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Tacho Lycos
2017 NASA Student Launch
Post-Launch Assessment Review

High-Powered Rocketry Team

911 Oval Drive

Raleigh NC, 27695

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1. Summary of FRR

1.1. University and Team Name

North Carolina State University High-Powered Rocketry Club
Tacho Lycos

1.2. Motor Used

The team selected the Aerotech L2200G motor for the full-scale rocket. It is a 99% L-Class motor, has a total impulse of 5104 N-s and a burn time of 2.27 seconds. It is 26.2 in. long and has a diameter of 2.95 in. The motor uses 4 propellant grains and is housed within an Aerotech 75mm/5120 casing.

1.3. Brief Payload Description

The team selected the target detection and upright landing challenge.

1.4. Vehicle Dimensions

Table 1: Vehicle Dimensions

PLAR	
Length	125.0 in
Diameter	6.2 in
Loaded Weight	52.1 lb
Center of Pressure	91.8 in
Center of Gravity	78.0 in

1.5. Altitude Reached

The vehicle reached a competition altitude of 5698 ft AGL.

1.6. Vehicle Summary

The launch vehicle was constructed from off-the-shelf G12 fiberglass and had an outer diameter of approximately 6 in. Fiberglass was chosen for its great strength to weight characteristics and all-weather durability. All couplers, the nosecone, and the motor tube were also constructed of off-the-shelf fiberglass. The bulkheads, centering rings, and fins were constructed from laminated sheets of 1/8 in birch plywood epoxied together to form sheets of varying thicknesses depending on the application. A Von-Karman nosecone was selected due to the low-drag characteristics as well as supplier availability.

The vehicle is composed of 4 sections (nosecone, AV bay, payload bay, and fin can) with 3 tethered sections in flight and a payload that separates at apogee. The AV bay and payload bay are fixed during flight but can separate on the ground in order to access the recovery avionics and GPS transmitter. At apogee, the vehicle separates between the fin can and payload bay ejecting the payload and deploying the 24 in drogue chute. The payload remains attached to the fin can for an extra 2 seconds as it is pulled from the rest of the vehicle. This is achieved by way of an ARRD pyrotechnic device that is controlled by a set of redundant altimeters housed on the fin can bulkhead. After the ARRD fires, the payload falls to the ground under its own parachute and the launch vehicle falls under drogue. At 800 ft, the redundant altimeters fire the ejection charges for the main chute which is deployed from between the nosecone and AV bay.

The main chute was downsized from an initial 14 ft diameter toroidal chute to a 10 ft elliptical based on a miscalculation of the landing energy requirement specified in the Student Launch Handbook. Along with this, the 14 ft chute caused a major hazard due to wind drift in previous launches and the team felt downsizing was appropriate and necessary. This change was reviewed and approved by NAR prior to competition launch.

1.7. Data Analysis & Results of Vehicle

In terms of recovery, the vehicle performed exactly as intended during the competition flight. All recovery devices, both drogue and main, were deployed as scheduled and slowed the vehicle to a safe landing speed. Figure 1 below shows a plot of the on-board altimeter data along with markings of when the recovery charges fired.

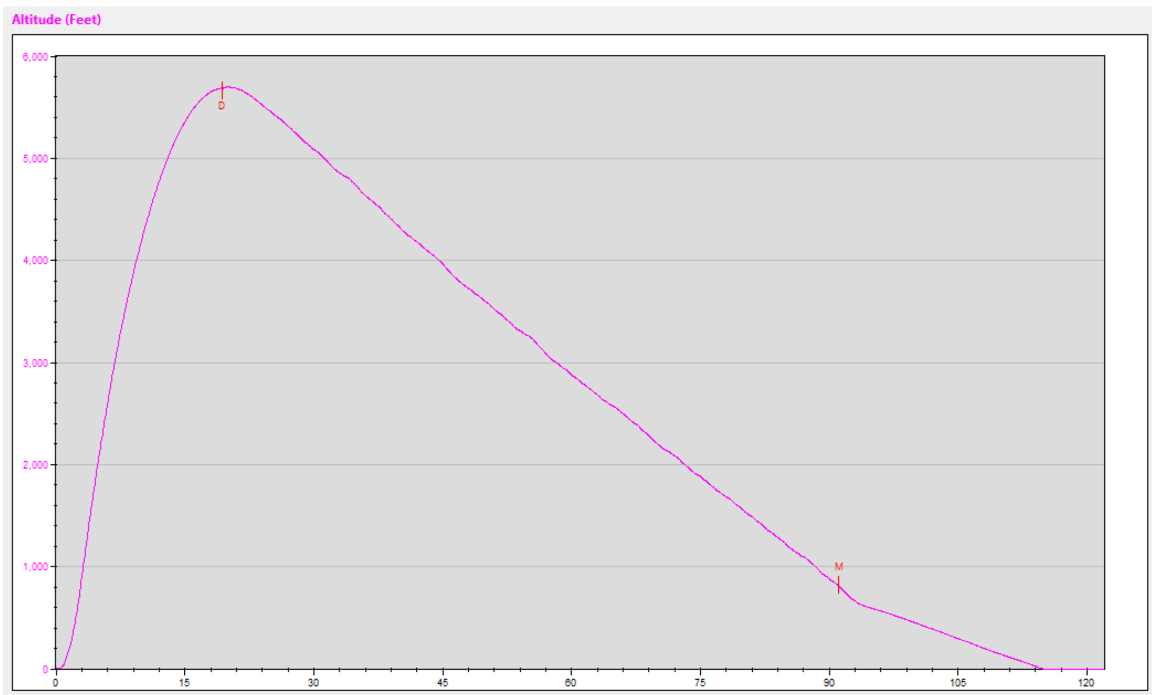

Figure 1: Competition Altimeter Altitude Plot

However, as stated in §1.5, the vehicle exceeded the allowed competition altitude of 5600 ft by approximately 100 ft and exceeded the predicted altitude by approximately 500 ft. The team has formulated a few theories as to why the vehicle traveled so high. The main chute was down-sized from a 14 ft diameter chute to 10 ft diameter chute, following NAR approval, based on miscalculation of landing energy requirements and to reduce wind-drift. The vehicle was also painted and clear coated following the qualification flight. The combination of paint and a smaller chute reduced the pad weight of the vehicle by 0.5 lb. The paint was simulated as regular finish paint in OpenRocket; however, if the finish was extra smooth dragged coefficient could have been reduced by a significant margin. Lastly, the conditions on launch day were pristine. Zero winds, clear skies, and high temperatures all contributed to extra altitude. With all of these factors taken into account, it is conceivable that the vehicle reached the altitude that it did and that the simulations were not updated accurately following FRR qualification.

1.8. Payload Summary

1.8.1. Payload Title

Piston Battering Ram (PBR).

1.8.2. Experiment Summary

The Payload Deployment System will detach the payload from the launch vehicle using an advanced retention release device (ARRD) after the payload bay and fin can have separated. After payload deployment, the Target Differentiation System (TDS), controlled by a Raspberry Pi 3 Model B microcontroller, will control all autonomous tasking for the onboard TDS. The TDS will use a Raspberry Pi Camera Module v2 to capture images of the landing zone. The microcontroller will process the images onboard, locate the targets in the landing zone, and differentiate between them. Once landed, the servo-controlled Upright Landing System (ULS) will deploy and upright the payload from its landing orientation if it is not already upright.

1.9. Data Analysis & Results of Payload

The payload was successfully jettisoned from the launch vehicle near apogee, as planned. Two redundant Jolly Logic Chute Releases were connected in series around the payload parachute, which was not the plan as of FRR. This change came about when safety officers prescribed this change during LRR in Huntsville. One Jolly Logic was set to release at 1000ft, the other at 800ft. However, shortly after separation from the launch vehicle, the parachute was fully deployed. This forced the payload to be under parachute for significantly more time than planned, but did not adversely affect wind drift in a noticeable manner.

The Target Detection System (TDS) did not operate as designed. During flight, the images taken by the Raspberry Pi Camera were corrupted and therefore the targets were not identified whatsoever. Although the source the problem has yet to be determined, a loose connection within the TDS circuit has been identified as the cause of the corrupted images.

Upon landing, the Upright Landing System (ULS) did not deploy as planned. It was determined that, during flight, the designated wires connecting the ULS servo to the Raspberry Pi became disconnected. This prevented the Raspberry Pi from communicating with the servo, which caused the ULS Legs to remain in the flight configuration after landing. In summary, the payload failed to meet the criteria for an upright landing.

1.10. Scientific Value

The goal of the PBR was to identify and differentiate three different targets as well as land upright autonomously. Advancements in computer vision and autonomous systems techniques are on the forefront of technological advancements, such as robotics and driverless vehicles. Therefore, the processes investigated in the payload portion of the project have a direct correlation to actual systems that can be used.

1.11. Visual Data Observed

The team has watched the competition launch several times to analyze the performance of the rocket. The launch went as planned with every recovery system event executing at the designed altitudes. The rocket was launched with minimal wind interference, causing apogee to be higher than estimated.

The PBR was not successful in completing all of the required tasks as outlined by the competition guidelines. The images taken during flight were corrupted and the ULS electronics became disconnected during flight. No usable images of the launch field were captured and the payload failed to land upright.

1.12. Lessons Learned

The NASA SL competition allowed for a team of undergraduate students to experience the lifecycle of a project from new product development to completion via documentation, design reviews, qualification, and verification and validation testing. The experience this gave undergraduate students was extremely helpful in regards to decide what areas of the engineering process students who are searching for jobs and internships would like to enter. Time management, interpersonal, organizational, and other skills were certainly developed/refined throughout the project. The ideas the group came up with had to be weighed against time more-so than anything else. Coursework, jobs, and extracurricular activities competed with the project for time commitments and availability. The product was a result of customer requirements and decisions the team made when weighing the time thought to make ideas come to fruition against the time available across the group. Overall, the team is happy with the product created for an ambitious challenge presented by NASA.

1.13. Educational Engagement Summary

<u>Salem Elementary School Outreach</u>
Where: Salem Elementary School, Apex, NC 27523
When: Friday December 2, 2016 2:30pm-4:30pm

Several members from the High-Powered Rocketry Club travelled to Salem Elementary School to visit an afterschool program run by the YMCA. The team gave a prepared presentation on what STEM is, example STEM careers, the engineering design cycle, and introductory water bottle physics. In addition to the presentation, the team brought a couple of subscale rockets from previous years. At the end of the presentation, the floor was open to questions and members of the club were able to answer the various questions asked. Following the presentation, there was a hands-on experiment with water bottle rockets where the students got to choose varying amounts of water and predict the amount of water that would lead to the rocket going the highest.

<u>Lacy Elementary School's STEM Night</u>
Location: Lacy Elementary School, Raleigh, NC 27607
When: Thursday January 19, 2017 5:00pm – 8:00pm

Members of the High-Powered Rocketry Club attended the Lacy Elementary School STEM night to give a presentation on high-powered rocketry, NASA SLI, and engineering at NC State. The team also brought a collection of previous years' rockets to have on static display and answer questions on the various components of the rockets. In addition, the club launched water bottle rockets with assistance from the students.

<u>Weatherstone Elementary STEM Expo</u>
Location: Weatherstone Elementary School, Cary, NC 27513
When: Saturday January 21, 2017 10:00am-2:00pm

The High-Powered Rocketry Club had a classroom at the Weatherstone Elementary STEM Expo to give a presentation on NASA SLI, high-powered rocketry, water bottle rockets, and engineering at NC State. The team will bring a small collection of previous rockets from previous years to show to the students. In addition, the team had a water bottle rocket workshop where students designed and built their own water bottle rocket to launch with some coaching from the team members.

<u>The Franciscan School Science Olympiad</u>
Location: The Franciscan School, Raleigh, NC 27613
When: Friday January 27, 2017 3:30pm-5:00pm

Amy S., Zach V., and John I. represented the High-Powered Rocketry Club at The Franciscan School where they gave a brief presentation on STEM, aerospace engineering, and what the club does. Following the presentation, they taught some of the participants that were part of a water bottle rocket Science Olympiad team on some tips and tricks to consider when designing their rockets. Following this, there was a quick demonstration of a water bottle rocket launch.

<u>Astronomy Days</u>
Location: North Carolina Museum of Natural Sciences, Raleigh NC 27601
When: Saturday January 28, 2017 9:00am-5:00pm, Sunday January 29, 2017 12:00pm-5:00pm

The High-Powered Rocketry Club continued its support of the Tripoli Rocket Association and helped at their booth at Astronomy Days. At Astronomy Days, the team talked to thousands of individuals about rockets and the club itself. The booth featured static displays of rockets both from the club and from the Tripoli Rocket Association plus posters describing high-powered rocketry designs and flights.

<u>NC MSEN Pre-College Program Presentation and Demonstration</u>
Location: North Carolina State University, Raleigh NC 27695
When: Thursday March 2, 2017 3:30pm-5:00pm

A group from the NC MSEN Pre-College Program came to North Carolina State University's Centennial Campus where members of the High-Powered Rocketry Club set up a presentation in one of classrooms. The presentation covered the engineering design cycle, what the club does, and water bottle rocket design. Following the presentation, the students were split up into teams and were able to design and build their own water bottle rockets with coaching from the team members. After the building of the rockets, the team brought the students outside and launched all the rockets that the students built.

1.14. Budget Summary

The final cost of the full scale and subscale payload was $1,414.46. The final cost for the full scale and subscale vehicle was $4,984.43. The travel cost for competition was $7,604.90. The total cost is $14,003.79.