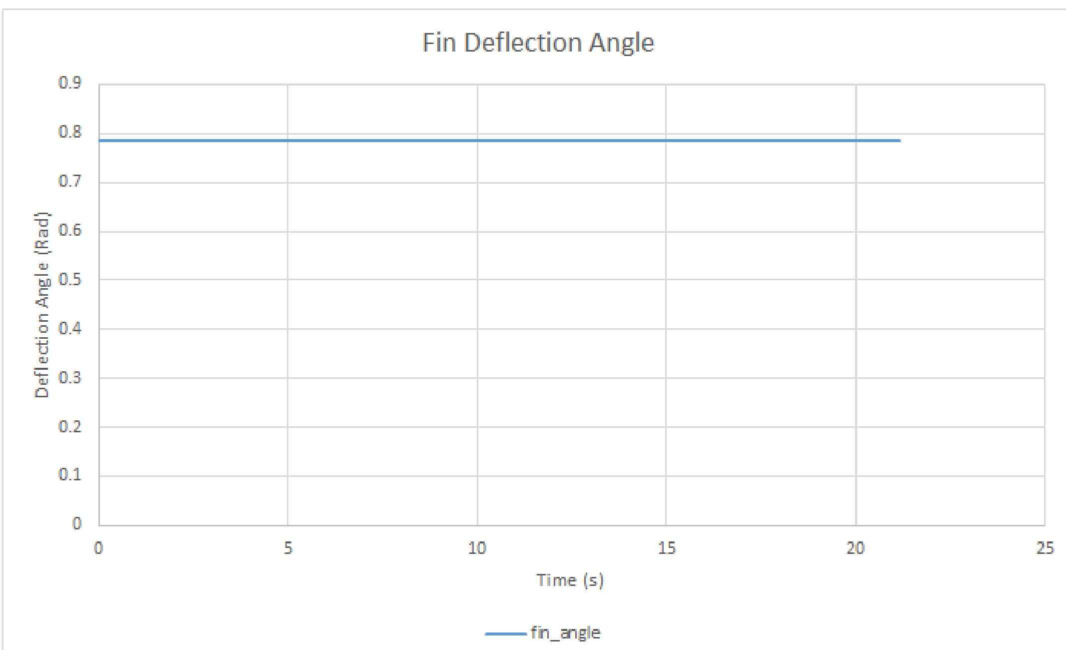

Figure 4: Fin Deflection Angle during Flight

On landing, the external control components had received minor damage, two of the pushrods were bent and one control horn was broken, as per the requirements though these parts could have easily been replaced within a short period and the ASP could have flown a second time that day.

The ultimate goal of the ASP was to prove that a system capable of controlling the attitude of a high powered rocket could be developed at the university level using components that could be procured on a budget. We believe, through the successful flight of the system, and through vigorous testing, that this goal has been met. Moving forward, the capabilities of the ASP can be expanded upon. New requirements can be set in order to make the ASP a more reliable and versatile system that could control rockets of many different parameters, with minor adjustment to the gains of the PID controller that guides it.

High speed footage and NASA provided footage were analyzed upon receiving them. Analysis of the high speed footage showed no flutter of the fins like what was seen at previous test launches. In previous launches, the code was not running, but this time the program was instructed to hold the fins in place until about 10 meters off the ground. This is likely the reason why no flutter is observed. Analysis of NASA footage clearly shows the roll being put onto the rocket as it ascended.

Lessons Learned:

During the competition, both throughout the year and during launch day, LTRL learned a few very important things. Many times throughout the year there were complications due to lack of communication about the integration of the pieces and systems within the rocket. In learning from this experience, the LTRL team has decided to hold regular integration meetings between the subsystems the following year. Furthermore, future projects will seek to account for the drag from specific payloads, as well as more accurately predict mass adjustments needed. Ballasts will also be designed so as to make adjusting the total mass of the rocket an easier process. Additionally, since an entire payload was rendered nonfunctional due to one faulty component, the importance of having spare parts was highlighted. When purchasing components which are inexpensive, purchasing extra components for field repairs may be advisable.

Summary of Overall Experience:

This year LionTech Rocket Labs participated in the student launch program successfully for the first time in 3 years. The goals of this year was to recruit new reliable team members, establish a strong funding plan, and to have engaging projects for newcomers.

Recruitment in late August and early September increased the clubs numbers considerably. Many of the clubs existing members now have moved into technical roles and their new teammates have taken to different divisions of our club to learn about the subsystems that interest them. The technical leads' quickly adopted their new teammates and got them involved with the project.

In previous years, LionTech had not participated in the competition because of management issues. This year many of the major management issues were solved but new ones arose. Despite the new issues the club managed to secure enough funding to design, build, and test our launch vehicle and payloads. The funding was even enough to transport 27 of the members down to Huntsville from State College. Each of the members that came down participated in outreach events as well as having considerable time spent working on the rocket and payloads.

The rocket itself achieved a final altitude of 5045 feet. During the course of the year, the subscale and fullscale vehicle saw many flight tests and were built strong enough to withstand some hard landings. The active stabilization required the team to test their knowledge of aerodynamics and control, and ultimately was a success when it was flown in Alabama. The terrain analysis package worked as expected, circling hazards and relaying the coordinates and size of hazard to the ground station. TAP's camera malfunctioned on launch day though so it was not tested at the competition site.

Overall this year the team was made of mostly sophomores and juniors who hadn't participated in the student launch program before this year. After having trouble in previous years the teams' main goal was to complete the competition. The team worked through solving all the issues that had prevented us from completing the competition in previous years. Alongside completing the competition, the team designed, built and tested some very interesting and challenging payloads. Next year, the team plans on using their new knowledge to perform better in the competition.

Educational Engagement Summary:

LTRL successfully completed eight outreach event over the past years in an effort to get students in grade kindergarten through twelfth grade engaged and excited about science, technology, engineering, and math. We were able to reach out to students across Pennsylvania of all ages in a variety of hands on activities and workshops. At each event we saw great curiosity about our projects and science in general from the students. In addition all of our teammates gained experience in communication and learned about the importance of community outreach. In the end, all of our goals set for the educational engagement program were met and exceeded. We hope to reach out to even more students with new and exciting activities next year.

Budget Summary:

Income:	Expense:
Boeing Corporation: $1000	Rocket: $5519.52
PSU Aerospace Engineering Dept: $5000	Vans with fuel: $2236.76
Penn State UPAC: $3784.68	Hotel Rooms: $3784.68
Club Dues: $1000	Outreach: $110.38
Interest: $4.28	
NASA Travel Reimbursement: $1500	
Total: +$12288.96	Totals: -$11151.34
Year close: +$1137.62	

Overall, we had a very sound year financially. Our donation from Boeing Corp helped us get started, and the grant from the Aerospace department funded our rocket almost entirely. For our travel funds, UPAC paid in entirety for our hotel costs. After that, our Club dues at $25 per person for the year worked well for netting us another $1000 for the trip along with the interest from our student account adding another $4.28. After we receive our travel expense reimbursement from NASA, we will be in the black by $1137.62.

All of our costs are accounted for, but most are still pending for disbursement including the payment for Enterprise. Many are still waiting to be reimbursed for rocket parts, more than half of our total rocket cost is still floating due to issues with one of our parts suppliers. We have more than enough money in the account to handle the charges coming through at any time however. Our outreach cost was almost entirely fuel, but also contained items such as banners, tri-fold posters and so on. All together we did quite well, and have more than a small amount of money left over for next year's rocket and competition expenses.