Tacho Lycos
2016 NASA Student Launch
MAV PLAR

High-Powered Rocketry Team

911 Oval Drive

Raleigh NC, 27695

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Contents

1. Team Name

Tacho Lycos High-Powered Rocketry Club at North Carolina State University

2. Motor Used

The team used the AeroTech L1150R motor for the full-scale rocket. It has a specific impulse of 790.6 seconds and a burn time of 3.1 seconds. It is 20.87 inches long and has a diameter of 2.95 inches.

3. Autonomous Ground Support Equipment (AGSE) Description

3.1. AGSE Title

The Autonomous Ground Support Equipment (AGSE) will be referred to as System To Orient Rocket on Mars (STORM).

3.2. Size and Mass

Table 1 AGSE Size

AGSE Size	Horizontal (inches)	Vertical (inches)
Length	132	73.5
Width	31.5	31.5
Height	31	133
Total Volume	128,898 in^3 (74.59 ft^3)	307,928 in^3 (178.2 ft^3)

Table 2 AGSE Weight

Weight (pounds)	
Robotic Arm Subassembly	4.2
Igniter Insertion Subassembly	5.9
Rocket Erection Subassembly	13.0
Launch Rail	8.8
Supporting Frame and Electronics Box	49.7
Blast Plate	3.9
Total Weight	85.5

3.3. Summarize Autonomous Procedure for AGSE

The system begins by initializing the robotic arm. The sample will be placed in a predetermined position away from the AGSE. The robotic arm will move to the sample and grasp it with the gripper. After procuring the sample, the robotic arm will move it to the payload section where it will be securely enclosed by polyurethane 'Pick 'N Pluck' foam. The robotic arm will then close the payload bay door and move a safe distance away from the rest of the system. The launch rail will then erect to 85 degrees from the horizontal. Once the launch angle is achieved, the igniter insertion system stepper motor will begin the procedure of raising the igniter into the vehicle’s motor.

4. Vehicle Dimensions

Table 3 Vehicle Dimensions

PLAR	
Length	102 in
Diameter	5.5 in
Loaded Weight	34.5 lbs
Center of Pressure	76.3 in
Center of Gravity	64.5 in
Stability	2.15 Caliber

5. Altitude Reached

The vehicle flew to 4,491 feet as reported by the officially marked competition altimeter.

6. Vehicle Summary

The body tube of the launch vehicle was constructed of 5.5 inch diameter fiberglass tubing. Fiberglass was chosen for the body tube for its high strength and durability. The nosecone was also fiberglass, with a 5.5 inch max diameter and a 3:1 ogival shape and an aluminum tip with a 0.375 inch bulkhead with a U-bolt attached. The vehicle was divided into four major sections: the nosecone, forward airframe, aft airframe, and fin section. The forward airframe was 25 inches long and had a 4 inch by 9 inch access hatch cut out in order to access the forward altimeter bay. The aft airframe was 24 inches long with a 4 inch by 9 inch access hatch for the altimeter bay and a 3 inch by 5 inch door for the sample payload to be inserted. The fin section was 34.5 inches long with a 4 inch by 10 inch hatch cut out to access the controls for the airbrake system. The fins were constructed of 0.25 inch aircraft grade birch plywood. They had a 12 inch root chord, 2.35 inch tip chord, height of 4.75 inches, and a sweep angle of 46.8 degrees. The airbrake flaps, located between the fins 90 degrees from the rail buttons, were 2 inches by 4 inches.

The drogue parachute was 18 inches in diameter and deployed between the forward and aft airframes at apogee. At 1,100 feet AGL, the Advanced Retention Release Device (ARRD) separated, releasing the forward half of the vehicle from the drogue. At 1,000 feet AGL, the 48 inch forward main parachute deployed from between the nosecone and forward airframe. At 700 feet AGL, the 84 inch aft main parachute deployed from between the aft airframe and fin section. All parts of the rocket were safely recovered.

7. Data Analysis & Results of AGSE

The vehicle achieved an altitude of 4,491 feet during the competition as determined by the officially designated altimeter. This altitude is lower than the predicted height by approximately 800 feet, most likely due to the high winds at launch. The severity of the wind's effect was not anticipated and will need to be more carefully considered for the club's future launches.

8. Scientific Value

The goal of the AGSE is to retrieve a sample and insert it into the rocket. On Mars, or any other distant body, a similar process will need to be done so that the soil sample can be processed on Earth. Therefore, the processes investigated in the AGSE portion of the project have a direct correlation to actual systems that can be used. Having a robotic arm obtain and secure the sample in the rocket is a feasible system. The AGSE must also erect the rocket into launch position 85 degrees from vertical and insert an igniter into the motor. The value of this process is to find ways to approach the problem that might one day serve as a means to execute the procedure extraterrestrially.

9. 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 properly. The rocket was launched into stiff winds and was buffeted by gusts as it ascended. This could be seen in the small oscillations as the rocket rose and in the large arc it traveled in as the rocket neared apogee. After the drogue chute deployed the wind could be seen in the turbulent descent of the rocket.

The AGSE was also successful in completing all of the required tasks as outlined by the competition guidelines. The rocket was able to secure the sample, seal the rocket, erect the rocket and insert the igniter all autonomously. The rocket erection and igniter insertion systems were extensively optimized but there was still room to improve the performance of the robot arm. The ten second delay after starting the system to allow the BeagleBone Black to boot could have been reduced with more testing. The insertion of the sample payload into the payload bay could have been done in less time as well with further iterations of the arm movements.

10. Lessons Learned

Over the past eight months, our team has learned several lessons through the design and construction process. When constructing our subscale rocket, we attempted to cut the access hatches out of the fiberglass tubing with a Dremel tool with a small, circular carbide bit. This created extremely high friction and the cutting had to be executed in a vented area to accommodate the smoke it produced. After consulting with a professor who specializes in composite materials, we acquired an oscillating tool which both sped up the process and eliminated the smoke produced. We learned the importance of using the best tool for the job instead of any tool that could perform the task.

We also learned how big of an impact wind can have on the altitude of the rocket. For our subscale launch, we were anticipating an apogee of approximately 1,900 feet AGL. We launched in close to 20 mile per hour wind and the subscale weathercocked severely into the wind and only reached 1,035 feet. There was also a stark difference between our full scale flights. Our test launch was in very low winds and had an apogee of 5,344 feet AGL. The competition launch had much higher winds and only achieved 4,491 feet, which is a 17 percent difference.

11. Summary of Overall Experience

The team feels that it has been successful in the overall goals that were set forth at the beginning of the year. We were able to pick up the sample, place the sample in a payload compartment, close and secure the payload compartment, raise the rocket to exactly 85.0 degrees, insert an igniter into the motor, launch the rocket, and recover it safely. The only place that we were disappointed was with the final flight of the rocket that only flew to 4491 feet, almost 800 feet under target. When flown in Bayboro, NC, the rocket reached an altitude about 60 feet above the mile target.

The team has greatly enjoyed participating in this competition. While it was much less of a pure rocketry competition, it was a true aerospace project. It required knowledge from multiple engineering disciplines and really pushed our team, because we are made of aerospace engineering majors and one computer science major. The team has learned a lot about what it takes to put all the little parts of the project together, which is what we found to be the hardest part of the competition.

12. Educational Engagement Summary

Event: STEM Career Fair for Students with Disabilities

Location: North Carolina Museum of Natural Sciences, Raleigh, NC 27601

When: Friday, October 9th from 11am to 2pm

Andrew M. and John I. represented the High-Powered Rocketry Club at a special career fair designed to aid students with physical and learning disabilities find support from local organizations and individuals who are successful in their field. Andrew and John spoke with many of these students about the opportunities available to them in various fields of engineering as well as courses offered at NC State University. The members brought several static displays of previous competition rockets to better explain how the rockets worked and to talk about the NASA Student Launch competition.

Presentation to NC-MSEN PCP Middle School Students

Location: Centennial Campus Magnet Middle School, Raleigh, NC 27607

When: Wednesday, December 16th from 2:30pm to 5pm

Several members from the High-Powered Rocketry Club travelled to the Centennial Campus Magnet Middle School (CCMMS) to visit an afterschool program as part of the North Carolina Mathematics and Science Education Network Pre-College Program (NC-MSEN PCP). This program is designed to prepare "underserved students at the middle and high school levels for careers in STEM." The team gave a presentation with information regarding engineering at NC State University, NASA SL & Centennial Challenges, basic rocket physics, rocket design considerations, and comparing the physics of water bottle rockets to high-powered rockets. Following the presentation, the 20 students were able to ask the team an extensive amount of questions regarding rocketry before building their own water bottle rockets. Members from the club were able to help students design their water bottle rockets for a future launch.

Event: Lacy Elementary School STEM Night

Location: Lacy Elementary School, Raleigh, NC 27607

When: Thursday, January 14th, 5pm to 7:30pm

Members of the High-Powered Rocketry Club attended the Lacy Elementary School STEM night to show the students the basics of how rockets work. The team showed videos of their own rocket launches and talked to around 100 parents and students about the competition and how families can build their own rocket. The team also launched some water bottle rockets to give the students a safe, hand-on experience with rockets.

Event: Astronomy Days

Location: North Carolina Museum of Natural Sciences, Raleigh NC 27601

When: January 30th and 31st, 2016

The High-Powered Rocketry Club partnered with Tripoli of Eastern NC to host a booth at the NC Museum of Natural Sciences' Astronomy Days. The event was held to promote awareness of STEM, space exploration, and astronomy. The team showed visitors the inner workings of both low- and high-powered rockets and answered any questions that the over 1000 visitors had about rockets, NC State, and NASA. The team also helped Tripoli promote their rocket launching event at Perkins Field in Butner, NC. Information of Tripoli of Eastern NC can be found at www.ncrockets.org.

Event: Sigma Gamma Tau Boy Scout Merit Badge Event

Location: NC State Centennial Campus, Raleigh, NC 27695

When: April 9, 2016

The High-Powered Rocketry Club is planning to partner with NC State's chapter of Sigma Gamma Tau in hosting the annual Boy Scout Merit Badge Event during the Spring semester of 2016. The event will begin with a model rocket launch and recovery for the enjoyment of the Scouts and their families. The Scouts are then shown a presentation by members of Sigma Gamma Tau before receiving their Space Exploration badges. This event will take place on NC State's Centennial Campus and usually involves 30-40 Boy Scouts and their families.

13. Budget Summary

The team spend a total of $11,276 on this project. The "on the pad" cost of the AGSE and launch vehicle, however, was only $5,368, which is well below the project budget of $7,500. The rest of the money spent was on travel, the subscale rocket, and tools. This allowed the team to stay within the operating budget of $13,500 received from Space Grant of North Carolina, the Engineering Technology Fund, and Engineering Council.